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RESEARCH ARTICLE

Variability of phenotypic and morphological characteristics of some *Lathyrus sativus* L. and *Lathyrus cicera* L. accessions and nutritional traits of their seeds

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Abstract The object of the study comprised 54 grass pea (*Lathyrus sativus*) accessions originating from Czech Republic, Hungary, Slovak Republic, Poland, Ukraine and Russia together with 18 red pea (*Lathyrus cicera*) accessions from Greece, Spain and Italy. The plants were grown under the same conditions in Poland. Some phenological and morphological traits of plants as well as some seed morphological properties and nutritive value were investigated. *Lathyrus sativus* seeds contained more protein (average 300 g vs. 255 g kg^{-1} dry matter (DM)), whereas the differences in the average contents of the other basic nutrients between both these species as well as between particular accessions were not substantial. Except for a low level of methionine, the protein of both species showed fairly high concentration of other exogenic amino acids (EAAI around 63–64%). Fat of both *L. sativus* and *L. cicera* seeds was found to contain a high level of polyunsaturated fatty acids (66.9 and 58.6%, respectively), mainly linoleic (57.4 and 47.2%, respectively). The researched *L. sativus* accessions had a quite low level of β-ODAP (733 mg with a range of 0.583–1.340 mg kg^{-1} DM). Slightly higher content of this ANF (1,168 mg with 911–1,349 mg kg $^{-1}$ DM) in *L. cicera* seeds was noted. Average tannin concentration in the *L. sativus* and *L. cicera* accessions reached 3.3 and 6.4 g kg^{-1} DM, respectively. Average content of this ANF in *L. sativus* significantly correlated with the colour of both, flowers and seeds; with generally, a darker colour associated with higher levels of tannins.

Keywords Antinutritional factors · *Lathyrus cicera* L. · *Lathyrus sativus* L. · Morphology · Nutrients · Seeds

Introduction

It is estimated that there are nearly at least 6,000 plant species in cultivation but only a few staple crops produce the majority of food supply. This may hold true, however, the substantial contribution of many minor species should not be underestimated. Among underutilized or neglected crops important from an agricultural point of view, there are a few species of *Lathyrus* genus with the two most known, i.e. *Lathyrus sativus* (grass pea) and *Lathyrus cicera* (red pea). *Lathyrus sativus* is grown primarily as a food crop, while *L. cicera* for both, food and forage (Campbell 1997; IPGRI 2000).

Vavilov (1951) described two separate centres of origin for Lathyrus, namely the Central Asiatic Centre

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and the Abyssinian Centre. Besides, this author and Jackson and Yunus (1984) found some trends in diversity in the smaller-seeded forms in south and south-west Asia, whereas around the Mediterranean, almost all the forms were characterized by large, white seeds and flowers.

Grass pea is a protein-rich pulse with ca. 30% crude protein content in its seeds. Due to a very hardy and penetrating root system, it can be grown on a wide variety of soil types, including very poor ones (Campbell et al. 1994). This trait is of primary importance taking into account rapid climate changes observed globally in the recent years. *Lathyrus* species have also a considerable potential in crop rotation, improving soil physical conditions, reducing the amount of disease and weed populations, with the overall reduction of production costs. Grass pea is an important crop cultivated in some regions of India, Pakistan, Nepal and Ethiopia and to a much lesser extent in many countries in Europe, the middle East, northern Africa, and in Chile and Brazil (Campbell et al. 1994). Apart from forms grown in South Asia, Africa and Mediterranean region, many accessions originate from south-central (Czech Republic, Hungary, Slovak Republic) and east-central Europe (Poland, Russia, Ukraine). In Poland grass pea is one of the least common grain legumes and in small-scale produced vegetable in eastern Poland. It was introduced to eastern Poland (presently—the Ukrainian territory) in XVII century, probably with settling of Tatars, who under the leadership of the Polish king Jan III Sobieski won the battle near Vienna against Turkey.

According to Milczak et al. (2001), grass pea seeds were brought by Tatars and accompanied their lentil seeds, probably as a weed. Over time, the crop found better growth and development conditions and consequently today as a dominant species is more popular than lentil. In Poland (Milczak et al. 2001), alike Italy (Tavoletti and Capitani 2000; Polignano et al. 2005; Piergiovanni et al. 2011, Lioi et al. 2011), Spain (De la Rosa and Martin 2001), Slovak Republic (Benkova and Zakova 2001) and Hungary (Lazanyi 2000), it is one of the relatively infrequent grain legumes. However, grass pea was not completely abandoned and has remained in small farms which continued small scale production for family consumption and the local market (Hammer et al. 1999; Tavoletti and Capitani 2000). According to Piergiovanni et al. (2011), the currently renewed interest in grass pea in Europe (e.g. in Poland and other countries of central Europe) and other regions with highly developed agriculture is justified by the potential in development of crop rotation for marginal land, high adaptability to organic farming system, possible use as an alternative to wheat in areas overexploited by cereals and rapeseed cultivation and a source of protein for nutritional purposes. The tolerance of grass pea to poor and acid soils (the majority of soils in Poland are like that) and recurrent harsh springs or summer drought make this crop particularly interesting. The increasing interest of both, farmers and plant breeders and lack of original Polish varieties inclined Milczak et al. (2001) to use the local landraces as initial material for breeding and release two promising cultivars—Derek and Krab. Presently, grass pea is considered as a model crop for sustainable agriculture (Vaz Patto et al. 2006; Skiba et al. 2007).

The other species, presented in this paper, *Lathyrus cicera*, called also red pea, is believed to have been domesticated in south-western Europe by 3000–4000 B.C. (Kislev 1989). *Lathyrus sativus* is probably a derivative from the genetically nearest wild species, *L. cicera*. The ability of *L. sativus* and *L. cicera* to hybridize was demonstrated by Lwin (1956) and Yunus and Jackson (1991). This implies a close association between both species. According to Campbell (1997), probable expansion of grass pea farming to southern France and Spain may have led to domestication of local *L. cicera.* It is a robust legume reaching a height of 20–100 cm with copper-coloured flowers and not winged at the corners pods, with angular brown or gray seeds black marking. Seeds and flowers are smaller than those of grass pea. It is distributed in the Mediterranean basin countries (from Portugal to Italy, Balkan countries and the Crime, Crete, Aegean Isles, Cyprus, Syria, Lebanon, Palestine, Jordan, Turkey, Egypt, Morocco, Algeria, Tunisia), Caucasus, Iraq, Iran, Central Asia (Turkmenia to Pamir-Altai), and introduced into South Africa (IPGRI 2000). Hanbury et al. (1995) and Siddique et al. (1996) reported *L. cicera* to show very good adaptation to arid land in South Australia as a potentially high yielding feed grain/forage crop. Yield of *Lathyrus cicera* was generally much higher than that of *L. sativus* and the lines with both high yield and low ODAP have been identified (Hanbury et al. 1995).

Similarly to the other species of *Lathyrus* genus, *L. sativus* and *L. cicera* ecotypes are classified on the basis of flower color, marking on pods, and size and color of seeds, which in many cases is connected with their geographical distribution. These characteristics, as well as yield and also nutritional traits of seeds have been estimated to describe the great variability of accessions of both, *L. sativus* and *L. cicera.* In our previous paper (Grela et al. 2010), we investigated morphological and nutritional traits of 31 accessions coming from either the countries of the Mediterranean basin (Italy, Spain) or west-central Europe (northern France, Germany and Poland) grown under the same conditions in Poland. There have been found some differences between these groups as well as within them, namely between particular accessions.

The aim of the present research was to perform a similar study comparing the phenological and morphological traits, as well as nutritional characteristics of the *Lathyrus sativus* accessions, originating from east-central (Russia, Ukraine, Poland) and south-central (Hungary, Czech Republic, Slovak Republic) Europe. Another study objective regarded some accessions of *L. cicera*—a species not cultivated in Poland or in other central European countries, coming primarily from Greece and grown at the same soil-climatic conditions in Poland.

