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ORIGINAL PAPER

INFLUENCE OF MULCHING AND FOLIAR NUTRITION ON THE FORMATION OF BULBS AND CONTENT OF SOME COMPONENTS IN LEAVES AND BULBS OF SPANISH BLUEBELL (*HYACINTHOIDES HISPANICA* (MILL.) ROTHM.)*

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Abstract

Hyacinthoides hispanica (Mill.) Rothm. is a typical spring geophyte and has been cultivated for a long time in gardens as an ornamental bulbous plant. Bulbs are not only the storage and dormant organs, but also a means for the plant's vegetative reproduction. In Poland, due to the climate, the wintering and reproduction of this plant can be a problem. The aim of the study was to determine the effect of foliar nutrition using phosphorous fertilizer and soil mulching on the formation of bulbs and content of some components in leaves and bulbs of *H. hispanica*. To this end, a field experiment was carried out in 2010-2012. Mulching the soil with pine bark had a beneficial effect on the weight of bulbs in the core, the average weight of one bulb and the weight, length, diameter and circumference of the largest bulb from the *H. hispanica*. Foliar fertilization positively influenced the growth of *H. hispanica* bulbs, increasing the weight of bulbs in the core and the length of the largest bulb. Leaves of *H. hispanica* accumulated more nitrogen, potassium, calcium and flavonoids than bulbs and also showed higher antioxidant activity. Leaves of *H. hispanica* contained (g kg^{-1} d.m.), average amounts of 38.6 N, 4.0 P, 24.6 K, 13.2 Ca and 0.6 Mg, while bulbs had 24.5 N, 3.8 P, 8.7 K, 3.1 Ca, 0.3 Mg. Mulching the soil with pine bark positively influenced the content of nitrogen and potassium in the leaves of Spanish bluebell, while less N-total and potassium was determined in the bulbs. The content of phosphorus, calcium and magnesium in the leaves and bulbs of *H. hispanica* did not depend significantly on the soil mulching and foliar nutrition using Fostar.

Keywords: pine bark, phosphorus, biological value, chemical composition.

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INTRODUCTION

Spanish bluebell (*Hyacinthoides hispanica* (Mill.) Rothm. from *Asparagaceae* family (*Asparagaceae* Juss.), is native to the western Iberian peninsula and North Africa and has been cultivated for a long time in gardens as an ornamental bulbous plant. It is a typical spring geophyte of deciduous forest (Grundmann et al. 2010, O'Rourke, Lysaght 2014). *H. hispanica* forms bulbs, from which leaves arise in spring, and immediately after that 1-3 inflorescences appear. The leaves are dry at the beginning of summer. It is usually advisable to grow *H. hispanica* on fertile, moderately moist, permeable, and humus abundant soils. It is tolerant to soil reactions (Błażewicz-Woźniak et al. 2018).

Plants produce bulbs for water and nutrients storing. Owing to these underground organs, plants are able to wait through adverse conditions before they begin the vegetative growth, form leaves and flowers, sometimes overtaking other groups of plants. Bulbs are not only the storage and dormant organs, but also a means of the pnats' vegetative reproduction through formation of advent bulbs or bulb division, although in natural conditions, *H. hispanica* reproduced mainly from seeds (Ietswaart et al. 1983). Species of *Hyacinthoides* genus are reproduced by means of separating the advent bulbs that grow at the stem of a mother bulb. It was found that vegetative reproduction can occur in bluebells at all ages, but this was observed when bulbs are planted individually rather than in crowded communities (Merryweather, Fitter 1995). In studies upon *Scilla peruviana*, Azizbekova et al. (1997) found that "during gradual senescence of leaves and roots of the mother bulb, the apical meristem of the primary daughter bulb undergoes a transition from vegetative to pre-floral development (June)". *H. hispanica* poses a threat to the native flora in England and Ireland, because it crosses with *Hyacinthoides non-scripta* (L.) Chouard ex Rothm. (Kohn et al. 2009, O'Rourke, Lysaght 2014). Although *H. hispanica* was introduced into British gardens before 1683, its presence in the wild was noted just 100 years ago. In Poland, due to the climate, the species is not a threat to native flora, and indeed the plant's wintering and reproduction can be a problem.

