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COMPARATIVE CHARACTERISTICS OF VEGETATIVE AND GENERATIVE SPHERE IN PLANTS OF WILD FLAX SPECIES

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ABSTRACT

For the first time, a comparative study of 5 annual and 6 perennial wild flax species ex situ on one test plot of the steppe zone of Ukraine is conducted. Similarity of the traits of vegetative and generative sphere in studied species is established, that indicates the close phylogenetic relationships between them. It is found that among the these wild species the biggest bush and largest lamina (300 mm^2) has *L. hirsutum* while the lowest rates of the habit traits shows *L. pubescens.* The given collection covers a wide range of flower color, but most species are characterized by blue corolla. Flower diameter ranges from 12 to 38 mm, boll diameter - from 2.9 to 7.1 mm, weight of 1.000 seeds - from 0.6 to 5.1 g. The seeds of all studied wild species contain oil with a fatty acid composition which is characteristic of the *Linum* genus, but significantly less than cultivated flax. It is found that *L. thracicum* has increased content of linoleic acid (almost 60%), *L. hispanicum* - higher content of saturated fatty acids (over 15%) and *L. grandiflorum* - oleic acid (about 24%). The studied species are of value as a genetic resource for potential use in gardening, agriculture and pharmaceuticals.

Keywords: *Linum* genus, annual and perennial wild species, traits of vegetative and generative sphere, biochemical indicators of seeds

1. INTRODUCTION

The variety of species is characterized by the biological diversity and it is the potential of genetic resources of cultivated plants. The study of genetically valuable species and introducing them to the culture has recently become particularly relevant (Kloppenburg et al., 1987; Ingram, 1996; Zhuchenko, 2009-2011).

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The genus *Linum* L. played an important role in economic and social development of mankind for thousands of years. It is important to note, that this crop is widely and effectively grown for a long time in various countries on different continents, as oil, and as the fiber plant (Cullis, 2011).

Although this genus is famous for one agricultural representative *L. usitattissimum*, but there is a large number of its bad-known wild relatives (Кутузова, 1998). Regarding wild species, there is only a small number of studies conducted in the field conditions or studies on the herbarium material (Ockendon, 1971).

In the *Linum* genus all species are divided into five sections – *Linum, Dasylinum, Syllinum, Cathartolinum*, and *Linastrum (Linopsis*) (McDill et al., 2009). According to the traditional view, *Linum* is initially diversified in Europe and Western Asia. Most species occurs in the Mediterranean region, and *Syllinum* and *Dasylinum* sections are entirely limited to the Mediterranean and Eurasia. At the same time, about 180 species of the *Linum* genus are distributed across the temperate and subtropical regions of the world.

Our research focuses on the comparative study of different species of flax on one experimental plot to identify the prospects for their domestication and inclusion in the genetic and breeding work.

2. MATERIALS AND METHODS

The collection of wild species of flax has been collected by us during the previous 10 years. Most of these species is part of a group of European flax. The collection includes perennial species *L. austriacum* L., *L. hirsutum* L., *L. narbonense* L., *L. perenne* L., *L. thracicum* Degen and annual species – *L. angustifolium* Huds., *L. bienne* Mill., *L. hispanicum* Mill., *L. crepitans* Dum., *L. grandiflorum* Desf., *L. pubescens* Banks and Solander. Most of the samples were initially obtained from N.I.Vavilov Research Institute of Plant Industry (VIR) and All-Russian Research Institute for Flax (VNIIL). The seeds of *L. pubescens* were purchased in «Bejo Zaden B.V.». The species of *L. austriacum* and *L. hirsutum* are native to the southern steppe of Ukraine where these studies were carried out. Seeds and vegetating plants of *L. austriacum* and *L. hirsutum* species were collected in situ, moved to the experimental plot and studied in detail in ex situ conditions (Poliakova, 2014).

The study of presented collection was carried out during 2011-2014 years. In the period of full bloom such traits as plant height, number of basal flowering stems, bush diameter and leaf area were analyzed. The diameter of the bush was measured at the flowering stage. Leaves were collected at the middle part of the main stem. Among traits of generative sphere such traits as diameter of the flower, the diameter of the boll and the weight of 1.000 seeds were analyzed. The flowers, bolls and seeds, formed on the main stem, were taken into account. The oil content in

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the seeds was defined by extraction. Fatty acid composition of seed oil was determined by gas-liquid chromatography using "HP-6980" analyzer. The protein content in the seeds was determined by Kjeldahl method. All indexes of morphological traits of vegetative and generative spheres and biochemical composition of seeds are average data for at least three years.

