

## FEATURES OF HYBRIDIZATION OF OIL FLAX WITH WILD ANNUAL SPECIES

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**Topicality.** Wild flax species are carriers of breeding valuable traits and can be used in breeding programmes to produce interspecific hybrids resistant to abiotic and biotic environmental factors, with higher yield potential than intraspecific ones due to large branching and the number of bolls on the stems. **Purpose** is in-depth study of wild annual flax species *L. angustifolium* and *L. hispanicum* for breeding valuable traits, including their crossings with cultivated flax samples to obtain interspecific hybrids with increased branching and high seed productivity. **Materials and Methods.** The research was carried out in 2017–2018 at the Institute of Oilseed Crops of NAAS. The research material was parental forms: wild annual homostylous species with  $n=15$  *L. angustifolium* and *L. hispanicum*, cultivated flax samples: L 5 (Czech Republic), L 6 (India), M 32/2 (Ukraine) and 12 interspecific combinations. Parental forms were studied based on morphological and economically valuable characteristics. The oil content in the seeds was determined using a laboratory AMB-1006 NMR analyser, the content of fatty acids in the oil was determined by gas-liquid chromatography using a Selmichrome-1 device. In interspecific hybrids, the number and percentage of setting of bolls and seeds in them were counted. **Results.** We obtained hybrid seeds as a result of interspecific crossing. Valuable traits of wild flax species for breeding are early maturity (68–71 days as compared to 76–89.5 days in cultivated flax samples), a large number of stems per plant (5.6–6.5 pcs. as compared to 1.4–2.9 pcs.), lateral shoots (16.8–17.9 pcs. as compared to 5.7–10.0 pcs.), bolls (48.9–61.2 pcs. as compared to 15.5–29.2 pcs.). It was found that wild flax species had a content of unsaturated linoleic and linolenic acids corresponding to the content of cultivated flax (13.0–16.2 % and 57.2–58.6 %, respectively). *L. hispanicum* had an increased level of saturated stearic acid (6.4 %) compared to other genotypes, where this indicator varied from 1.7 to 3.8 %. **Conclusions.** It was revealed that the level of setting the hybrid bolls and seeds decreased in the result of adverse weather conditions. A higher percentage of bolls and seeds setting were in crosses where cultivated flax was used as a maternal component.

**Key words:** cultivated flax, *L. angustifolium*, *L. hispanicum*, morphological trait, economically valuable trait, interspecific crossing, hybrid seed, seed setting

**Introduction.** Modern agriculture puts forward increased demands on the quantitative and qualitative characteristics of crops. Breeding work aimed at developing varieties with high genetic potential for productivity and adapted to climate change requires the involvement of the gene pool of wild plant species [1, 2].

Intraspecific hybridisation is the main method of developing source material in plant breeding, using which a large number of varieties have been developed. However, the reserves of intraspecific recombinant variability are gra-

dually being exhausted; therefore interspecific hybridisation is used in the world breeding practice to obtain new hybrid forms that inherit the valuable qualities of parental components [3, 4].

According to numerous researchers, introgression of new gene complexes can lead to fundamentally new genotypes. Interspecific hybridisation between cultivated and wild flax can provide valuable germplasm for flax breeding and facilitate the study of the genetic mechanism underlying economic traits [5].

Interspecific crosses result in a wider range

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of variability, among which new forms can be identified, as well as donors of valuable traits [6].

Species of the genus *Linum* L. are widely distributed in all regions of the world. Researchers have identified from 100 to 300 species with a different number of chromosomes (12–64) [6, 7]. These species also differ in their morphological, physiological and biochemical characteristics. Oil flax *Linum humile* Mill. is included in the group with  $n = 15$ . This group also includes the wild annual species *L. angustifolium* Huds., *L. hispanicum* Mill., *L. bienne* Mill., *L. crepitans* (Boenn.) Dumort, which are the related crops of cultivated flax. It is believed that the cultivated flax originated from the hybridisation of several closely related species [8–10].