Phosphorus fertilization plays an important role in ornamental plants production. At the initial stages of their growth, it ensures an appropriate development of roots, thus resistance to drought and nutrient deficiency at the later stages. By phosphorus supply, well-rooted plants are able to survive periodical water deficiencies and low temperatures in winter (Bednarek, Reszka 2007, Koc, Skwierawski 2008, Michałojć, Konopińska 2009). At the phosphorus deficiency, there is strong inhibition of the growth, with reduced flowering and seed setting. Prolonged lack of phosphorus in the soil can lead to plant fading (Ciereszko 2003, Bezak-Mazur, Stoińska 2013). Phosphorus is also indicated to play the role in arbuscular mycorrhiza (AM) at species of the *Hyacinthoides* genus (Merryweather, Fitter 1995, Ebuele et al. 2016). Insufficient phosphorus intake by a plant's roots can result from excessively high pH of soil or extremely low temperatures. It is assumed that phosphorus is not taken at temp. below 10-12°C and such conditions occur on field plantations in early spring. At lower temp. phosphorus more readily penetrates the plants through leaves rather than roots, and the transport rate increases along with the temperature increase and better light conditions (Byszewski, Sadowska 1974, Kruczek, Sulewska 2005).

The aim of the study was to determine the effect of foliar nutrition using phosphorous fertilizer and soil mulching on the formation of bulbs and content of some components in leaves and bulbs of *H. hispanica*.

MATERIAL AND METHODS

A field experiment was carried out in 2010-2012 at the ES Felin belonging to University of Life Sciences in Lublin (Poland, 22°56′E, 51°23′N), on grey brown podzolic soil (AP) developed from loess formations covering the cretaceous marls with a textural composition corresponding to medium dusty loam (BN-78/9180-11). Spanish bluebell, *Hyacinthoides hispanica* (Mill.) Rothm. cv. White City was the experimental plant. The following factors were considered in the experiment: 1) soil mulching: a) without mulch, b) mulching using pine bark; 2) foliar nutrition: a) without nutrition, b) foliar nutrition using Fostar fertilizer. The control consisted of plants grown without mulching and foliar nutrition.

H. hispanica bulbs of size 8/9 were planted into the ground on September 23, 2010 at a spacing of 20 × 20 cm to a depth of 8 cm. Before planting, they were treated with Topsin M 500 SC. The experiment was based on completely randomized sub-blocks in 3 replicates. The replicate was a plot of 1.20 m^2, on which 24 plants were grown. Surface of the soil in the half area of the experiment was covered with pine bark, which was supplemented every year to approximately 6 cm thickness. After planting bulbs in the 0-20 cm soil layer, 25.5 mg P, 9.6 mg K and 4.4 mg Mg 100 g^{-1} of the soil on average were determined. The soil had neutral pH 6.94 (Błażewicz-Woźniak et al. 2018). Every year in spring (March 20), fertilization with ammonium nitrate in the amount of 60 kg N ha^{-1} was applied. Liquid fertilizer Intermag Fostar (composed of 5.0% m m^{-1} N, 15.4% m m^{-1} P) was used for foliar nutrition on four dates, at weekly intervals from April 30 to May 21. The weather conditions during the vegetation of *H. hispanica* in years 2010-2012 are shown in Table 1.