3. RESULTS

Specificity of the species is characterized by habit traits, as well as colour and size of the individual parts of the plant. However, some scientists take under consideration the traits of vegetative sphere not only as qualitative characteristics, but quantitative ones with almost continuous variation (Ockendon, 1971).

3.1. Traits of vegetative sphere

Characteristic traits of vegetative sphere of plants are shown in Table 1 and Figure 1. Studies have shown that the highest (about 75 cm) and the largest bush (diameter is more than 54 cm) has *L. hirsutum*. Perennial species of *Linopsis* section (former *Adenolinum*, *Linastrum*) vary in height and diameter of the bush from 40 to 60 cm. The plants of *L. thracicum* have the smallest height (36.0 cm) and a more "compact" size with a diameter up to 38 cm.

Among annual species, *L. grandiflorum* is notable for higher plant height (up to 50 cm) and a large number of lateral stems, which supply an ornamental effect to this species. Species of *L. angustifolium* and *L. bienne* are characterized by lower index of height, but more quantity of lateral stems. *L. crepitans* is more similar to cultivated flax by its appearance than the other annual species. The lowest index of habit was found in *L. pubescens* .

All investigated species have simple, alternate, sessile, oblong, extended lanceolate leaves (Figure 1). As we can see from the presented data, *L. hirsutum* has the largest lamina with an area of more than 300 mm^2. *L. thracicum, L. grandiflorum and L. pubescens* also have fairly large leaves with area of more than 200 mm^2. The rest of the species has this criterion from 30 to 70 mm^2. *L. hirsutum and L. pubescens* are also characterized by intensive pubescens of leaves and stem with protruding hairs that is the distinctive feature for *Dasylinum* section.

3.2. Traits of generative sphere

All investigated species have bisexual, regular, five-petalled flowers, almost spherical bolls with smooth, ovoid, small, shiny seeds. The flowers begin to open in a short time after sunrise on a sunny day or a little later in cloudy weather.

Table 2 and Figure 2 show that the diameter of the flower in wild species varies from 12 to 40 mm. Most species has separate petals. In this regard, *L. hirsutum, L. thracicum, L. pubescens*

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have a distinction, because of fused lower edges of petals. As a result of this feature, blossoming in these species is longer and the flowers stay on the plant almost till the evening.

As it can be clearly observed from the data (Table 2, Figure 2), *L. hirsutum* has the largest flower (more than 38 mm in diameter). *L. grandiflorum* has a big flower (more than 36 mm) as well, while the smallest one (12 mm) – *L. hispanicum.*

The investigated collection covers a wide variety of flower colours. But most of the species has a blue colour. These are: *L. austriacum, L. narbonense, L. perenne, L. angustifolium, L. bienne, L. hispanicum, L. crepitans. L. pubescens* is notable for its specific pink colour of corolla petals. Light purple flower colour is characteristic we have identified natural populations of *L. hirsutum*, and bright red – *Linum grandiflorum*. *L. thracicum* is the only species, whose flowers have a yellow colour.

L. austriacum have blue flower with a diameter of more than 30 mm, five unjoint petals, open shape and similar to the cultivated flax. In natural environment of Zaporizhzhya region we have selected an albiflorous sample of *Linum austriacum L. lus. Albiflorum* (Poliakova, 2014).

The presented species have almost spherical boll with a diameter from 3 to 7 mm. As it can be observed from the Figure 2, almost all wild species have strongly dehiscent bolls. An exception is *L.bienne*, which has slightly dehiscent bolls and *L. pubescens* with unopened, dense bolls.

The seeds are oblong, flat, smooth, from light to dark brown colour, small. Cultivated flax refers to small-seeded crops, but its wild relatives have considerably less weight indicators of 1.000 seeds. Only in *L. crepitans* the dimensions of this trait reach 5 grams, but the rest of species, which were investigated, have the range of 3.0 to 0.6 g.

3.3. Biochemical indicators of seeds

The data on biochemical content of seeds in different wild species of *Linum genus* are extremely limited. According to our data, the protein content is in the range of 16-26%. The lowest amount was found in *L. narbonense*, and the biggest one – in *L. thracicum* (Figure 3). All investigated wild species contain considerably less oil in the seeds than the cultivated flax. *L. crepitans*, which has more than 41% of oil, is the closest to the cultivated flax according to this indicator. Oil content of the other wild species varies from 24% to 35%. In general, perennial species differ from annual ones by lower content of both protein and oil.