Wild flax species are carriers of various breeding-value traits due to their biological characteristics. They have a complex of adaptive traits, in particular, genes for resistance to extreme environmental factors and numerous diseases that affect cultivated flax. Early ripening is a valuable trait because warming climate requires the expansion of oil flax to regions with higher precipitation than in the regions of Eastern and Southern Ukraine where oil flax is typically grown. Interspecific flax hybrids have the potential for higher yields than intraspecific ones due to extensive branching and the high number of bolls on the stems [11, 12]. In addition, interspecific flax hybrids have genetic diversity in the fatty acid composition of the oil, which allows for the development of varieties for use as technical, food, and medical products with different acid ratios [13].

Despite the relevance of interspecific hybridisation of flax, there are very few scientific papers in this area. Interspecific hybridisation is a more labour-intensive method of breeding source material than intraspecific hybridisation. The genus *Linum* is heterogeneous in terms of the number, size and structure of chromosomes; therefore interspecific hybridisation is not always successful even within groups with an equal number of chromosomes. The number of species involved in distant hybridisation is limited by progamy and postgamy incompatibility. For this reason, annual homostylic species, such as *L. angustifolium*, *L. hispanicum*, *L. bienne*, *L. crepitans*, which have the same number of chromosomes ( $n = 15$ ) as cultivated flax, are used for crossing, because they easily cross with cultivated

flax and give fertile offspring [4, 14].

For the first time interspecific hybrids from crossing cultivated flax and wild species *L. angustifolium* were obtained by T. Tammes [15]. Later, *L. usitatissimum* was successfully crossed with other species with  $n = 15$  such as *L. hispanicum*, *L. nervosum*, *L. pallescens*, which gave fertile offspring due to the identical ploidy and similar chromosome size. Successful crosses were also recorded in a group of flax species with  $n = 9$ . Among them were *L. alpinum*, *L. altaicum*, *L. austriacum*, *L. julicum*, *L. narbonense*, *L. perenne* [4, 16]. The hybridisation of *L. humile* with *L. crepitans*, *L. hirsutum*, *L. hispanicum* was carried out, resulting in fertile plants [4].

**Materials and Methods.** The research was carried out at the Institute of Oilseeds of NAAS in 2017–2018. As a result of diallel crosses, 12 interspecific combinations were obtained. Hybridisation was carried out according to the generally accepted method [17]. We pollinated 30 flowers of each crossing combination in 2017 and 35 flowers in 2018. Castration of flowers of mother plants was carried out in the morning at 6.00–10.00 a.m. during the colouring of the bud cone. Pollination was carried out with pollen from 3–5 flowers of the parental form immediately after castration, using protherogyny (the ability of the pistil stigma to mature a day earlier than pollen).

As parental forms, we used two wild annual homotic species *L. angustifolium* and *L. hispanicum* with  $n = 15$  and three cultivated flax samples – *L. humile* – L 5 (Czech Republic), L 6 (India), M 32/2 (Ukraine). Twenty plants were analysed for morphological traits (flower and capsule diameter, colour of flower and seeds, capsule cracking at ripening), economically valuable traits (duration of the growing season, plant height, number of stems per plant, number of lateral shoots per plant, number of capsules per plant, number of seeds per plant, 1000 seed weight), biochemical parameters (oil content, fatty acids in oil).

Morphological characters were described according to the catalogue "Genetic collection of *Linum usitatissimum* L." [18]. The oil content in the flax seeds was determined using a laboratory NMR analyser AMV-1006, the fatty acid content in the oil was determined by gas-liquid chromatography using the SelmiChrom-1

device. The number and percentage of hybrid capsules and seeds set in direct and reverse interspecific crosses were calculated. Mathematical processing was carried out according to generally accepted methods of statistical processing of experimental data [19].

The agroclimatic conditions of oilseed flax cultivation in 2017–2018 were different in terms of the main hydrothermal parameters (precipitation, temperature). The weather conditions in April 2017 during sowing and seedling stage were characterised by a high moisture supply (120.0 mm) compared to 2018 (12.0 mm) and the long-term average (35.0 mm). In May

and June 2017–2018, during flax budding and flowering, soil and air drought caused the pollen and pistil stigma to dry out, which negatively affected the set of bolls and seeds in them. Over the years of research, the amount of precipitation in July, during seed filling and ripening, was slightly less than the long-term average. The total precipitation in 2017 was 182.1 mm compared to 76.0 mm in 2018. The air temperature during the growing season of flax in 2018 exceeded the indicators of 2017. Thus, 2018 was drier and less favourable for the flax growth and development compared to 2017 (Table 1).