Chemical analysis of plant material

Leaf samples for chemical analyses were collected from each combination on June 1, 2011 and 2012. In the dry plant material, the content of N, P, K,

Table 1

Mean monthly air temperatures and amount of precipitation in ES Felin during the experiment in 2010-2012

	Year	Month											
		01	02	03	04	05	06	07	08	09	10	11	12
Temperature (°C)	2010								20.2	12.5	5.6	6.4	-4.7
	2011	-0.9	-4.5	2.4	10.2	14.3	18.6	18.4	18.8	15.2	8.0	2.4	1.9
	2012	-1.9	-7.4	4.4	9.5	15.0	17.3	21.4					
	mean for 1951-2005	-3.5	-2.7	1.1	7.4	13.0	16.2	17.8	17.1	12.6	7.8	2.5	-1.4
Amount of precipitation (mm)	2010				24.5	156.7	65.6	101.0	132.8	119.0	11.2	46.8	32.4
	2011	24.8	25.2	8.1	29.9	42.2	67.8	189.0	65.3	5.4	28.5	1.0	34.5
	2012	33.6	22.1	28.6	34.0	56.3	62.8	52.3					
	mean for 1951-2005	22.7	25.6	26.3	40.2	57.7	65.7	83.5	68.6	51.6	40.1	38.1	31.5

Ca, Mg was determined. Total N was determined by the Kjeldahl method, phosphorus – colorimetrically, potassium, calcium and magnesium – by means of atomic absorption spectrometry (AAS). *H. hispanica* onions were dug out in the first half of October. After cleaning the cores, the weight of all bulbs obtained from one plant, the number of bulbs in the core, and the dimensions and weight of the largest and smallest bulbs, were determined. The bulbs were cleaned of impurities and roots, dried and ground. N, P, K, Ca, Mg were determined using the same methods as for leaves. Plant material was also subjected to laboratory analysis in order to determine the content of free phenolic acids using the Arnov method based on the recommendations of FP VI (2002), converting the content into gallic acid (GAE), flavonoids (Christ and Müller spectrophotometric method according to FP VI (2002), expressing the content in terms of rutine (RE), total polyphenols (TPC) using the spectrophotometric method with Folin-Ciocalteu reagent at wavelength $\lambda = 765$ nm, expressing the content of polyphenols converted into gallic acid (GAE). Furthermore, the antioxidant activity of the extracts from tested raw materials was determined using a test against DPPH radical (1,1-diphenyl-2-picrylhydrazyl).

The results were statistically analyzed by the analysis of variance (ANOVA) (the significance of differences was evaluated using the Tukey's method with the significance levels $p = 0.05$) and in the SAS (SAS Enterprise Guide 5.1, SAS Inst., Cary, N.C., U.S.A.) program (for the leaves of each plant, 5 separate extractions were performed and the results were expressed as average values ± standard deviations. The significance of the results was determined at $p < 0.05$).

RESULTS AND DISCUSSION

Biometric features of bulbs

The average weight of *H. hispanica* bulbs in the core, regardless of experimental factors, was 52.5 g (Table 2). The core consisted of an average of 32.3 bulbs, and the average weight of one bulb was 1.65 g and was in the range 0.35-7.63 g. The largest bulb on the core weighed on average 6.29 g (25.5 mm in length, diameter 19.3 mm, circumference 60.7 mm), and the smallest 0.16 g (8.3 mm in length, 4.7 mm in diameter, circumference 14.6 mm). Spanish bluebell grown without soil mulching, after 2 years of vegetation, produced from 2 to 64 bulbs in the core from one bulb, with an average unit weight from 0.35 to 1.75 g, while in the cultivation with pine bark mulch, it produced from 14 to 76 bulbs with an average unit weight of 1.07 to 7.63 g. According to Ortiz (2011), bulbs of *H. hispanica* are spherical and have a diameter of (1)1.5-3 × (0.8)1-2.5(3) cm. In studies carried out in the Netherlands, the length of *Scilla hispanica* (*H. hispanica*) bulbs measured for six populations was: in mm 24(20-26); 19(14-26);2(16-26); 25(13-31); 21(16-25);13(1-17) and bulb width in mm 23(18-25); 21(12-3);19(15-27;24(13-31); 18(15-24);11(9-15) (Ietswaart et al. 1983).