In our research, in general, all wild species had a fatty-acid composition of oil which is characteristic of the genus *Linum* with a predominance of linolenic acid and can be referred to the *Linum*-type (Table 2). At the same time we found out that the content of valuable linoleic

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acid in *L. thracicum* reaches almost 60%. *L. hispanicum* is notable of higher content of saturated fatty acids in oil (7.8% and 7.4% of palmitic and stearic acids respectively) and *L. grandiflorum* – oleic acid (24.0%).

4. DISCUSSION

The studied species of the *Linum* genus are annual and perennial grasses. In perennial species the stem lignifies. Most researchers attributes *L. hirsutum* to perennials. However, our long-term observations of plants in situ and ex situ in the southern Steppe of Ukraine show that this species has biennial cycle of development and is monocarpic (Poliakova and Lyakh, 2014).

We established similarity in morphology of vegetative and generative traits in studied wild flax species that indicates a close phylogenetic relationship between them. However, many traits show some phenotypic plasticity. This is especially noticeable in habit traits. According to some authors, it is because of phenotypic plasticity of habit traits there is a "blurring" of their expression when comparing smaller taxonomic groups of flax (Ockendon, 1971).

According to our observations, the most constant traits, that are virtually independent of variations in size of the plant, are diameter of the flower, linear seed size and weight of 1.000 seeds. Therefore, they appear to be the most genetically controlled by species' differences.

Taking into account the large flower and its bright coloration, in our opinion, such perennial species *L. austriacum* L., *L. hirsutum* L., L. *narbonens*e L., *L. perenne* L., *L. thracicum* Degen and annual species *L. grandiflorum* Desf. and *L. pubescens* are promising for use in landscape compositions and ornamental landscaping .

More common in wild species is blue coloration of the corolla petals, which is characteristic of cultivated flax. According to Joshua McDill, unlike blue-colored, yellow-colored flax is less represented in eastern Eurasia, and has a greater diversity in America and Africa (McDill et al., 2009).

Annual species *L. grandiflorum* has been already involved in breeding work, unlike the rest of the studied wild flax. In recent years, a highly ornamental varieties of this species were developed, that were different not only in flower coloration, but also in its shape. In Zaporozhye National University the varieties with crimson, bright red, pink, apricot, light apricot, and white flowers and with a different shape of the flower were created. A variety of flower colors allowed to study the genetics of this trait (Lyakh, 2013).

Flax seeds are characrerized by high oil and protein content, that determines their high value. However, insufficient knowledge of biochemical parameters of wild flax seeds, in our view, is

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holding back a number of issues in genetics and the evolution of this plant, as well as its application in preventive medicine. Increased content of some fatty acids in the oil of *L. thracicum*, *L.hispanicum* and *L.grandiflorum* that we identified in the course of our studies, allows to consider them as donors of valuable traits in the genetic and breeding work with flax.

In conclusion, in the present study 11 species of wild flax were investigated on a large number of traits. Plants were characterized on the basis of habit, colour and size of the individual parts of the plant (flowers, leaves, bolls and seeds). We obtained the original data on the biochemical composition of these types of seeds as well. This study opens up prospects for their use in landscaping, as well as in the programs of interspecific hybridization as sources of valuable genes.

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Table 1. Main characteristics of vegetative sphere in perennial and annual wild species of flax.

Species	Plant height, cm	Number of flowering stems, pcs.	Bush diameter, cm	Leaf area, mm^2
Linum austriacum	47.4±0.83	37.5 ± 2.74	60.0 ± 1.68	36.9 ± 0.48
Linum hirsutum	74.6 ± 4.31	7.6 ± 0.75	54.5 ± 4.20	301.3±0.82
Linum narbonense	53.7 ± 0.93	33.8 ± 3.76	42.9 ± 2.02	30.9 ±0.34
Linum perenne	58.8 ± 0.51	49.6 ± 3.71	57.0 ± 1.61	36.9 ±0.67
Linum thracicum	36.0 ± 1.68	11.4 ± 0.86	38.3 ± 2.10	267.4 ±1.03
Linum angustifolium	40.1 ± 3.86	3.3 ±0.60	-	40.1 ±0.92
Linum bienne	35.4 ± 6.14	3.79 ± 0.78	-	49.0 ±0.49
Linum crepitans	45.2 ± 2.90	1.5 ±0.50	-	69.3 ±1.12
Linum hispanicum	28.5 ± 3.47	2.6 ± 3.47	-	40.3 ±0.76
Linum	49.1 ± 4.85	4.1 ± 0.99	22.5 ± 2.15	272.6 ±0.88

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grandiflorum				
Linum pubescens	29.6 ± 0.80	1.2 ± 0.12	-	218.9 ±1.05

Table 2. Main characteristics of the generative sphere in perennial and annual wild species of flax.