Our work was aimed at an in-depth study

**Table 1. Weather conditions of the oil flax in the growing season 2017–2018**

| Month  | Precipitation (mm) |      |                    | Average monthly temperature, (°C) |      |                    |
|--------|--------------------|------|--------------------|-----------------------------------|------|--------------------|
|        | 2017               | 2018 | Long-term averages | 2017                              | 2018 | Long-term averages |
| April  | 120.6              | 12.0 | 35.0               | 9.7                               | 15.0 | 8.5                |
| May    | 6.5                | 6.0  | 40.0               | 17.4                              | 20.4 | 16.0               |
| June   | 10.0               | 36.0 | 62.0               | 23.5                              | 24.2 | 19.4               |
| July   | 45.0               | 22.0 | 58.0               | 24.3                              | 24.8 | 22.6               |
| Total: | 182.1              | 76.0 | 195.0              | -                                 | -    | -                  |

of wild annual flax species with  $n = 15$  *L. angustifolium* and *L. hispanicum* for valuable breeding traits, their crossing with cultivated flax samples to obtain interspecific hybrids with increased branching and high seed productivity.

**Results and Discussion.** The species *L. angustifolium* and *L. hispanicum*, which we used for crossing with cultivated flax, belong to annual homostylic wild species with  $n=15$ . The study of morphological characters revealed that they had small, linear-lanceolate leaves of grey-green colour. *L. angustifolium* has a slightly larger number of leaves than *L. hispanicum*. Their five-petalled flowers are small, 12–16 mm in diameter, with separate petals, bisexual, regular shaped. In samples of cultivated flax, the flower diameter is 25–28 mm. The bolls are small, spherical, with a pointed beak. The boll diameter was 4.1–4.7 mm compared to 7.8–9.7 mm in the samples of cultivated flax. The flower and capsule size of *L. angustifolium* was characterised by a larger diameter than that of *L. hispanicum*. The flower and capsule size of *L. angustifolium* was characterised by a larger diameter than that of *L. hispanicum*. The small size of the flax flower complicates interspecific hybridisation.

According to our observations, *L. angustifolium* had a more intense violet-blue flower

petal colour compared to *L. hispanicum*, which has a lighter pale blue flower. Seeds are small, oblong, flat, smooth, light brown in colour.

The capsules of wild species crack at ripening, which is a disadvantage for breeding work with them. In *L. hispanicum*, cracking is more severe than in *L. angustifolium*, probably due to the smaller size of the capsule.

Sample L 5 (Czech Republic) belongs to the *L. crepitans* (Boenn.). The plant is green, the leaves are broadly lanceolate, and the leafiness is medium. Flower and capsule are medium (25.0 mm and 8.3 mm, respectively), seeds are medium brown. The flower is blue with blue veins and anthers. Capsule is strongly cracked at maturity. Sample L 6 (India) belongs to the subsp. *Latifolium* L. The plant is dark green, the leaves are broadly lanceolate, and the leafiness is medium. The flower and capsule are large (26.0 mm and 9.7 mm, respectively); the seeds are large, dark brown. The flower is blue-violet with purple veins and blue anthers. The flower and capsule are large (26.0 mm and 9.7 mm, respectively), the seeds are large, dark brown. The flower is blue-violet with purple veins and blue anthers. Very hard capsule shells do not crack and are difficult to thresh. Sample M 32/2 (Ukraine) belongs to the subsp. *L. intermedium* Crer. The plant is dark green, tall, with high

leafiness. Flower and capsule are medium (28.0 mm and 7.8 mm respectively), with medium yellow seeds. The flower is white with veins

coloured at the pedicel, anthers are cream. The capsules do not crack at maturity (Table 2).