Based on statistical analysis, it was shown that the yield of *H. hispanica* bulbs was significantly affected by mulching and foliar nutrition. Many studies indicate the positive effect of soil mulching on bulb yield. Mulching improves the soil moisture and protects the plant root system from frost (Laskowska et al. 2012). In the analyzed experiment, soil mulching with pine bark had a beneficial effect on the weight of bulbs in the core, the average weight of one bulb and the weight, length, diameter and circumference of the largest bulb on the core. This is confirmed by the studies of Laskowska et al. (2012), in which pine bark mulching of the *Allium aflatunese* B. Fedtsch planted on September 15, had a positive effect on the number and weight of bulbs. Mulching the soil with pine bark in the *H. hispanica* cultivation resulted in a significantly larger weight of bulbs in the core (average 84.4 g) than in plants grown without mulching (20.6 g), howealthough it did not affect the biometric features of the smallest bulb fraction, which is understandable because they are the youngest ones. The positive effect of soil mulching using pine bark on bulb yield results from its beneficial effect on the soil. Pine bark cover stabilized the soil temperature in the bulb growth zone, protecting it from sudden temperature changes. The soil not covered with mulch warmed up more and in the cold days it lost the heat faster (Figure 1).

Organic mulch protects the soil against negative effects of low temperatures, which often determines the effects of growing the bulbous plants. Weaker growth and formation of bulbs can be explained by the frosting of plants growing without mulching (Błażewicz-Woźniak et al. 2018). In the studies of Waźbińska et al. (2003), wintering of *Scilla campanulata* cultivated

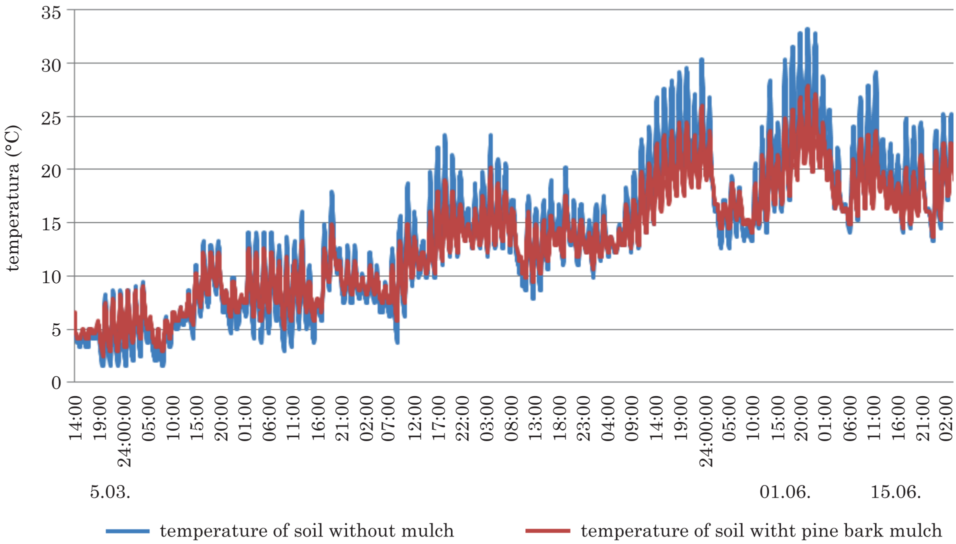

Fig. 1. Effect of mulching with pine bark on soil temperature in the root zone of *H. hispanica* during the growing season

near Olsztyn without soil mulching left 34.8-69.3% of the plants. REKOWSKA (1998), investigating the impact of litter from black film, recorded a significant increase in garlic commercial yield by 16.2% compared to a non-mulched plantation. The increase in the number of *Allium sativum* L. bulbs by 31-39% under the influence of soil mulching was also confirmed by studies of ISLAM et al. (2007). Composted pine bark ensured a better growth of gladiolus plants and increased bulb crop (GRZESZKIEWICZ 1978). In studies by MARCINEK and LASKOWSKA (2014), early covering the soil with organic mulch after planting the bulbs and leaving the straw until the end of the growing season had a positive effect on the yielding of tulips and increased the weight of first-class bulbs. A larger yield of daughter bulbs was obtained in the *Acidanthera bicolor* Perry. crop mulched using bark and high peat (KOCIRA, LASKOWSKA 2006). Mulching the soil with bark has benefited the growth of *Allium ursinum* L. expressed, among others, through the weight of bulbs (KĘSIK et al. 2011). In mulched objects, the unit weight of bulbs was by 2.2 g higher than in non-mulching objects.