Materials and methods

Plant material

The object of the study were 73 accessions of two species of *Lathyrus* genus: *Lathyrus sativus* L. (grass pea)—54 accessions and *Lathyrus cicera* L. (red pea)—18 accessions. Among fifty four grass pea accessions from south-central and east-central Europe, thirty eight originated from Slovak Republic, two from Czech Republic, in threes from Hungary as well as from Poland and in fours from Russia and Ukraine. The all red pea accessions came from south Europe: sixteen from Greece and two from Italy and Spain, one each. Except for the seeds of three Polish grass pea accessions (cultivars: Derek, Krab and Mutant), which were obtained from the *Lathyrus* collection of the Institute of Plant Genetics, Polish Academy of Sciences, in Poznań, the seeds of remaining forms came from the Genebank in Gatersleben (Germany).

Field trial

The field trial was set up in a randomized complete block design with three replications on the Experimental Field of the Institute of Plant Genetics in Cerekwica, Poland (51°55′N, 17°21′E) in 2009. The seeds were sown into experimental plots (1.5 × 3 m, without the edge rows) at seed spacing 300 × 150 mm. The plant growth habit was recorded at the onset of flowering period and flowering time in the number of days from sowing till first flower opening. Plant height was measured at physiological maturity from ground to the top of the longest branch. Flower color was assessed on fresh open flowers of dorsal petal. After harvest, there were evaluated pod shape of mature pods and number of pods per plant, seeds per pod from randomly selected 10 plants per plot. The obtained mature seeds were used to study seed shape, seed coat color and seed size. All the above mentioned traits were scored according to the Descriptors for *Lathyrus* ssp. (IPGRI 2000). A rainfall level during the vegetation period from March to end of August 2009 reached 431 mm and was lower as compared to 2008 (457 mm) but markedly higher than in the very dry year 2007 (372 mm). Distribution of rainfall in each month proved to be very interesting. In comparison to very rainy April 2008 (112.4 mm) in the sowing period 2009 (30th March), no precipitation was recorded in the first decade of April (0.2 mm) with 19.6 mm total rainfall in this month. The water stress increased in the first and second decade of May (12.4 and 12.8 mm). The strong drought was broken in the third decade of May (60.2 mm) directly in the beginning of flowering and very rainy period prolonged through all June with amount of 160 mm (61.8, 24.8 and 73.4 mm in the three decades, respectively). Extremely high rainfall level in June accompanied a low average air temperature (14.6°C) notably lower in comparison with June 2008 and 2010 (17.3 and 18.0°C respectively). This anomaly weather had negative impact on plant flowering, pod setting and in consequence, seed yield. Advantageous rainfall distribution in July (33.4; 34 and 12 mm in decades) allowed for optimal plant harvest at the end of that month.

Chemical analyses

The content of dry matter and basic nutrients in the ground seed samples (250 g of each accession) was determined according to AOAC (2000). The polyphenolic compound (tannins) level was estimated using the method described by Waniska et al. (1992). The neurotoxin concentration (β-ODAP) was measured by the technique of capillary electrophoresis on the apparatus Spectra Phoresis 1000 following the protocol of Arentoft and Greirson (1995) with glass capillary 70 cm × 35 μm, 200 mM phosphate buffer of pH 8.6, and voltage 25 kV, temperature 26.5–35°C and the wave length 195 nm.

Fatty acid determination was performed using the gas chromatography method on a Varian CP-3800 chromatograph. The chromatograph operating conditions for fatty acid separation were: capillary column CP WAX 52CB DF 0.25 mm of 60 m length, gas carrier—helium, flow rate—1.4 ml/min, column temperature 120°C gradually increasing by 2°C/min, determination time—127 min., feeder temperature—160°C, detector temperature—160°C, other gases—hydrogen and oxygen.

Amino acids were analyzed by Sykam Amino Acid Analyzer (Laserchrom HPLC Laboratories Ltd. Inc., Rochester, UK). Before analysis, the samples were hydrolyzed with 6 N HCl for 24 h at 110°C. Methionine and cysteine were analyzed as Met sulfone and cysteic acid after cold performic acid oxidation overnight before the hydrolysis. Tryptophan was determined after NaOH hydrolysis for 22 h at 110°C.

Statistics

For some phenotypic and morphological characteristics, as well as contents of nutrients and antinutritional factors (β-ODAP and tannins) in seeds the means and standard error of the means was calculated. The data for *L. sativus* accessions, originating from two different European regions (south-central Europe and east-central Europe) were compared using t-test. Pearson correlation analysis between β-ODAP or tannin content and intensity of flower colour score (from white to dark blue) and seed coat colour (from cream to dark brown) in *L. sativus* was performed using the software SAS (SAS 1993).

Results

The research results obtained from the observation and analyses of the field trial serve as the basis to achieve the main goal of the present paper including the analyses of nutritional traits of seeds. Tables 1 and 2 summarize the characteristics of the *L. sativus* and *L. cicera* accessions, respectively, examined for phenotypic and morphological traits. The results indicate wide variation of all traits. The average plant height of grass pea was 85 cm (Table 1). For the accessions from south-central Europe, these characteristics varied from 56.2 to 111.2 cm and for east-central Europe from 65.7 to 104.8 cm. As compared to *L. sativus* accessions, plants of *L. cicera* of 46.1 cm average height, were almost twice shorter and their height ranged from 35.6 to 57.4 cm. A relatively narrow range of days from sowing till flowering of grass pea from 58 to 65 days was observed. Average age of *L. cicera* plants at flowering start was the same as for grass pea (62 days) between 58 and 84 days due to very much delayed beginning of flowering of LAT 257/85, accession from Italy. Among 54 analyzed accessions of grass pea, 28 of them presented white flowers and 26 produced white-blue or blue colour. White flowers appeared more frequently in the plants of Polish, Russian and Ukrainian accessions. Near 70% of *L. cicera* accessions showed red colored flowers, whereas the remaining lines had bright red or rosa-red flowers. Flower size ranged from medium to large for grass pea and small for *L. cicera.* Pods per plant for grass pea with average value of 39.7 differed ($P \leq 0.05$) between south-central and east-central Europe accessions (37.9 vs. 53.5, respectively) with the highest values of this trait in the Polish accessions (63.7–82.8). The average number of pods in *L. cicera* plants amounted to 34.2.

Generally, all accessions presented two types of pod shape: linear (both narrow as well as broad) and broad-elliptical with small differences between the analyzed forms. For grass pea there were on average 2.3 seeds in one pod. The number of 3.0 seeds per pod exceeded only 2 Polish accessions (Derek and Mutant). As compared to grass pea, the *L. cicera* produced more seeds per pod—average 4.1, ranging from 3.2 up to 4.7. Apart from absolutely spherical seed shape of Polish spontaneous Mutant, other accessions showed a typical for grass pea angular and sharp-edged shape with more oblate seeds typical for large-seeded forms. Especially wide variation was noted for seed size, expressed by 1,000 seeds weight (TSW). Average value of this trait for grass pea was 203 g (variation 86–366 g) with considerably higher

Table 1 Origin and some phenological and morphological traits of grass pea (*Lathyrus sativus* L.) accessions