According to economically valuable traits,

**Table 2. Characteristics of annual wild species and cultivars of cultivated flax by morphological characteristics, 2017–2018**

| Type                    | Diameter, mm |          | Colour      |            | Cracking of the boll during ripening |
|-------------------------|--------------|----------|-------------|------------|--------------------------------------|
|                         | flower       | boll     | flower      | seed       |                                      |
| <i>L. angustifolium</i> | 16±0.38      | 4.7±0.19 | violet-blue | pale brown | strong                               |
| <i>L. hispanicum</i>    | 12±0.23      | 4.1±0.12 | pale blue   | pale brown | strong                               |
| L 5                     | 25±0.35      | 8.3±0.21 | blue        | brown      | strong                               |
| L 6                     | 26±0.23      | 9.7±0.25 | blue-violet | dark-brown | no                                   |
| M 32/2                  | 28±0.32      | 7.8±0.14 | white       | yellow     | no                                   |

wild species of *L. angustifolium* and *L. hispanicum* were characterised by short stature (25.8–34.4 cm) compared to samples of cultivated flax, the plant height of which was 41.6–52.2 cm, a large number of stems per plant (5.6–6.5 pcs. vs. 1.4–2.9 pcs.), a large number of lateral shoots per plant (16.8–17.9 pcs. vs. 5.7–10.0 pcs.). The wild species of *L. hispanicum* was characterised by a greater number of stems and lateral shoots per plant than *L. angustifolium*.

The number of bolls per plant in wild species was also much higher compared to cultivated flax samples (48.9–61.2 pcs. vs. 15.5–29.2 pcs.). Accordingly, the number of seeds per plant was much higher (261.7–338.1 pcs. vs. 96.4–163.7 pcs.). The capsules and seeds of wild species of *L. angustifolium* and *L. hispanicum* are very small; the weight of 1000 seeds was 1.3–1.6 g against 5.3–10.6 g in cultivated flax samples. The seeds of *L. hispanicum* are smaller than in *L. angustifolium*.

The duration of the growing season of the studied wild samples was characterised by early maturity (68–71 days). The value of sample L 5 also is in its early ripening (76 days). Sample L 6 is mid-ripening (84 days), and M 32/2 is late-ripening (89.5 days).

It should be noted that the drought conditions in 2018 reduced the level of economically valuable traits compared to 2017 (Table 3).

Flaxseed oil in its composition is unique. The fatty acid composition of flax seeds includes five acids: saturated palmitic and stearic acids and unsaturated oleic, linoleic and linolenic acids. The content of unsaturated acids determines the use of oil. The value of the wild genotype lies in the qualitative composition of the oil, which can be used in various industries,

including preventive medicine. According to the literature, the composition of unsaturated fatty acids in wild genotypes had no difference from that of cultivated flax (*L. usitatissimum*), in which linolenic acid prevails. The oil content of wild species was within 25–41 %, which is much lower than that of oil flax [20, 21].

The results of our research showed that wild species were characterised by low oil content (25.8–33.2 %) compared to cultivated flax samples, which had an oil content of 41.6–44.3 %. By the content of saturated palmitic fatty acid, wild species were equal to cultivated flax samples (6.9–7.7 %). In terms of saturated stearic acid content, its increased level (6.4 %) was found in *L. hispanicum*, compared to other genotypes, in which this indicator was in the range of 1.7–3.8 %. The content of unsaturated oleic acid was higher in cultivated flax samples (19.9–20.3 %) compared to wild species, where this indicator was 14.8–15.7 %. The content of unsaturated linoleic and linolenic acids in wild species was similar to that of cultivated flax (13.0–16.2 % and 57.2–58.6 %) (Table 4).

Weather conditions had a significant impact on the results of interspecific hybridisation: the number of flax hybrid bolls and seeds was higher in the more favourable year of 2017 than in the dry year of 2018. Significant air and soil droughts during flax flowering resulted in drying of pollen and pistil stigmas and negatively affected the set of hybrid bolls and seeds. In 2017, the percentage of hybrid capsule set varied from 20.0–93.3 %, and in 2018, due to dry weather conditions, the level of hybrid capsule set was significantly lower and amounted to 2.9–65.7 %. At the same time, the minimum percentage of capsule set in both 2017 and 2018 was