Foliar nutrition, of both mulched and non-mulched plants, had a positive effect on *H. hispanica* bulb formation. Feeding with Fostar affected the increased bulb weight in the core and length of the largest bulb in the core. Weight of bulbs of plants fed with P was by 15.3 g higher, on average, than that of non-fertilized plants. Leaf fertilization induced an increase in the number of large and small bulbs in the yield of *Scilla sibirica* (LASKOWSKA 1992). In the study by AISHA et al. (2007), increasing the doses of P and K enhanced the total yield of onion and had a beneficial influence on the weight, length and diameter of bulb.

The interaction of soil mulching and P foliar nutrition had a positive impact on the length of the largest bulb in *H. hispanica* core. The longest bulbs were produced by plants growing in bark mulched soil and treated with Fostar (average of 35.5 mm), while the shortest, among the largest bulbs, were formed by plants grown in non-mulched soil without foliar nutrition (average of 19.4 mm). Roots of bulbous plant species can be damaged by the soil motion due to repeated frosting and defrosting in winter. Laskowska and Słowińska-Jurkiewicz (1996) reported that soil mulching using pine bark positively affected the winter maintenance of the soil structure set in autumn. The positive influence of P fertilization on tulip bulb size was also recorded by Sajid et al. (2013).

Content of selected components in leaves and bulbs

Based on the chemical analyses, it was found that bluebell leaves, regardless of the experimental factors, contained the average amounts of the following elements in dry matter: 38.6 g N-total, 4.0 P, 24.6 K, 13.2 Ca and 0.6 g Mg kg^{-1} (Table 3). Studies performed by Ebuele et al. (2016) on natural sites of *H. non-scripta* growth revealed that total P in plants (aerial and underground parts) ranged between 0.84-4.0 g kg^{-1}. In the analyzed experiment on *H. hispanica* bulbs, average amounts of 24.5 g N, 3.8 P, 8.7 K, 3.1 Ca, 0.3 g kg^{-1} Mg in d.m. were determined. Lower accumulation of potassium in bulbs than in leaves of bulbous plant species was confirmed by other authors. In leaves of *Allium cepa* L. Pire et al. (2001) determined an average amount of 4.54% K, an only 1.78% K in underground organs, while in bulbs there was 1.26% Ca, and in leaves - 2.75%. Also leaves of *Allium cepa* var. *proliferum* were more abundant in calcium (1.90% Ca) than bulbs (0.27) (Jadczak 2005). Less total nitrogen was recorded in *Allium ursinum* L. bulbs than in leaves (Kęsik et al. 2011). Trémolières et al. (2009), depending on the phonological phase, determined from 1.33 to 2.29% N in bulbs, and from 3.30 to 5.40% in leaves of *A. ursinum*. Soil mulching using pine bark did not affect the P, Ca, and Mg content in leaves and bulbs of *H. hispanica*. Significant differences occurred in the case of potassium. Leaves of plants grown in bark-mulched soil contained an average of 32.2 g K kg^{-1}, but without mulching there was 15.3 g less K. Potassium is responsible for the proper water management of the plant, as it regulates the osmotic potential and cell turgor. In addition, it reduces the adverse impact of water stress and low temperatures (Michałojć, Konopińska 2009). Soil mulching had a positive effect on the nitrogen content of the Spanish bluebell leaves. Plants growing on plots mulched with bark accumulated an average of 40.5 g kg^{-1} N-total in the leaves, and without mulch – 36.7 g N, while less N and K were determined in the bulbs of plants cultivated using mulching. Similar results, in relation to *A.ursinum*, were obtained by Kęsik et al. (2011). Mulching the soil with pine bark decreased the total nitrogen content in the leaves and bulbs of bear's garlic, but it had a positive effect on the accumulation of protein in