Accession code	Country of origin	Days to onset of flowering	Plant height (cm)	Flower colour	Number of pods per plant	Number of seeds per pod	Seed coat color	TSW (g)
LAT 469/75	Slovakia	63	75.4	White-blue	26.6	2.1	Cream with slightly pigmentation	227.7
LAT 470/75	Slovakia	58	79.6	White-blue	33.2	2.6	Cream with dark hilum	185.1
LAT 471/75	Slovakia	58	99.2	White-blue	60.8	2.9	Cream with dark hilum	210.9
LAT 472/80	Slovakia	58	90.4	White-blue	35.2	2.6	Cream with slight pigmentation	219.3
LAT 473/80	Slovakia	63	86	White	31.6	2.2	Cream	221.2
LAT 474/75	Slovakia	63	72	White-blue	31.8	1.8	Cream with brown hilum	231.7
LAT 475/80	Slovakia	59	78.2	White-blue	33.6	2.1	Cream	256.7
LAT 476/80	Slovakia	59	87.4	White	39.2	2.0	Cream	167.1
LAT 479/77	Slovakia	60	94.8	White-blue	28.6	2.3	Cream with dark hilum	186.3
LAT 480/77	Slovakia	60	82.4	White-blue	31.0	2.2	Cream with brown edge	205.1
LAT 481/77	Slovakia	63	63.4	White	27.0	1.9	Cream	234.5
LAT 484/77	Slovakia	63	61	White	29.2	2.3	Cream	147.8
LAT 485/77	Slovakia	63	56.2	White	20.8	1.8	Cream	226.8
LAT 486/77	Slovakia	63	62.8	White-blue	21.8	2.1	Cream-grey with dark edge	206.9
LAT 487/77	Slovakia	60	93	White	37.6	1.9	Cream	185.6
LAT 488/79	Slovakia	63	71.2	White	40.8	2.6	Cream	198.2
LAT 489/79	Slovakia	63	81.2	White-blue	40.9	2.1	Grey-dark grey with dark edge	150.3
LAT 491/79	Slovakia	65	69.4	White	34.2	3.0	Cream	171.7
LAT 495/82	Slovakia	63	81.6	White-blue	39.2	2.7	Bright grey with pigmentation and brown edge	158.6
LAT 496/82	Slovakia	63	74.2	White	30.6	2.6	Cream	150.9
LAT 497/82	Slovakia	64	100.6	Blue	59.4	2.6	Grey. Dark grey with brown edge	254.1
LAT 499/83	Slovakia	63	78.2	White-blue	25.4	1.8	Cream with dark edge	214.2
LAT 4001/84	Slovakia	60	86.4	Blue	33.8	1.7	Dark grey—bright brown with dark hilum	221.5

Table 1 continued

Accession code	Country of origin	Days to onset of flowering	Plant height (cm)	Flower colour	Number of pods per plant	Number of seeds per pod	Seed coat color	TSW (g)
LAT 4002/84	Slovakia	64	76	White-blue	30.0	2.2	Dark brown with dark hilum	222.2
LAT 4003/84	Slovakia	65	85	White-blue	46.2	2.3	Cream to slightly grey. Brown with dark edge	190.5
LAT 4004/84	Slovakia	65	83.2	White-blue	29.6	1.8	Cream to slightly grey. Brown with dark edge	204.1
LAT 4018/86	Slovakia	65	82.6	White	30.2	2.2	Cream	224.5
LAT 4019/86	Slovakia	64	80.4	White-blue	56.6	2.4	Cream to slightly grey. Brown with dark edge	182.5
LAT 4020/86	Slovakia	63	78.4	White-blue	35.0	1.9	Cream with dark hilum	240.7
LAT 4021/86	Slovakia	65	74.6	White	42.0	2.1	Cream	276.7
LAT 4022/86	Slovakia	59	88.4	White	28.2	1.9	Cream	244.8
LAT 4023/86	Slovakia	60	102.8	White-blue	51.4	1.8	Cream with dark hilum	207.9
LAT 4044/97	Slovakia	63	97.4	White-blue	52.6	2.6	Cream to slightly brown with dark hilum	228.2
LAT 4057/99	Slovakia	60	74.6	White	29.0	1.6	Cream	200.9
LAT 4058/99	Slovakia	63	99.8	White	49.2	2.3	Cream	213.8
LAT 4059/99	Slovakia	63	111.2	White	57.2	2.5	Cream	222.4
LAT 400/99	Slovakia	63	102.4	White-blue	28.8	2.0	Cream with dark hilum	222.2
LAT 4066/1	Slovakia	64	93.4	White-blue	39.8	2.2	Cream with dark hilum	243.9
LAT 441/80	Hungary	64	89	White	48.8	1.9	Cream	289.1
LAT 455/75	Hungary	59	81.2	White	40.6	2.4	Cream	192.3
LAT 494/82	Hungary	58	89.4	White	54.2	1.8	Cream	366.3
LAT 477/80	Czech	63	97	White-blue	42.8	2.5	Cream to grey with brown hilum	238.7
LAT 478/80	Czech	63	100.4	White	45.0	2.3	Cream	179.9
LAT 447/78	Russia	65	104.8	White	54.4	2.9	Beige-cream	204.1
LAT 448/73	Russia	63	91.8	White	52.6	2.5	Cream	202.8
LAT 466/82	Russia	64	97.6	White	41.2	2.4	Cream with slightly brown hilum	181.3
LAT 467/79	Russia	60	98.4	Dark-blue	53.4	3.0	Dark brown	165.5

Table 1 continued

Accession code	Country of origin	Days to onset of flowering	Plant height (cm)	Flower colour	Number of pods per plant	Number of seeds per pod	Seed coat color	TSW (g)
LAT 434/75	Ukraine	65	90.4	White	39.2	2.6	Cream	162.9
LAT 435/80	Ukraine	64	86.6	White-blue	41.6	2.1	Grey to slightly brown	164.3
LAT 465/78	Ukraine	59	103.8	White	49.8	2.7	Cream	164.9
LAT 4011/84	Ukraine	63	87.3	White	31.0	2.9	Cream	109.8
Derek	Poland	61	73	White	63.7	3.3	Beige-cream	120.2
Krab	Poland	62	65.7	White	82.8	3.0	Cream	165.4
Mutant	Poland	61	79.5	White	79.2	3.3	Cream	85.7
Mean of south-central Europe accessions[a]	*62*	*84*			*37.9[a]*	*2.2[a]*		*214.5[b]*
Mean of east-central Europe accessions[a]	*63*	*89*			*53.5[b]*	*2.8[b]*		*157.0[a]*
Average of all accessions	62	85			39.7	2.3		202.8
Min.		58	56.2		20.8	1.6		85.7
Max.		65	111.2		82.8	3.3		366.3
SEM		0.50	1.16		0.83	0.05		3.89

[a] Means of characteristics given in columns for these regions of central Europe marked with different letters differ significantly ($P < 0.05$)

($P \leq 0.05$) weight of *L. sativus* accessions originating from south-central Europe in comparison to those from east-central European countries (214 vs. 157 g). The smallest seeds (86 g TSW) had Mutant (Polish), whereas the heaviest ones (366 g TSW)—LAT 494/82 (Hungarian accession). Average TSW of *L. cicera* amounted to 71 g, with the lowest weight (32 g TSW) of Italian LAT 257/85 and the highest (83 g TSW)—Greek LAT 214/79.

The average content of basal nutrients, minerals as well as antinutritional factors (ANFs) in *L.sativus* and *L. cicera* (DM basis) are presented in Tables 3 and 4.

Average content of basal nutrients in grass pea was similar in accessions originating from both, south-central and east-central Europe. However, somewhat higher level (statistically insignificant) of crude protein and ether-extract in grass pea lines of south-central Europe accessions in comparison with the lines from east-central Europe (309 vs. 296 g and 8.1 vs. 7.0 g, respectively) were noted. Alike, the content of minerals was similar in the accessions originating from these parts of Europe, except a slightly higher (statistically insignificant) manganese level in the south-Europe lines (17.1 vs. 10.6 mg kg^{-1}). The average level ANFs—tannins and β-ODAP was equal to 3.30 and 734 mg kg^{-1} respectively, with their higher contents (however statistically insignificant) in accessions from south Europe (3.48 vs. 3.13 and 746 vs. 651 mg kg^{-1} respectively). The differences between accessions in tannin content were not great (2.7–4.2 g kg^{-1} DM), whereas the β-ODAP level appeared to be more differentiated. The lowest content (583 mg kg^{-1}) was reported for LAT 4044/97, while the highest level of this ANF (1,340 mg kg^{-1}) for DM of LAT 496/82 accession. Both accessions came from Slovak Republic.