**Table 3. Characteristics of annual wild species and cultivated flax samples by economically valuable traits, 2017–2018**

| Trait                                    | Year             | <i>L. angustifolium</i> | <i>L. hispanicum</i> | L 5          | L 6         | M 32/3       |
|--|------------------|-------------------------|----------------------|--------------|-------------|--------------|
| Duration of the growing season, days     | 2017             | 69±0.48                 | 71±0.57              | 77±0.62      | 85±0.64     | 91±0.81      |
|  | 2018             | 67±0.61                 | 70±0.58              | 75±0.58      | 83±0.72     | 88±0.95      |
|  | <b>(average)</b> | <b>68</b>               | <b>71</b>            | <b>76</b>    | <b>84</b>   | <b>89.5</b>  |
| Plant height, cm                         | 2017             | 36.2±0.60               | 26.1±1.17            | 46.1±0.65    | 42.8±0.36   | 55.7±0.62    |
|  | 2018             | 32.5±0.53               | 25.4±0.57            | 44.9±1.67    | 40.4±0.59   | 48.6±1.64    |
|  | <b>(average)</b> | <b>34.4</b>             | <b>25.8</b>          | <b>45.5</b>  | <b>41.6</b> | <b>52.2</b>  |
| Number of stems per plant, pcs.          | 2017             | 6.0±0.24                | 7.5±0.35             | 1.3±0.15     | 1.6±0.15    | 2.9±0.11     |
|  | 2018             | 5.1±0.12                | 5.5±0.19             | 1.5±0.25     | 1.4±0.13    | 2.8±0.44     |
|  | <b>(average)</b> | <b>5.6</b>              | <b>6.5</b>           | <b>1.4</b>   | <b>1.5</b>  | <b>2.9</b>   |
| Number of lateral shoots per plant, pcs. | 2017             | 17.8±0.39               | 18.9±0.53            | 6.4±0.54     | 6.0±0.49    | 9.9±0.42     |
|  | 2018             | 15.8±0.64               | 16.8±0.35            | 5.5±0.40     | 5.3±0.74    | 10.0±0.49    |
|  | <b>(average)</b> | <b>16.8</b>             | <b>17.5</b>          | <b>6.0</b>   | <b>5.7</b>  | <b>10.0</b>  |
| Number of bolls per plant, pcs.          | 2017             | 58.4±3.76               | 74.1±3.98            | 19.6±0.77    | 18.8±1.16   | 30.3±1.23    |
|  | 2018             | 39.4±0.95               | 48.3±1.02            | 17.9±2.18    | 12.1±0.58   | 28.1±3.81    |
|  | <b>(average)</b> | <b>48.9</b>             | <b>61.2</b>          | <b>18.8</b>  | <b>15.5</b> | <b>29.2</b>  |
| Number of seeds per plant, pcs.          | 2017             | 329.5±7.92              | 444.5±11.94          | 113.4±3.66   | 97.9±3.62   | 216.2±6.91   |
|  | 2018             | 193.9±16.17             | 231.6±28.26          | 104.6±6.71   | 94.8±7.91   | 110.9±10.28  |
|  | <b>(average)</b> | <b>261.7</b>            | <b>338.1</b>         | <b>109.0</b> | <b>96.4</b> | <b>163.7</b> |
| 1000 seeds weight, g                     | 2017             | 1.6±0.02                | 1.3±0.01             | 7.2±0.11     | 10.7±0.05   | 6.0±0.02     |
|  | 2018             | 1.5±0.01                | 1.2±0.02             | 4.8±0.08     | 10.4±0.03   | 4.5±0.05     |
|  | <b>(average)</b> | <b>1.6</b>              | <b>1.3</b>           | <b>6.0</b>   | <b>10.6</b> | <b>5.3</b>   |