Table 2

Influence of bark mulching and Fostar fertilization on bulb formation by *H. hispanica* and bulb biometric features

Mulching A	Foliar nutriton B	Weight of bulbs in the core (g)	Number of bulbs in the core (pcs.)	Average weight of 1 bulb (g)	Largest bulb in the core				Smallest bulb in the core			
					weight (g)	length (mm)	diameter (mm)	circum-ference (mm)	weight (g)	length (mm)	diameter (mm)	circum-ference (mm)
Without mulching	without nutrition	15.9	24.1	0.72	2.14	19.4	14.1	44.4	0.12	7.4	4.5	14.1
	Fostar	25.3	30.3	0.90	2.90	22.6	13.5	42.4	0.19	8.6	4.8	14.9
	mean	20.6	27.2	0.81	2.52	21.0	13.8	43.4	0.16	8.0	4.6	14.5
Pine bark mulch	without nutrition	73.8	37.8	2.03	8.80	24.6	25.4	79.7	0.10	7.1	3.9	12.2
	Fostar	95.1	37.3	2.95	11.32	35.5	24.4	76.5	0.23	10.3	5.5	17.3
	mean	84.5	37.5	2.49	10.06	30.1	24.9	78.1	0.16	8.7	4.7	14.7
Mean	Without nutrition	44.9	30.9	1.37	5.47	22.0	19.8	62.0	0.11	7.3	4.2	13.1
	Fostar	60.2	33.8	1.92	7.11	29.1	18.9	59.5	0.21	9.4	5.1	16.1
	mean	52.5	32.3	1.65	6.29	25.5	19.3	60.7	0.16	8.3	4.7	14.6
$LSD_{0.05}$ for: mulching A		14.7	ns	0.75	2.27	3.55	3.39	10.6	ns	ns	ns	ns
nutrition B		14.7	ns	ns	ns	3.55	ns	ns	ns	ns	ns	ns
A x B		ns	ns	ns.	ns	6.69	ns	ns	ns	ns	ns	ns

ns – no significant differences

Table 3

The influence of experimental factors on the content of selected nutrients in leaves and bulbs of *H. hispanica* in 2011-2012