Species	Flower diameter, mm	Boll diameter, mm	Weight of a 1.000 seeds, g
Linum austriacum	31.0 ± 0.37	6.1 ± 0.09	1.6 ± 0.09
Linum hirsutum	38.7 ± 0.93	4.0 ± 0.08	0.7 ± 0.03
Linum narbonense	25.7 ± 2.45	4.9 ± 0.07	1.2 ± 0.11
Linum perenne	28.2 ± 1.72	5.3 ±0.14	1.5 ± 0.11
Linum thracicum	32.1 ± 2.43	4.5 ± 0.12	0.9 ± 0.11
Linum angustifolium	15.8 ± 0.44	4.5 ± 0.20	1.6 ± 0.11
Linum bienne	14.3 ± 0.40	4.5 ± 0.27	1.7 ± 0.11
Linum crepitans	17.2 ± 0.48	7.1 ±0.19	5.1 ± 0.11
Linum hispanicum	12.0 ± 0.20	4.2 ±0.15	1.2 ± 0.11
Linum grandiflorum	36.1 ± 1.56	5.9 ± 0.37	2.9 ± 0.11
Linum pubescens	23.4 ± 0.48	2.9 ± 0.25	0.6 ± 0.11

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Table 3. Variation of fatty acid content in seeds of wild flax species.

Species	Fatty acid composition,%				
	C16:0	C18:0	C18:1	C18:2	18:3
Perennial species					
L. austriacum	3.5	1.5	19.4	20.1	55.5
L. hirsutum	2.7	0.8	12.3	20.8	63.4
L. narbonense	3.4	0.9	16.5	18.7	60.5
L. perenne	3.9	1.2	20.7	22.1	52.1
L. thracicum	4.0	1.4	18.3	59.5	16.8
Annual species					
L. angustifolium	6.2	4.8	20.3	15.5	53.2
L. bienne	6.7	5.6	18.2	14.6	54.9
L. crepitans	5.6	3.4	16.9	14.8	59.3
L. hispanicum	7.8	7.4	18.8	11.8	54.2
L. grandiflorum	5.0	3.4	24.0	10.8	56.8
L. pubescens	6.7	2.8	13.8	13.4	63.3
LSD05	0.44	0.57	1.74	0.97	2.67

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Figure 1. Comparative dimensions and leaf shape of wild flax species (from left to right): a) ***L. austriacum, L. narbonense, L. perenne, L. hirsutum, L. thracicum;*** **b)** ***L. angustifolium, L. bienne, L. crepitans, L. hispanicum, L. grandiflorum, L. pubescens.***

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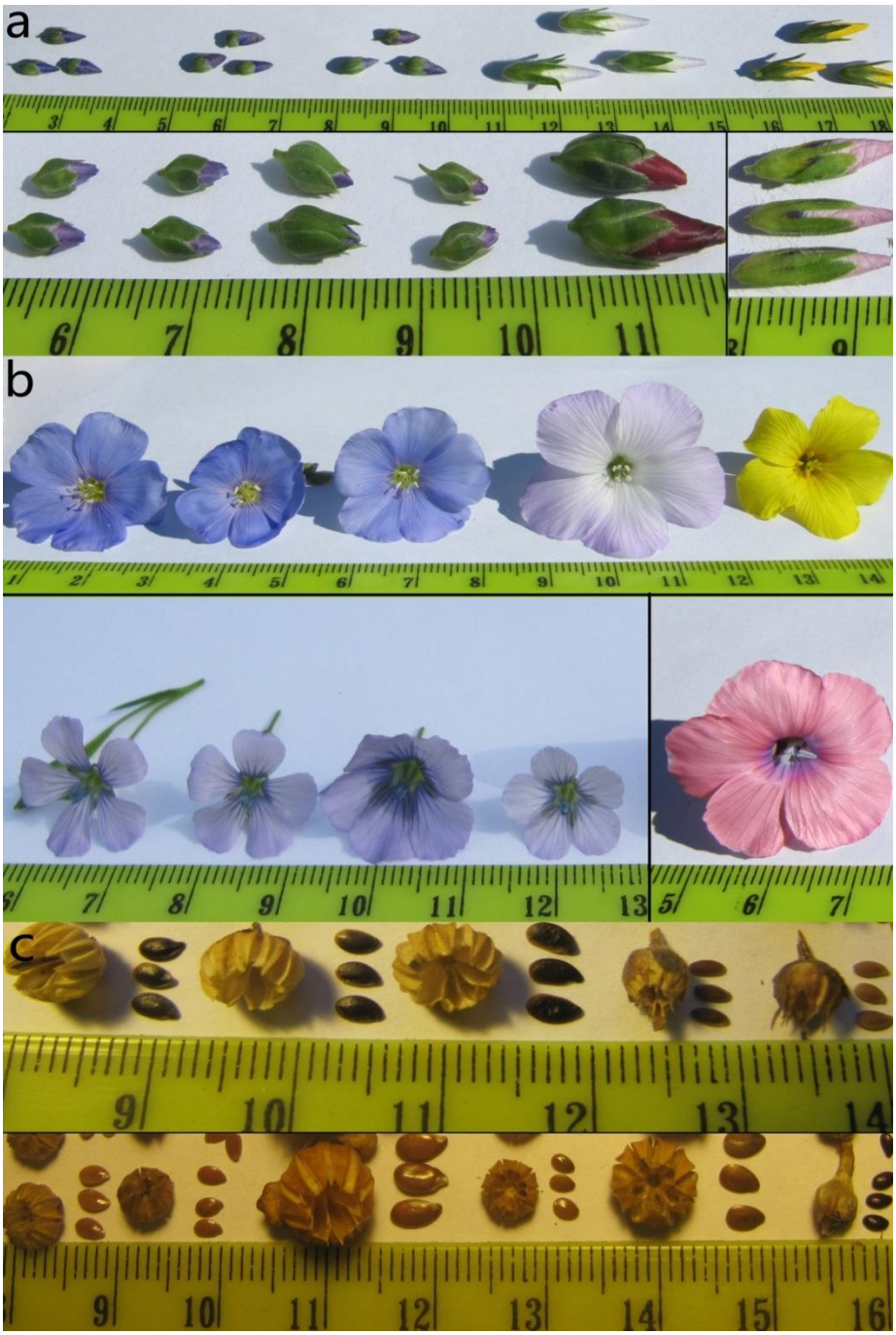