**Table 4. Characteristics of annual wild species and cultivated flax samples by biochemical parameters, 2017–2018**

| Trait  |           | Year           | <i>L. angustifolium</i> | <i>L. hispanicum</i> | L 5         | L 6         | M 32/3      |
|--|-----------|----------------|-------------------------|----------------------|-------------|-------------|-------------|
| Oil content, %                                   |           | 2017           | 34.0                    | 26.5                 | 42.3        | 43.7        | 44.6        |
|  |           | 2018           | 32.4                    | 25.2                 | 40.9        | 43.4        | 43.9        |
|  |           | <b>average</b> | <b>33.2</b>             | <b>25.9</b>          | <b>41.6</b> | <b>43.6</b> | <b>44.3</b> |
| Content of saturated fatty acids in the oil, %   | palmitic  | 2017           | 7.1                     | 7.8                  | 7.0         | 7.1         | 6.6         |
|  |           | 2018           | 6.6                     | 7.6                  | 6.3         | 6.8         | 7.6         |
|  |           | <b>average</b> | <b>6.9</b>              | <b>7.7</b>           | <b>6.7</b>  | <b>7.0</b>  | <b>7.1</b>  |
|  | stearic   | 2017           | 3.1                     | 6.5                  | 2.0         | 3.9         | 1.7         |
|  |           | 2018           | 2.2                     | 6.2                  | 1.9         | 3.6         | 1.6         |
|  |           | <b>average</b> | <b>2.7</b>              | <b>6.4</b>           | <b>2.0</b>  | <b>3.8</b>  | <b>1.7</b>  |
| Content of unsaturated fatty acids in the oil, % | oleic     | 2017           | 16.3                    | 15.6                 | 21.0        | 19.8        | 19.1        |
|  |           | 2018           | 15.1                    | 13.9                 | 19.8        | 20.0        | 22.1        |
|  |           | <b>average</b> | <b>15.7</b>             | <b>14.8</b>          | <b>20.4</b> | <b>19.9</b> | <b>20.6</b> |
|  | linoleic  | 2017           | 16.2                    | 14.7                 | 15.3        | 12.0        | 8.4         |
|  |           | 2018           | 16.2                    | 14.1                 | 15.4        | 11.5        | 10.1        |
|  |           | <b>average</b> | <b>16.2</b>             | <b>13.0</b>          | <b>15.4</b> | <b>11.8</b> | <b>9.3</b>  |
|  | linolenic | 2017           | 57.3                    | 56.3                 | 54.7        | 57.2        | 64.2        |
|  |           | 2018           | 59.9                    | 58.1                 | 56.6        | 58.1        | 58.6        |
|  |           | <b>average</b> | <b>58.6</b>             | <b>57.2</b>          | <b>55.7</b> | <b>57.7</b> | <b>61.5</b> |

observed in the direct combination *L. angustifolium* × L 6 (2017 – 20.0 %; 2018 – 2.9 %), and the maximum was in the reverse combination L 6 × *L. angustifolium* (2017 – 93.3 %; 2018 – 65.7 %).

The reason is that the sample L 6 has a large flower, therefore, when L 6 was the maternal form in the combination, it was better pollinated by the much smaller pollen of the wild species,

and vice versa, the very small flower of the wild species was not pollinated by the large pollen grains of the sample L 6.

A clear pattern is determined in all combinations of crossing, namely, if the maternal form is cultivated flax, the percentage of hybrid bolls set on the plant and the number of seeds per boll is higher (42.9–67.8 %) compared to the wild flax as the maternal form (15.3–35.6 %).

The number of hybrid seeds in the bolls was small and, depending on the crossing combination, varied from 14 to 118 in 2017 and from 2 to 93 in 2018. The average number of seeds per boll is known to be 10 [9]. According to our data, interspecific hybrids formed significantly fewer seeds per boll on average (from 2.0 to 4.5 seeds

in 2017 and from 1.1 to 4.3 seeds in 2018).

The low percentage of boll and seed set in interspecific hybrids is explained by such reasons as injury to small buds during castration (the size of wild species buds is several times smaller than the bud of cultivated flax), as well as by the fact that pollen tubes do not germinate in the style tissues or do not reach the ovary. The scientific literature describes cases when pollen tubes germinated normally, reaching the ovary, and even fertilised it, but at the same time, there was no normal development of the embryo and no viable seeds were formed [22]. The colour and size of hybrid seeds were inherited on the maternal line (Table 5).