Experimental factors			Leaves					Bulbs				
			content of nutrient (g kg^{-1} d.m.)									
Mulching A	nutrition B	year	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Without mulching	without nutrition	2011	35.7	4.0	18.9	12.3	0.6	25.8	4.0	10.1	2.9	0.3
		2012	35.8	3.7	12.6	9.7	0.5	26.3	4.2	9.0	3.2	0.3
		mean	35.8	3.9	15.8	11.0	0.5	26.1	4.1	9.6	3.1	0.3
	Fostar	2011	39.1	4.2	22.0	15.6	0.6	26.4	4.2	9.2	3.0	0.3
		2012	36.3	3.9	14.3	11.6	0.6	26.6	4.0	10.0	3.2	0.4
		mean	37.7	4.1	18.1	13.6	0.6	26.5	4.1	9.6	3.1	0.4
	mean	2011	37.4	4.1	20.4	13.9	0.6	26.1	4.1	9.7	3.0	0.3
		2012	36.1	3.8	13.5	10.7	0.6	26.5	4.1	9.5	3.2	0.4
		mean	36.7	4.0	16.9	12.3	0.6	26.3	4.1	9.6	3.1	0.3
Pine bark mulch	without nutrition	2011	41.5	3.9	33.2	13.8	0.7	22.7	3.1	7.8	2.8	0.3
		2012	36.9	4.0	25.3	11.8	0.8	24.5	3.6	8.4	3.0	0.3
		mean	39.2	3.9	29.2	12.8	0.7	23.6	3.4	8.1	2.9	0.3
	Fostar	2011	43.2	3.7	38.2	16.6	0.6	22.3	3.7	7.9	3.3	0.4
		2012	40.3	4.5	32.0	14.0	0.8	21.3	3.3	6.9	3.1	0.3
		mean	41.7	4.1	35.1	15.3	0.7	21.8	3.5	7.4	3.2	0.4
	mean	2011	42.3	3.8	35.7	15.2	0.6	22.5	3.4	7.9	3.1	0.4
		2012	38.6	4.3	28.7	12.9	0.8	22.9	3.5	7.7	3.1	0.3
		mean	40.5	4.0	32.2	14.0	0.7	22.7	3.4	7.8	3.1	0.3
Mean	without nutrition	2011	38.6	3.9	26.0	13.0	0.6	24.3	3.6	9.0	2.9	0.3
		2012	36.4	3.9	19.0	10.8	0.7	25.4	3.9	8.7	3.1	0.3
		mean	37.5	3.9	22.5	11.9	0.6	24.8	3.7	8.8	3.0	0.3
	Fostar	2011	41.1	4.0	30.1	16.1	0.6	24.4	4.0	8.6	3.2	0.4
		2012	38.3	4.2	23.2	12.8	0.7	24.0	3.7	8.5	3.2	0.4
		mean	39.7	4.1	26.6	14.4	0.6	24.2	3.8	8.5	3.2	0.4
	mean	2011	39.9	3.9	28.1	14.5	0.6	24.3	3.8	8.8	3.0	0.3
		2012	37.3	4.0	21.1	11.8	0.7	24.7	3.8	8.6	3.1	0.3
		mean	38.6	4.0	24.6	13.2	0.6	24.5	3.8	8.7	3.1	0.3
$LSD_{.05}$ for: mulching A			0.37	ns	0.72	ns	ns	0.32	ns	0.13	ns	ns
mutrition B			ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
AxB			ns	ns	1.49	ns	ns	ns	ns	ns	ns	ns

ns – no significant differences

the fresh weight of leaves. Also Błażewicz-Woźniak et al. (2008) noted that organic mulch slightly increased the potassium content in the soil, but this did not affect the accumulation of this element in onion. Regarding the potassium content in the thickening of *Foeniculum vulgare* Mill., the impact of mulching was unequivocal (Błażewicz-Woźniak 2010). The soil covered with plant mulch contained slightly more potassium and magnesium in the arable layer as compared to the unprotected soil, and the onion accumulated slightly more N-total and potassium (Błażewicz-Woźniak et al. 2008). Bark mulch slightly decreased the level of leaf nitrogen, but increased the level of leaf phosphorus and potassium in all years of the cultivation of strawberry plants (*Fragaria*×*ananassa* Duch.) (Sønsteby et al. 2004). "Organic mulches probably have much more potassium in their structure and with regulation of soil temperature and moisture helped to increase the soil available potassium. Higher K uptake in the mulched plots could be attributed to the higher K supply through the mulch material" (Kumar 2014). The study proved that mulched soil contained more nutrients: on average 25.4 mg P 100 g^{-1} was recorded, compared to just 14.6 mg P 100 g^{-1} in non-mulched soil. Bark-protected soil also contained more K and Mg (Błażewicz-Woźniak et al. 2018). The tendency of a higher amount of available phosphorus in the soil in mulched plots was established by Sinkevičienė et al. (2009). Escuer and Vabrit (2017) did not notice any changes in the content of P, K, Ca and Mg in pine-bar mulched soils in relation to soil without mulching. In studies by Adamczewska-Sowińska and Turczuk (2016), the use of mineral and organic mulches significantly affected the content of P, K, Mg and Ca in garlic chives. Błażewicz-Woźniak et al. (2012) found that bark mulch protected the soil against losses of Mg and K in the cultivation of *Salvia splendens*, increasing the availability of these nutrients for plants. According to Licznar and Licznar (2008), the use of pine bark for mulching contributed to the soil acidity increase and available forms of potassium, while reducing the share of alkaline cations in the sorption complex. Plots mulched with organic materials had significantly higher soil K concentrations than non-mulched ones (Broschat 2007).