The average crude protein content in 1 kg of red pea seeds, lower than in grass pea, amounted to nearly 255 g kg^{-1} DM (Table 4). On average, the seeds contained 6.5 g ether extract, 64 g crude fiber, 638 g N free extract and 176 g NDF (Neutral

Table 2 Origin and some phenological and morphological traits of red pea (*Lathyrus cicera* L.) accessions

Accession code	Country of origin	Days to onset of flowering	Plant height (cm)	Flower colour	Number of pods per plant	Number of seeds per pod	Seed coat color	TSW (g)
LAT 206/79	Greece	58	44.8	Red	26.0	3.9	Dark brown to black	75.5
LAT 207/84	Greece	63	43.2	Red	37.8	4.2	Dark brown	74.7
LAT 208/79	Greece	63	45.4	Bright red	39.2	4.6	Bright brown	72.3
LAT 209/84	Greece	63	38.0	Red	36.2	4.2	Dark brown	67.3
LAT 212/84	Greece	60	38.2	Red	38.0	4.3	Dark brown	75.6
LAT 214/79	Greece	59	35.6	Red	22.6	3.8	Dark brown	83.3
LAT 215/92	Greece	58	44.0	Rosa red	34.8	3.5	Bright brown	74.4
LAT 216/92	Greece	63	53.6	Red	40.2	4.5	Dark brown	82.3
LAT 217/92	Greece	65	48.6	Bright red	32.8	4.7	Dark brown	74.3
LAT 218/97	Greece	59	44.8	Red	42.4	4.4	Bright brown	78.4
LAT 220/8	Greece	60	43.8	Red	45.0	4.5	Bright brown	71.9
LAT 223/79	Greece	60	49.2	Rosa red	36.6	4.3	Bright brown	82.8
LAT 226/92	Greece	59	43.8	Red	28.4	4.0	Bright brown	73.7
LAT 228/79	Greece	60	57.4	Bright red	44.8	4.4	Bright brown	72.4
LAT 231/79	Greece	64	43.6	Red	20.8	3.8	Bright brown	69.1
LAT 250/80	Greece	63	50.4	Red	29.6	4.3	Bright brown	60.3
LAT 256/79	Spain	63	49.2	Rosa red	27.4	4.1	Dark brown	64.4
LAT 257/85	Italy	84	55.4	Red	25.2	3.2	Bright and dark brown	32.1
Average of all accessions		62	46.1		34.2	4.1		71.3
Min.		58	35.6		20.8	3.2		32.1
Max.		84	57.4		45.0	4.7		83.3
SEM		1.25	1.11		0.92	0.09		1.51

Detergent Fibre) in 1 kg dry matter. The mean concentration of potassium, phosphorus, calcium and magnesium was 9.5, 4.5, 1.8 and 1.2 g kg^{-1} DM, respectively. The seeds of investigated *L. cicera* accessions had a fairly high level of tannins (average 6.4 g kg^{-1} DM), which, however, was far higher (16.6 g kg^{-1} DM) in Italian LAT 257/85 accession. The average β-ODAP level reached 1,168 mg kg^{-1} DM and it ranged from 911 to 1,344 mg kg^{-1} DM) between the accessions.

Table 3 Average content of basal nutrients, minerals and ANF_S in 1 kg seeds' DM of grass pea (*L. sativus* L.) originating from Europe

Item	South-central Europe			East-central Europe			Mean		All accessions			
	Slovakia	Hungary	Czech	Poland	Russia	Ukraine	South-central Europe	East-central Europe	Average	Min	Max	SEM
Nutrients, (g)												
Crude ash	40.2	37.9	39.8	37.6	36.6	41.5	39.3	38.6	39.7	32.2	40.1	0.16
Crude protein	300.9	306.7	303.8	307.4	295.8	288.7	303.8	297.3	300.4	288.7	322.4	0.98
Ether extract	7.9	8.0	7.2	8.2	6.1	7.1	7.7	7.1	7.7	4.9	10.4	0.16
Crude fiber	59.1	50.9	61.5	48.1	62.5	61.2	57.2	57.3	58.5	44.5	64.9	0.58
N free extract	591.9	596.5	587.7	598.7	599.0	601.5	592.0[a*]	599.7[b]	593.6	556.1	627.8	1.55
NDF	169.2	161.3	171.6	156.2	171.9	171.3	167.4	166.5	168.5	142.5	189.2	2.25
ADF	76.7	76.1	78.2	67.5	77.3	76.1	77.0	73.6	76.2	59.3	87.6	1.55
Minerals												
Ca (g)	1.22	1.39	1.24	1.09	1.11	1.22	1.3	1.1	1.2	1.02	1.44	0.01
P (g)	6.22	5.83	5.92	5.69	5.62	6.39	6.0	5.9	6.1	5.35	6.62	0.03
Mg, g	1.36	1.36	1.39	1.22	1.27	1.53	1.4	1.3	1.4	1.06	1.81	0.02
K, g	10.06	8.27	8.63	10.87	8.41	9.45	9.0	9.6	9.8	8.03	11.02	0.13
Na, g	0.30	0.29	0.38	0.19	0.35	0.29	0.3	0.3	0.3	0.16	0.36	0.02
Cu, mg	7.71	7.81	8.53	8.31	7.82	11.24	8.0	9.1	8.0	7.09	11.85	0.38
Zn, mg	30.06	27.12	27.41	20.94	27.12	35.12	28.2	27.7	29.4	24.6	36.7	0.75
Fe, mg	47.12	44.87	42.74	39.14	44.18	49.23	44.9	44.2	46.3	41.1	54.8	1.42
Mn, mg	17.46	11.09	11.42	9.92	10.51	11.28	13.3	10.6	15.5	9.63	18.5	0.77
ANF_S												
Tannins, g	3.46	2.83	3.01	3.00	3.43	2.93	3.1	3.1	3.3	2.72	3.72	0.06
ODAP, mg	746.5	651.2	877.5	707.2	647.5	613.2	758.4	656.0	733.5	563.6	1340.4	12.82

* In a row, means marked with different letters are significantly different ($P < 0.05$)

Concentration values of amino acids (g/16gN) in the investigated *Lathyrus* genus are presented in Table 5 (*L. sativus*) and in Table 6 (*L. cicera*). The results regarding both species reveal small differentiation between accessions originating from different regions of Europe, as well as between each accession. The differences between both species in amino acids composition of protein were not great, either.

In fat of *L. sativus* linoleic and linolenic acids constituted 57.4 and 9.1%, respectively (Table 7). Total unsaturated fatty acids (MUFA + PUFA) in grass pea fat reached 82.4%. Fat of *L. cicera* seeds comprised 47.2 and 9.1% linoleic and linolenic acids, respectively. Unsaturated fatty acids altogether accounted for 70.5% of the evaluated accessions of red pea fat (Table 8).

Discussion

Lathyrus sativus is a much-branched, spreading, seldom typically straggling or semi-erect in plant growth habit. The stems are slender, quadrangular with winged margins. Plant height has been found to vary greatly. Variation of this trait depends on the environmental condition, particularly a soil type and

Table 4 Average content of basal nutrients, minerals and ANF_S in 1 kg seeds' DM of red pea (*L. cicera* L.) originating from Europe

Item	Greece	Italy	Spain	All accessions			
				Average	Min	Max	SEM
Nutrients, g							
Crude ash	37.1	39.2	40.2	37.4	34.8	40.8	0.47
Crude protein	255.1	256.4	244.2	254.6	238.4	274.9	2.59
Ether extract	6.4	6.5	7.8	6.5	5.3	7.9	0.14
Crude fiber	61.8	74.8	83.6	63.7	52.5	83.9	0.33
N free extract	639.6	623.1	624.2	637.8	619.8	653.2	3.07
NDF	174.4	185.2	197.6	176.3	152.4	198.2	3.83
ADF	76.1	80.4	84.2	76.8	65.7	84.6	1.40
Minerals							
Ca, g	1.79	1.51	1.75	1.8	1.29	1.97	0.04
P, g	4.48	4.47	5.07	4.5	4.03	5.32	0.10
Mg, g	1.17	1.25	1.29	1.2	0.86	1.41	0.03
K, g	9.43	9.92	11.05	9.5	8.33	11.05	0.09
Na, g	0.29	0.27	0.27	0.3	0.24	0.33	0.01
Cu, mg	8.45	7.65	9.55	8.5	7.19	10.5	0.42
Zn, mg	22.87	23.43	27.32	23.1	19.6	27.7	1.26
Fe, mg	45.53	46.28	48.65	45.7	41.1	52.8	2.85
Mn, mg	8.54	9.16	10.54	8.7	7.86	10.54	0.60
ANF_S							
Tannins, g	5.71	16.62	7.81	6.4	5.12	16.62	0.66
ODAP, mg	1159.5	1214.4	1264.5	1168.5	910.8	1345.2	12.05