**Conclusions.** An in-depth study of annual

**Table 5. Results of interspecific crosses of flax, 2017–2018**

| Year                                    | Number of hybrid bolls, pcs. | Boll setting, % | Number of hybrid seeds, pcs. |                         | Seed colour | Hybrid seed size |
|---|------------------------------|-----------------|------------------------------|-------------------------|-------------|------------------|
|   |                              |                 | total                        | average number per boll |             |                  |
| <i>1</i>                                | <i>2</i>                     | <i>3</i>        | <i>4</i>                     | <i>5</i>                | <i>6</i>    | <i>7</i>         |
| <i>L. angustifolium</i> × L 6           |                              |                 |                              |                         |             |                  |
| 2017                                    | 6                            | 20.0            | 14                           | 2.3                     | pale brown  | small            |
| 2018                                    | 1                            | 2.9             | 2                            | 2.0                     | pale brown  | small            |
| <i>L 6</i> × <i>L. angustifolium</i>    |                              |                 |                              |                         |             |                  |
| 2017                                    | 28                           | 93.3            | 118                          | 4.2                     | brown       | large            |
| 2018                                    | 23                           | 65.7            | 93                           | 4.0                     | brown       | large            |
| <i>L. angustifolium</i> × M 32/2        |                              |                 |                              |                         |             |                  |
| 2017                                    | 11                           | 36.7            | 38                           | 3.5                     | pale brown  | small            |
| 2018                                    | 7                            | 20.0            | 12                           | 1.7                     | pale brown  | small            |
| <i>M 32/2</i> × <i>L. angustifolium</i> |                              |                 |                              |                         |             |                  |
| 2017                                    | 17                           | 56.7            | 50                           | 2.9                     | yellow      | average          |
| 2018                                    | 10                           | 28.6            | 41                           | 4.1                     | yellow      | average          |
| <i>L. angustifolium</i> × JI 5          |                              |                 |                              |                         |             |                  |
| 2017                                    | 7                            | 23.3            | 15                           | 2.1                     | pale brown  | small            |
| 2018                                    | 4                            | 11.4            | 9                            | 2.3                     | pale brown  | small            |
| <i>1</i>                                | <i>2</i>                     | <i>3</i>        | <i>4</i>                     | <i>5</i>                | <i>6</i>    | <i>7</i>         |
| <i>L 5</i> × <i>L. angustifolium</i>    |                              |                 |                              |                         |             |                  |
| 2017                                    | 26                           | 86.7            | 110                          | 4.2                     | brown       | average          |
| 2018                                    | 18                           | 51.4            | 20                           | 1.1                     | brown       | average          |
| <i>L. hispanicum</i> × JI 6             |                              |                 |                              |                         |             |                  |
| 2017                                    | 12                           | 40.0            | 42                           | 3.5                     | pale brown  | small            |
| 2018                                    | 10                           | 28.6            | 30                           | 3.0                     | pale brown  | small            |
| <i>JI 6</i> × <i>L. hispanicum</i>      |                              |                 |                              |                         |             |                  |
| 2017                                    | 17                           | 56.7            | 65                           | 3.8                     | brown       | large            |
| 2018                                    | 14                           | 40.0            | 60                           | 4.3                     | brown       | large            |
| <i>L. hispanicum</i> × M 32/2           |                              |                 |                              |                         |             |                  |
| 2017                                    | 8                            | 26.7            | 16                           | 2.0                     | pale brown  | small            |
| 2018                                    | 5                            | 14.3            | 12                           | 2.4                     | pale brown  | small            |
| <i>M 32/2</i> × <i>L. hispanicum</i>    |                              |                 |                              |                         |             |                  |
| 2017                                    | 11                           | 36.7            | 39                           | 3.5                     | yellow      | average          |
| 2018                                    | 10                           | 28.6            | 16                           | 1.6                     | yellow      | average          |

Table 5 continuation

| 1                           | 2  | 3    | 4   | 5   | 6          | 7       |
|-----------------------------|----|------|-----|-----|------------|---------|
| <i>L. hispanicum</i> × JI 5 |    |      |     |     |            |         |
| 2017                        | 20 | 66.7 | 48  | 2.4 | pale brown | small   |
| 2018                        | 5  | 14.3 | 8   | 1.6 | pale brown | small   |
| JI 5 × <i>L. hispanicum</i> |    |      |     |     |            |         |
| 2017                        | 23 | 76.7 | 104 | 4.5 | brown      | average |
| 2018                        | 15 | 42.9 | 64  | 4.3 | brown      | average |

homostylic wild flax species with n=15 *L. angustifolium* and *L. hispanicum* was carried out for morphological, economically valuable traits and biochemical parameters in comparison with cultivated flax samples.

For flax breeding, the valuable traits of wild flax species are their early maturity (68–71 days vs. 76–89.5 days for cultivated flax samples), a large number of stems per plant (5.6–6.5 pcs. vs. 1.4–2.9 pcs.), lateral shoots (16.8–17.9 pcs. vs. 5.7–10.0 pcs.), bolls (48.9–61.2 pcs. vs. 15.5–29.2 pcs.).