Figure 2. Comparative characteristics of the traits of generative sphere in wild flax species: a - buds; b - flowers; c - bolls and seeds (from left to right): *L. austriacum, L. narbonense, L. perenne, L. hirsutum, L. thracicum* (upper row); *L. angustifolium, L. bienne, L. crepitans, L. hispanicum, L. grandiflorum, L. pubescens* (lower row).

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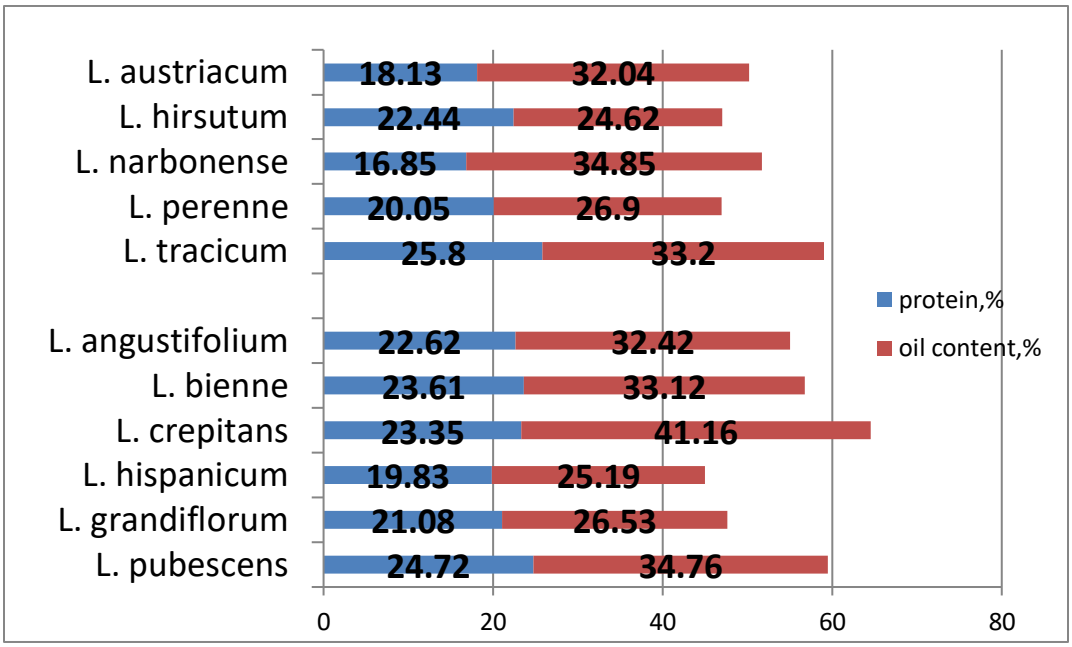

Figure 3. Protein and oil content in the seeds of wild flax species.