precipitation level during vegetation period. In comparison to the earlier years in Poland, 2009 belonged to the wet test years and therefore, relatively high average plant height and wider range of this characteristics presented in this research paper. The previous studies on grass pea in Poland indicated that at normal annual rainfall amount about 600 mm (Dmochowska 2011), the plant height can be over 80 cm (Rybiński 2003). In 2002, at 516 mm rainfall level, plant height of grass pea mutants ranged from 67.8 up to 94.3 cm but in 2003, exceptionally dry (331 mm), it oscillated between 25.6 and 42.7 cm (Kozak et al. 2008). Relatively low plant height (from 37.2 to 63.6 cm) and uniform maturity of plants were observed in the experiment in 2006 and associated with strong abiotic stress caused by long term drought (Grela et al. 2010). According to Campbell (1997), plant height has been found to differ largely and in India it varied from 15 to 68 cm while in Canada between 24.5 and 172 cm. A great part of the accessions studied in the present paper derived from Slovakia. In the experiment conducted by Benkova and Zakova (2001), plant height of Slovak grass pea was found within 74.2 to 99.7 values, average 85.5 cm, which was consistent with our experimental data. A very wide height range, from 20 to 100 cm was established for the accessions of *L. cicera* (IPGRI 2000) as compared with the accessions presented in this paper (35.6–57.4 cm). Generally, the number of days till the onset of flowering in this study was similar to that reported for grass pea by Grela et al. (2010)—(58 up to 66 day after sowing), which proved that accessions from the Mediterranean region started flowering earlier as compared to those from Germany or Poland. In the present study, the earliest flowering plants of grass pea (58 days) included three accessions from Slovak Republic (LAT 470/75, LAT 471/75 and LAT 472/80). Hanbury et al. (1995) noted much broader range for Mediterranean type environment (south Australia) for grass pea and red pea. The mean values for both species were 98 and 103 days within the range of 73–123 and 95–138 days, respectively.

Table 5 Average amino acid composition (% of protein) of grass pea (*L. sativus* L.) seeds

Amino acids	South-central Europe			East-central Europe			Mean		All accessions			
	Slovakia	Hungary	Czech	Poland	Russia	Ukraine	South-central Europe	East-central Europe	Average	Min	Max	SEM
Asp	8.49	8.55	8.76	9.63	9.00	8.12	8.51	8.85	8.58	8.12	9.63	0.06
Thr	3.27	3.06	3.28	3.39	3.31	3.17	3.26	3.28	3.26	3.06	3.44	0.01
Ser	4.07	3.71	4.02	4.09	4.18	3.75	4.04	4.00	4.03	3.71	4.18	0.02
Glu	13.20	12.44	13.19	14.45	13.76	11.96	13.15	13.29	13.18	11.95	14.45	0.10
Pro	5.80	5.71	5.29	6.91	5.19	4.83	5.77	5.53	5.72	4.83	6.91	0.08
Gly	3.29	3.19	3.41	3.59	3.46	3.13	3.29	3.38	3.31	3.13	3.68	0.02
Ala	3.76	3.71	3.92	4.17	3.95	3.61	3.76	3.89	3.79	3.60	4.21	0.03
Cys	1.60	1.49	1.62	1.98	1.64	1.81	1.59	1.79	1.63	1.49	1.98	0.02
Val	3.68	3.69	3.65	4.02	3.73	3.52	3.68	3.73	3.69	3.52	4.02	0.02
Met	0.83	0.72	0.86	0.88	0.89	0.84	0.82	0.87	0.83	0.72	0.99	0.01
Ile	3.01	2.96	3.07	3.12	3.17	2.81	3.01	3.03	3.01	2.81	3.17	0.02
Leu	5.39	5.24	5.44	5.83	5.69	5.01	5.38	5.48	5.40	5.01	5.82	0.03
Tyr	2.27	2.12	2.28	2.35	2.39	2.10	2.26	2.27	2.26	2.10	2.44	0.02
Phe	3.55	3.32	3.53	3.51	3.66	3.28	3.53	3.48	3.52	3.28	3.77	0.02
His	2.25	2.24	2.38	2.56	2.31	2.12	2.26	2.31	2.27	2.12	2.56	0.02
Lys	5.53	5.52	5.82	5.94	5.79	5.29	5.54	5.65	5.56	5.52	5.94	0.03
Arg	6.82	6.49	7.12	7.80	6.78	6.12	6.81	6.82	6.81	6.12	7.80	0.06
Trp	1.09	0.93	0.94	1.01	1.03	1.14	1.07	1.06	1.07	0.93	1.14	0.01
EAAI	64.3	64.1	64.3	68.2	65.9	62.4	64.3	65.3	64.5	62.4	68.2	0.27

EAAI essential amino-acid index

The flowers of grass pea are found in blue color, pink, red, white or various combination of these (Campbell 1997). All local forms in Poland have only a white flower color as compared to the collection lines from Italy, Spain and France with white or white-cream, but also blue or light blue flowers (Grela et al. 2010). In the present work, except for two accessions (the Ukrainian and Russian), other nine forms originated from east-central Europe (Russia, Ukraine and Poland) produced only pure white flower. The accessions from Slovakia presented coloured flowers, (white blue 21 and blue 2 accessions) as well as white ones (15 accessions). Evaluation of the selected traits in 34 grass pea accessions originating from Slovak Republic Genebank confirmed the presence of plants with coloured flower (Benkova and Zakova 2001). According to IPGRI (2000), the geographical distribution goes as follows: the blue-flowered lines are concentrated in Southwest Asia and Ethiopia, whereas the white and mixed-colour lines are found in Europe, the Canary Island and countries of the former USSR.

In the presented investigations, all lines of *L. cicera* had red flowers with only minor colour variation. In opinion of other authors, the plants present copper-coloured flowers and not winged at the corners pods.

On the whole, the grass pea plants subjected to the geographical distribution, present a wide variation of pod shapes from broad-elliptical, oblong-elliptical, medium oblong-elliptical to broad-linear. In this paper, the accessions from east-central Europe show more linear type of pod shape for the smallest-seed accessions from Poland, Ukraine and Russia and more elliptical for a few larger-seeded types from Slovakia and LAT 494/82 from Hungary. The analysis of Slovak accessions by Benkova and Zakova (2001) showed that pod number per plant varied from 17.6 to 45.1 with a mean of 27.2. In our study the number of pods per plant of the Slovak accessions appeared to be by about 10 greater with a wider range from 20.8 to 60.8. The highest number of pods per plant (above 60) was observed in grass pea of the Polish accessions. This characteristics is directly associated with

Table 6 Average amino acid composition (% of protein) of red pea (*L. cicera* L.) seeds

Amino acids	Greece	Italy	Spain	All accessions			
				Average	Min	Max	SEM
Asp	8.54	8.10	8.99	8.54	8.10	8.99	0.10
Thr	3.27	3.21	3.31	3.27	3.21	3.31	0.01
Ser	4.01	3.75	3.99	3.99	3.74	4.00	0.03
Glu	12.85	12.05	12.85	12.81	12.05	12.85	0.11
Pro	5.42	6.08	6.63	5.52	5.42	6.63	0.14
Gly	3.21	3.10	3.39	3.21	3.10	3.39	0.03
Ala	3.65	3.51	3.94	3.66	3.51	3.94	0.05
Cys	1.58	1.56	1.59	1.58	1.56	1.59	0.00
Val	3.62	3.54	3.74	3.62	3.54	3.74	0.02
Met	0.84	0.76	0.83	0.84	0.76	0.84	0.01
Ile	2.85	2.82	3.17	2.87	2.82	3.17	0.04
Leu	5.27	5.04	5.55	5.27	5.04	5.55	0.06
Tyr	2.20	2.06	2.26	2.20	2.06	2.25	0.02
Phe	3.51	3.33	3.70	3.51	3.33	3.69	0.04
His	2.07	1.94	2.20	2.07	1.94	2.20	0.03
Lys	5.52	5.31	5.99	5.53	5.31	5.98	0.08
Arg	6.02	5.59	6.22	6.01	5.59	6.22	0.07
Trp	1.13	1.17	1.03	1.13	1.03	1.17	0.02
EAAI	63.10	61.27	65.21	63.12	61.27	65.21	0.45