It was found that the content of unsaturated linoleic and linolenic acids in wild flax species was equal to that of cultivated flax (13.0–16.2 % and 57.2–58.6 %, respectively). In *L. hispanicum*, an increased level of saturated stearic acid (6.4 %) was found compared to other genotypes, in which this indicator was in the

range of 1.7–3.8 %.

Interspecific hybridisation and breeding work with wild flax species is complicated by their small flowers (12–16 mm vs. 25–28 mm in cultivated flax), short stature (25.8–34.4 cm vs. 41.6–52.2 cm), very small seeds (1.3–1.6 g vs. 5.3–10.6 g), strong cracking of bolls during ripening, and low oil content (25.9–33.2 % vs. 41.6–44.3 %).

It was found that weather conditions affect the setting of hybrid bolls and seeds, in particular the percentage of setting hybrid bolls was 20.0–93.3 % in the more favourable 2017, and 2.9–65.7 % in the dry 2018.

A higher percentage of boll and seed set was observed in crosses with cultivated flax as the maternal form (42.9–67.8 %) compared to the maternal form of wild flax (15.3–35.6 %).

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**Товстановська Т. Г., Поляков О. І. Особливості гібридизації льону олійного з дикими однорічними видами. Зернові культури. 2023. 7 (2). 217–225.**

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**Актуальність.** Дикі види льону є носіями селекційно-цінних ознак і можуть використовуватися в селекційних програмах для отримання міжвидових гібридів, стійких до абіотичних і біотичних факторів середовища, з більшим потенціалом врожайності, ніж внутрішньовидові, за рахунок великого галуження та кількості коробочок на стеблах. **Мета.** Поглиблене вивчення диких однорічних видів льону *L. angustifolium* і *L. hispanicum* за цінними селекційними ознаками, включення їх у схрещування зі зразками культурного льону для отримання міжвидових гібридів з підвищеним галуженням і високою насінневою продуктивністю. **Матеріали і методи.** Дослідження проводили у 2017–2018 рр. в Інституті олійних культур НААН. Матеріалом для досліджень були батьківські форми: дикі однорічні гомостильні види з  $n = 15$  *L. angustifolium* і *L. hispanicum*, зразки культурного льону: Л 5 (Чехія), Л 6 (Індія), М 32/2 (Україна) та 12 міжвидових комбінацій. Батьківські форми досліджували за морфологічними та господарсько-цінними ознаками. Вміст олії в насінні визначали на лабораторному ЯМР-аналізаторі АМВ-1006, вміст жирних кислот в олії – методом газорідинної хроматографії на приладі «Селміхром-1». У міжвидових гібридів підраховували кількість та відсоток зав'язування коробочок та насіння в них. **Результати.** Вивчено однорічні гомостильні дикі види льону з  $n = 15$  *L. angustifolium* і *L. hispanicum* за морфологічними, господарсько-цінними ознаками та біохімічними показниками в порівнянні зі зразками культурного льону. Проведено міжвидові схрещування та отримано гібридне насіння. Цінними для селекції льону ознаками диких видів є їх ранньостиглість (68–71 діб проти 76–89,5 діб у зразків культурного льону), велика кількість стебел на рослині (5,6–6,5 шт. проти 1,4–2,9 шт.), бічних пагонів (16,8–17,9 шт. проти 5,7–

10,0 шт.), коробочок (48,9–61,2 шт. проти 15,5–29,2 шт.). Встановлено, що за вмістом ненасичених лінолевої і ліноленової кислот дикі види мали характерний для культурного льону склад (13,0–16,2 % та 57,2–58,6 % відповідно). У *L. hispanicum* встановлено підвищений рівень насиченої стеаринової кислоти (6,4 %) порівняно з іншими генотипами, у яких цей показник був у межах 1,7–3,8 %.

**Висновки.** Виявлено зниження рівня зав'язаності гібридних коробочок і насіння в них внаслідок впливу несприятливих погодних умов. Показано вищий відсоток зав'язування коробочок і насіння в них у схрещуваннях, де в якості материнської форми був культурний льон.

**Ключові слова:** льон культурний, *L. angustifolium*, *L. hispanicum*, морфологічна ознака, господарська ознака, міжвидове схрещування, гібридне насіння, зав'язування насіння