Foliar nutrition with Fostar did not significantly affect the content of N, P, K, Ca and Mg in Spanish bluebell leaves and bulbs. However, there was a tendency to slightly increase the content of N-total, K and Ca in the leaves of plants with foliar treatment. Michałojć and Konopińska (2009) showed an increased content of P and K in leaves of lettuce fed with PK-based foliar fertilizers. Wach and Błażewicz-Woźniak (2012) noted significant effect of foliar nutrition with phosphorus on the concentration of this element in blueberry leaves. Increasing the applied levels of natural P and K to bulbous plants caused improved the nutritional value of onion bulb tissues (Aisha et al. 2007). The interaction of mulching with phosphorus foliar nutrition positively affected the accumulation of nutrients in Spanish bluebell leaves. Plants cultivated using pine bark and foliar nutrition accumulated more N-total (41.7), K (35.1) and Ca (15.3 g kg^{-1}) in leaves, and the least of these nutrients were absorbed in cultivation without mulches and feeding (control), while in the case of bulbs, more N-total (26.5) and K (9.6 g kg^{-1}) were determined in the cultivation without mulch but with feeding.

Plant material of *H. hispanica* was also subjected to laboratory analysis to determine the content of basic non-nutritive biologically active substances (Table 4). The leaves contained more flavonoids than bulbs and were charac-

Table 4

Percentage of non-nutrititive biologically active substances and antioxidant activity of *H. hispanica* extracts

Compounds	Raw material		
	leaves	bulbs	*p-value*
Phenolic acids % GAE kg^{-1} d.w. mean ± SD	1.01 ± 0.21^{a}	1.98 ± 0.35^{b}	<0.0001
Flavonoids % QE kg^{-1} d.w. mean ± SD	1.54 ± 0.41^{b}	0.71 ± 0.14^{a}	<0.0001
Sum of polyphenols % GAE kg^{-1} d.w. mean ± SD	3.21 ± 0.34^{a}	4.17 ± 0.81^{b}	<0.0001
DPPH % scavenging activity mean ± SD	38.63 ± 3.016^{b}	17.10 ± 1.476^{a}	<0.0001

The content of the sum of polyphenols and phenolic acids is given in terms of gallic acid – GAE;
Content of flavonoids calculated as quercetin – QE;
Different letters *a*, *b* ... in lines indicate statistically significant differences ($p < 0.05$);
d.w. – dry weight;
Values expressed are means ± SD of three parallel measurements;
DPPH= 2,2'-diphenyl-1-picrylhydrazyl

terized by more than double the concentration of DPPH. Bulbs and leaves of some species of the *Hyacinthoides* genus were used in folk medicine. The therapeutic effect of the compounds contained has been indicated in research (MULHOLLAND et al. 2013). The bulbs of *Hyacinthoides non-scripta* are reported to have diuretic and styptic properties.

CONCLUSIONS

1. Mulching the soil with pine bark had a beneficial effect on the weight of bulbs in the core, the average weight of one bulb and the weight, length, diameter and circumference of the largest bulb from the *H. hispanica* core.

2. Foliar fertilization positively influenced the growth of *H. hispanica* bulbs, increasing the weight of bulbs in the core and the length of the largest bulb.

3. Leaves of *H. hispanica* accumulated more nitrogen, potassium, calcium and flavonoids than bulbs and also showed higher antioxidant activity.

4. Leaves of *H. hispanica* contained the average amounts (g kg^{-1} d.m.) of 38.6 N-total, 4.0 P, 24.6 K, 13.2 Ca and 0.6 Mg, while bulbs had 24.5 N, 3.8 P, 8.7 K, 3.1 Ca, 0.3 Mg.

5. Mulching the soil with pine bark positively influenced the content of nitrogen and potassium in the leaves of Spanish bluebell, while less N-total and potassium were determined in the bulbs.

6. The content of phosphorus, calcium and magnesium in the leaves and bulbs of *H. hispanica* did not depend significantly on the soil mulching and foliar nutrition using Fostar.

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