EAAI essential amino-acid index

Table 7 Average fatty acid (FA) composition (% of total FA) of grass pea (*L. sativus* L.) seeds

Fatty acid	South-central Europe			East-central Europe			Mean		All accessions			
	Slovakia	Hungary	Czech	Poland	Russia	Ukraine	South-central Europe	East-central Europe	Average	Min	Max	SEM
C 14:0	0.68	0.67	0.55	0.62	0.58	0.63	0.67	0.61	0.66	0.47	0.79	0.02
C 14:1	0.49	0.38	0.43	0.53	0.42	0.44	0.48	0.46	0.48	0.32	0.57	0.01
C 16:0	10.27	9.34	11.43	10.07	9.38	9.36	10.26	9.56	10.12	8.68	12.54	0.19
C 16:1	0.64	0.52	0.57	0.38	0.54	0.41	0.63	0.45	0.59	0.29	0.76	0.02
C 18:0	4.91	5.36	5.03	6.89	4.37	4.49	4.95	5.10	4.98	4.21	7.19	0.19
C 18:1	13.41	15.18	14.04	14.44	13.39	11.48	13.56	12.98	13.44	10.38	17.38	0.29
C 18:2	57.37	56.78	55.03	56.49	57.94	59.18	57.22	58.00	57.38	51.62	60.63	0.49
C 18:3	9.12	8.49	9.29	6.78	9.96	10.23	9.08	9.19	9.11	6.56	11.08	0.20
C 20:0	1.15	0.67	0.72	1.17	0.91	0.92	1.10	0.98	1.07	0.59	1.32	0.03
C 20:1	0.29	0.51	0.42	0.57	0.45	0.46	0.31	0.49	0.35	0.21	0.61	0.02
C 20:4	0.39	0.35	0.63	0.57	0.41	0.42	0.40	0.46	0.41	0.29	0.78	0.02
C 22:1	0.59	0.84	0.62	0.91	0.74	0.83	0.61	0.82	0.65	0.49	1.02	0.02
Other	0.69	0.91	1.24	0.58	0.91	1.15	0.73	0.91	0.77	0.53	1.44	0.03
SFA	17.01	16.04	17.73	18.75	15.24	15.40	16.98	16.26	16.83	13.82	19.68	0.27
MUFA	15.42	17.43	16.08	16.83	15.54	13.62	15.59	15.19	15.51	12.48	18.54	0.27
PUFA	66.88	65.62	64.95	63.84	68.31	69.83	66.70	67.64	66.89	59.67	72.78	0.58

Table 8 Average fatty acid (FA) composition (% of total FA) of red pea (*L. cicera* L.) seeds

Fatty acid	Greece	Italia	Spain	All accessions			
				Average	Min	Max	SEM
C 14:0	1.75	1.82	1.64	1.75	1.49	1.98	0.02
C 14:1	0.29	0.32	0.28	0.29	0.24	0.34	0.01
C 16:0	16.29	17.05	16.31	16.33	15.98	17.67	0.16
C 16:1	0.62	0.58	0.42	0.61	0.33	0.76	0.05
C 18:0	7.61	7.73	7.42	7.61	6.81	9.01	0.16
C 18:1	10.31	9.21	9.73	10.22	8.78	10.85	0.24
C 18:2	47.16	47.41	46.83	47.16	44.46	49.53	0.32
C 18:3	9.03	9.11	9.94	9.08	8.72	10.63	0.15
C 20:0	2.59	2.41	2.23	2.56	1.92	2.72	0.04
C 20:1	0.49	0.47	0.62	0.50	0.39	0.72	0.03
C 20:2	2.34	2.75	2.69	2.38	2.09	2.82	0.06
C 22:1	0.25	0.28	0.42	0.26	0.21	0.44	0.04
Other	1.27	1.16	1.47	1.27	1.03	1.54	0.05
SFA	28.24	29.01	27.60	28.25	26.40	31.08	0.27
MUFA	11.96	10.86	11.47	11.88	9.48	12.51	0.29
PUFA	58.53	58.97	59.46	58.60	56.57	61.19	0.42

branches per plant. More branching plants are characteristic for accessions of Polish origin. Campbell (1997) found some correlation between pods per plant, plant height and seed size. The small-seeded lines normally had more seeds per pod than the larger-seeded lines (Campbell et al. 1994; Campbell 1997). In the present research, an average seed number per pod for grass pea was equal to 2.3 and it ranged from 1.6 to 3.3 with the highest values obtained for small-seeded forms from Poland. In contrast, the Hungarian line LAT 494/82 with the highest 1,000 seed weight (366 g) produced only 1.8 seeds per pod. As increased seed size usually is also highly correlated with higher yield, plant breeders might want to consider increased seed number per pod in larger-seeded types as an effective means to increase the yield. According to the Canadian investigations, seeds per pod varied from 1 to 4.3 (Campbell 1997), in India 1.6 to 4.6 (Pandey et al. 1995), in Nepal 2 to 5 (Yadov 1995) and in Italy 1 to 5 with a mean of 2.6 (Polignano et al. 2005). Besides, higher pod number per plant is commonly related to later maturity and growing plant biomass.

In our studies, *L. cicera* accessions as compared to grass pea, were characterized by a narrow range of pod number per plant (20.8–45.0) but markedly higher seed number per pod with a mean 2.3 versus 4.1 for grass pea and red pea, respectively. The Hanbury et al. (1995) researches performed in Australia demonstrated that yield of *L. cicera* was generally much higher than of either *L. sativus or L. ochrus* and the promising lines of those species with high yielding and low β-ODAP were selected (Siddique et al. 1996).

As reported by Desphande and Campbell (1992) and Campbell (1997), seed coat color of grass pea is closely associated with the color of flowers. The present research results have confirmed this statement. In this study, white flowering plants produced, as a rule, seeds with cream coat—among 28 accessions with white flowers, 25 had cream seed coat and 2 cream-beige. The white-blue flowering plants developed mainly cream seeds with dark or brown hilum (11 accessions) or cream seeds with dark or brown edge (8 accessions). The other white-blue and also blue flowering accessions had grey (5) or brown (2 accessions) seeds.

The wide variation in seed size noted in the present investigations may be valuable to the breeder, especially at the confirmed correlation between seed size and yield reported by Hanbury et al. (1995). Among Slovak grass pea accessions, small-seeded as well as large-seeded plants lines could be found in range of 1,000-seed weight from 147 to 276 g with mean of 209 g in the present study. Again, Hanbury et al. (1995) informed about a large-seeded form of grass pea originating from Czechoslovakia, analyzing 451 lines from different geographical distribution. That is consistent with the results obtained for Slovak accessions (Benkova and Zakova 2001) range from 232 to 354 g with mean of 286 g. Contrary to the Slovak and Hungarian accessions, the lines from the western Russia, Ukraine and Poland countries with a similar geographical position presented types with smaller seeds, whose 1,000-seed weight oscillated between 85.7 and 204.1 g with mean of 156.9 g. It implies similar origin of small-seeded form for a part of accessions from Slovakia and almost all originating from Russia, Ukraine and Poland. Thus, the hypothesis of Milczak et al. (2001) that grass pea was probably introduced to east Poland and the other countries of east Europe by Tatars in XVII century may be supported. Seeds of accessions from south-central Europe (Slovak Republic, Czech Republic and Hungary) resemble the Mediterranean region types more, which according to Jackson and Yunus (1984), Campbell (1997), Hammer et al. (1989) and Grela et al. (2010) are large-seeded ones opposite to small-seeded accessions from Indian subcontinent (Campbell et al. 1994). In comparison to small-seeded types from Asia with 1,000-seed weight from 29.5 to 67.6 g (Sarwar et al. 1995), accessions originating from the Mediterranean region (Spanish landraces) ranged from 140 to 368 g with a mean of 257 g (De la Rosa and Martin 2001).

Unlike grass pea, the investigated *L. cicera* accessions had considerably lower 1,000-seed weight with mean of 71.3 g, similar to small-seeded types of grass pea from India and Ethiopia (Hanbury et al.1995).

With exception of protein, the proximate contents of the nutrients in *L. sativus* and *L. cicera* were generally quite close with only some higher N-free extract, crude fibre, as well as NDF and ADF (Acid Detergent Fibre) contents of *L. cicera.*

Average content of crude protein in all investigated grass pea accessions (30% in DM), was higher by 3 percent units as compared to the data from our previous investigations on this species (Grela et al. 2010) and that agreed with the results given by Hanbury et al. (2000)—mean (29.4%) from 9 publications. Content of this nutrient in red pea, proved to be lower by nearly 5 percent units and, therefore, similar to the results obtained in Franco Jubete (1991) and Hanbury (2000) studies but lower than that reported by Aletor et al. (1994).

Amino acid composition of protein of both investigated species was very much alike, comparable with the results published by Hanbury et al. (2000), Yan et al. (2006) and Karadag and Yavuz (2010). Among the essential amino acids, the most limiting biological value of diet protein for monogastrics are usually lysine and methionine. Like the most of the pulse seeds, the protein of the evaluated species is quite rich in lysine, whose content fully covers requirements of growing monogastrics, whereas poor in methionine, satisfying only half of their dietary needs (NRC 1994; NRC 1998). Calculated according to Oser (1959) the average essential amino acid index (EAAI) of *L. sativus* and *L. cicera,* reached 64.4 and 63.1, respectively.

Both *L. sativus* and *L. cicera* are not fat abundant, its average content in 1 kg seeds DM of these species amounted to 7.1 and 6.5 g, respectively. Its composition, however, is highly valuable, for both, human and animals, as over half of it is usually composed of polyunsaturated fatty acids (PUFA). In fat of *L. sativus,* PUFA accounted for 67% (mainly linoleic 57% and linolenic acid 9%). Some lower percentage of these acids (51 and 6%, respectively) was determined in the seeds of *L. sativus* accessions investigated in our previous work (Grela et al. 2010). Average fatty acid composition of *L. cicera* seeds fat was similar to grass pea, except for lower (by 10%) linoleic acid, but higher content of saturated fatty acids – palmitic and stearic acids (by 6 and 3%, respectively). These results correspond with those presented by Hanbury et al. (2000).

Mineral contents in seeds (expressed in 1 kg DM basis) of both investigated species were alike, with a slightly lower level of phosphorus (4.5 g vs. 6.1 g), zinc (20.1 mg vs 29.4 mg) and manganese (8.7 mg vs. 15.5 mg) but higher calcium concentration (1.8 g vs. 1.2 g) in *L. cicera* in comparison to *L. sativus.* The differences between accessions were not substantial, either. The results correspond to those obtained by Hanbury et al. (1999), Hanbury and Hughes (2003) and Urga et al. (2005). Generally, except for potassium, the mineral contents in *Lathyrus* species, like in seeds of other pulses, are not high and their levels do not meet the growing animals nutritional requirements (NRC 1994; NRC 1998).

Lathyrus sativus as well as *L. cicera*, belong to the high protein plants. They have got large potential as the crops for the areas where they are now grown as well as to other regions, where their adaptation or desirable features make them very attractive to produce (Campbell 1997). Their wider utilization however, is limited by ANFs contents – mainly β-ODAP, but also by other ANFs—tannins and trypsin inhibitor. Although the environmental conditions can affect ANFs content in seeds, their levels depend mainly on a genotype (Hanbury et al. 1999). Content of β-ODAP in the seeds of the examined *L. sativus* accessions (average 733 mg kg $^{-1}$) was rather low, lower in comparison to its level (847 mg kg $^{-1}$ DM) determined in our previous study on other European accessions (Grela et al. 2010). These results agree with those established by Pandey et al. (1997) in grass pea varieties bred for low ODAP content. Vedna (2001) reported that this level of β-ODAP can be considered safe for human consumption. Content of this ANF in *L. sativus* seeds obtained in the Abd El-Moneim et al. (2010) investigations was 2–3 times higher. Hanbury et al. (1999) highlighted great differentiation of β-ODAP level (from 400 to 7,600 mg kg $^{-1}$) in seeds of this species regarding the origin of the investigated lines of grass pea.

Contents of β-ODAP in seeds of the *L. cicera* accessions presented in this work (from 911 to 1,344 mg, with average 1,168 mg kg^{-1} DM) were similar to those from the studies carried out by Aletor et al. (1994), but lower than that achieved by Hanbury et al. (1999).

Tannins have been claimed to affect adversely protein digestibility from plant-based diets (Marquardt 1989). Content of these ANFs in the studied *L. sativus* accessions (average 3.3 kg^{-1} DM) was close to the level determined by Wang et al. (1998) and 3 times higher in comparison with the results reported by Deshpande and Campbell (1992) but twice lower than in grass pea seeds evaluated by Urga et al. (2005). Similarly to Deshpande and Campbell (1997), tannin concentration was significantly ($P < 0.05$) correlated with the color of flowers ($r = 0.64$) as well as the colour of their seeds ($r = 0.69$), noteworthy darker colours are associated with generally higher levels of tannins. Tannin content in *L. cicera* was nearly twice higher in comparison with their contents in *L. sativus*. Similar concentration of this ANF in *L. cicera* was established by Hanbury et al. (2000).

Conclusion

The morphological evaluation of 54 European *L. sativus* accessions under study allowed to distinguish two groups of countries of their origin, i.e. the countries from south-central Europe (Czech Republic, Hungary, Slovak Republic) and east-central European countries (Poland, Russia, Ukraine). The grass pea accessions from south-central Europe had on average lower pod number per plant (37.9 vs. 53.5) and lower number of seeds per pod (2.2 vs. 2.8) but higher thousand seeds weight (214 g vs. 157 g) in comparison with the accessions from east-central Europe. Therefore, it may be conceived that the accessions from south-central Europe were formed mainly under the influence of the Mediterranean basin area, whereas the lines from east-central Europe accessions were primarily affected by the landraces coming from the Asia continent.

Average contents of basal nutrients in the seeds of each investigated accessions of *L. sativus* species were similar in both groups regarding their origin (south-central or east-central European countries). Both, the seeds of *L. sativus* as well as *L. cicera* represent protein rich food/feed with about 30 and 25% respectively, of this nutrient in dry matter. Except low methionine level, their protein characterizes fairly high level of other exogenic acids (EAAI around 63–64%). They are not rich in fat (<1%), but it is valuable thanks to high level of polyunsaturated fatty acids.

The investigated *L. sativus* accessions shoved a low level of β-ODAP (safe for human consumption) and typical tannin content. The seeds of *L. cicera* had somewhat higher contents of these ANFs.

References

Abd E-M, Nakkoul H, Masri S, Ryan J (2010) Implications of zinc fertilization for ameliorating toxicity (Neurotoxin) in grasspea (*Lathyrus sativus*). J Agric Sci Tech 12:69–78

Aletor VA, Abd El-Moneim A, Goodchild AV (1994) Evaluation of the seeds of selected lines of three *Lathyrus* spp. for β-N-oxalylamino-l-alanine (BOAA), tannins, trypsin inhibitor activity and certain in vitro characteristics. J Sci Food Agric 65:143–151

AOAC (2000) Official methods of analysis. AOAC, Washington, DC, USA, ISBN: 0-935584-67-6

Arentoft AM, Greirson BN (1995) Analysis of 3-(N-oxalyl)-l-2, 3-diaminopropanoic acid and its α-isomer in grass pea (*Lathyrus sativus*) by capillary zone electrophoresis. J Agric Food Chem 43:942–945

Benkova M, Zakova M (2001) Evaluation of selected traits in grass pea (*Lathyrus sativus* L.) genetic resources. Lathyrus Lathyrism Newslett 2:27–30

Campbell CG (1997) Promoting the conservation and use of underutilized and neglected crops. Int Plant Genet Res Institute (IPGRI), Rome, vol 18

Campbell CG, Mehra RB, Agrawal SK, Chen YZ, Abd El Moneim AM, Khawaja HIT, Yadow CR, Tay JU, Araya WA (1994) Current status and future strategy in breeding grasspea (*Lathyrus sativus* L.). Euphytica 73:167–175

De la Rosa L, Martin I (2001) Morphological characterization of Spanish genetic resources of *Lathyrus sativus* L. Lathyrus Lathyrism Newslett 2:31–34

Desphande SS, Campbell CG (1992) Genotype variation in BOAA, condensed tannins, phenolics and enzyme inhibitors in grass pea (*Lathyrus sativus* L.). Can J Plant Sci 72:1037–1047

Dmochowska H (2011) Environment and environmental protection. In: Concise statistical yearbook of Poland 2011, Central Statistical Office, Warsaw, p 41

Franco Jubete F (1991) Los titarros. El cultivo de Lathyrus en Castilla y León. Junta de Castilla y León, Valladolid

Grela ER, Rybiński W, Klebaniuk R, Matras J (2010) Morphological characteristics of some accessions of grass pea (*Lathyrus sativus* L.) grown in Europe and nutritional traits of their seeds. Genet Resour Crop Evol 57(5):693–701

Hammer KG, Laghetti G, Perrino P (1989) Collection of plant genetic resources in South Italy, 1988. Kulturpflanze 37: 401–414

Hammer K, Knüpffer H, Laghetti G, Perrino P (1999) Seeds from a past. A catalogue of crop germplasm in Central and North Italy. Germplasm Institute of CNR, Bari

Hanbury CD (2000) Lathyrus grain as quality animal feed. Grain Legumes 30:10–11

Hanbury C, Hughes B (2003) Lathyrus cicera as quality feed for laying hens. Lathyrus Lathyrism Newslett 3:44–46

Hanbury CD, Marker A, Siddique KHM, Perry MW (1995) Evaluation of *Lathyrus* germplasm in a Mediterranean type environment in south-western Australia, vol 8, CLIMA Occasional Publication, Perth

Hanbury CD, Siddique KHM, Galwey NW, Cocks PS (1999) Genotype-environment interaction for seed yield and ODAP concentration of *Lathyrus sativus* L. and *L. cicera* L. in Mediterranean-type environments. Euphytica 110:45–60

Hanbury CD, White CL, Mullan BP, Siddique KHM (2000) A review of the potential of *Lathyrus sativus* L. and *L. cicera* L. grain for use as animal feed. Anim Feed Sci Technol 87:1–27

IPGRI (2000) Descriptors for *Lathyrus* ssp. International Plant Genetic Resources Institute, Rome

Jackson MT, Yunus AG (1984) Variation in the grass pea (*Lathyrus sativus* L.) and wild species. Euphytica 33: 549–559

Karadag Y, Yavuz M (2010) Seed yields and biochemical compounds of grass pea (*Lathyrus sativus L.*) lines grown in semi-arid regions of Turkey. Afr J Biotechnol 9(49): 8343–8348

Kislev ME (1989) Origins of the cultivation of *Lathyrus sativus* and *L. cicera* (Fabaceae). Econ Bot 43:262–270

Kozak M, Bocianowski J, Rybiński W (2008) Selection of promising genotypes based on path and cluster analyses. J Agric Sci 146:85–92

Lazanyi J (2000) Grass pea and green manure effects in the Great Hungarian plain. Lathyrus Lathyrism Newslett 1:28–30

Lioi L, Sparvoli F, Sonnante G, Laghetti G, Lupo F, Zaccardelli M (2011) Characterization of Italian grass pea (*Lathyrus sativus* L.) germplasm using agronomic traits, biochemical and molecular markers. Genet Resour Crop Evol 58: 425–437

Lwin S (1956) Studies in genus *Lathyrus*. M.Sc. Thesis, Manchester University

Marquardt RR (1989) Dietetary effects of tannins, vicine and convicine. In: Huisman J, Van der Poel TFB, Liener IE (eds) Recent advances of research in antinutritional factors in grain legume seeds. Pudoc, Wageningen, pp 141–155

Milczak M, Pędziński M, Mnichowska H, Szwed-Urbaś K, Rybiński W (2001) Creative breeding of grass pea (*Lathyrus sativus* L.) in Poland. Lathyrus Lathyrism Newslett 2:18–23

NRC (1994) Nutrient requirements of poultry, 9th edn. National Academy Press, Washington, DC

NRC (1998) Nutrient requirements of swine, 10th edn. National Academy Press, Washington, DC

Oser BL (1959) An integrated essential amino acid index for predicting biological value of proteins. Academic Press, New York, pp 295–311

Pandey RL, Agraval SK, Chitale MW, Sharma RN, Kashyap OP, Geda AK, Chandrakar HK, Agrawal KK (1995) Catalogue of grasspea (*L. sativus* L.) germplasm. I. Gandhi Agric Univ Press, Raipur

Pandey RL, Sharma RN, Chitale MW (1997) Status of *Lathyrus* genetic resources in India. In: Lathyrus genetic resources network (LGNR), Proceedings of IPGRI-ICARDA-ICAR, pp 7–14

Piergiovanni AR, Lupo F, Zaccardelli M (2011) Environmental effect on yield, composition and technological seed traits of some Italian ecotypes of grass pea. J Sci Food Agric 91:122–129

Polignano GP, Uggenti P, Olita G, Bisiganano V, Alba V, Perrino P (2005) Characterization of grass pea (*Lathyrus sativus* L.) entries by means of agronomically useful traits. Lathyrus Lathyrism Newslett 4:10–14

Rybiński W (2003) Mutagenesis as a tool for improvement of traits in grasspea (*Lathyrus sativus* L.). Lathyrus Lathyrism Newslett 3:27–31

Sarwar CDM, Sarkar A, Murshed ANMM, Malik MA (1995) Variation in natural population of grass pea. In: *Lathyrus sativus* and Human Lathyrism, pp 161–164

Siddique KHM, Loss SP, Herwig S, Wilson J (1996) Growth, yield and neurotoxin (ODAP) concentration of three *Lathyrus* species in Mediterranean-type environments of Western Australia. Austr J Exp Agric 36:209–218

Skiba B, Gurung AM, Pang CK (2007) Genome mapping and molecular breeding in *Lathyrus*. In: Kole C (ed) Genome mapping and molecular breeding in plants, volume 3 pulses, sugar and tuber crops. Springer, Berlin, pp 123–131

Tavoletti S, Capitani E (2000) Field evaluation of grass pea population collected in the Marche region (Italy). Lathyrus Lathyrism Newslett 1:17–20

Urga K, Fufa H, Biratu E, Husain A (2005) Evaluation of *Lathyrus sativus* cultivated in Ethiopia for proximate composition, minerals, ODAP and anti-nutritional components. Afr J Food Agric Nutr Dev 5:1–16

Vavilov NI (1951) Phytogeographic basis of plant breeding. In: Verdoorn F (ed) The origin, variation, immunity, and breeding of cultivated plants, vol 13. The Ronald Press Company, New York, pp 13–54

Vaz Patto MC, Skiba B, Pang ECK, Ochatt SJ, Lambein F, Rubiales D (2006) *Lathyrus* improvement for resistance against biotic and abiotic stresses: from classical breeding to marker assisted selection. Euphytica 147:133–147

Vedna K (2001) Field evaluation of grass pea (*Lathyrus sativus* L.) germplasm for its toxicity in the northwestern hills of India. Lathyrus Lathyrism Newslett 2:82–84

Wang X, Warkentin TD, Briggs CJ, Oomah BD, Campbell CG, Woods S (1998) Trypsin inhibitor activity in field pea (*Pisum sativum* L.) and grass pea (*Lathyrus sativus* L.). J Agric Food Chem 46:2620–2623

Waniska RD, Hugo L, Rooney LW (1992) Practical methods to determine the presence of tannins in sorghum. J Applied Poult Res 1:122–128

Yadov CR (1995) Genetic evaluation and varietal improvement of grasspea in Nepal. In: Lathyrus genetic resources in Asia. Proceedings of regional workshop, December 27–29, Raipur, India, pp 21–27

Yan ZY, Spencer PS, Li ZX et al (2006) *Lathyrus sativus* (grass pea) and its neurotoxin ODAP. Phytochemistry 67(2):107–121

Yunus AG, Jackson MT (1991) The gene pools of grass pea (*Lathyrus sativus* L.). Plant Breed 106:319–328