DOI: 10.36710/IOC-2026-40-06
UDC 633.854.54:631.527

Received: 16.03.2026
Reviewed: 08.04.2026
Published: 01.05.2026

# EFFECTIVENESS OF THE USE OF INTERSPECIFIC HYBRIDIZATION IN CREATING FLAX BREEDING MATERIAL WITH ALTERED PLANT HABIT

**T. G. Tovstanovska[1], V. O. Lyakh[1,2]**

*[1]Institute of Oilseed Crops, National Academy of Agrarian Sciences of Ukraine,*
*[2]Zaporizhzhia National University*

**The creation of highly productive source material is one of the strategic directions of oilseed flax breeding. To a large extent, this depends on the expansion of genetic diversity, in particular, by involving wild species as sources of many valuable traits. The purpose of the work is to determine the effectiveness of using interspecific hybridization in creating breeding material with a changed plant habit. The research was conducted at the Institute of Oilseed Crops of the NAAS in 2023-2025. The material was five flax lines from interspecific crosses: ML 43, ML 74, ML 102, ML 233, ML 282, as well as the promising line ML 515 and its parental forms – a sample of cultivated flax M 32/2 (Ukraine) and the wild species *L. angustifolium*. The study of breeding material was carried out in accordance with methodological recommendations. Structural analysis of the samples was carried out on 20 plants. The oil content was determined on an AMV-1006 NMR analyzer, the fatty acid content was determined by gas-liquid chromatography on a Selmichrome-1 device. The results of the studies showed that, in terms of plant habit, the lines exceeded the control in terms of both the number of stems per plant (2.8-3.2 pcs. vs. 1.2 pcs. in the control) and the number of lateral shoots (12.9-14.0 pcs. vs. 8.1 pcs.). Lines ML 102 and ML 233 were characterized by high growth and exceeded the control by 12.9-18.1 cm. In terms of seed productivity, the lines exceeded the control by the number of bolls by 10.3-15.5 pcs., by the mass of seeds per plant – by 0.36-0.58 g. The best indicators of the mass of 1000 seeds had the lines ML 74 (6.5 g) and ML 102 (6.4 g), and oil content – ML 102 (45.4%) and ML 233 (44.6%). All lines were characterized by a high content of linolenic acid in the oil (52.3-56.7%). The promising line ML 515, with high yield (2.2 c/ha), linolenic acid content in oil (61.4%), and marker traits, was submitted to the state variety testing as the Romance variety. The lines created by interspecific hybridization are promising material for breeding for high yield.**

***Keywords:*** cultivated flax, wild species, interspecific crossing, plant habit, number of stems, number of lateral shoots, promising line

***Introduction.*** Oil flax is a unique crop with great potential for use in many sectors of the economy (Golshenas, 2023; Wang et al., 2025). Profitable cultivation of oil flax depends on the availability of varieties with high yields and resistance to stress factors of growing conditions, therefore, the creation of highly productive starting material is one of the strategic directions in breeding of this crop. To a large extent, this depends on the expansion of genetic diversity, which is achieved, in particular, by attracting wild species. Existing flax varieties used in production belong to one species and have a narrow genetic base (Vikas and Nandan, 2016; Hoque et al., 2020; Kaur et al., 2023). In addition, the genetic diversity of flax varieties has decreased due to long-

Copyright © The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/)

term cultivation and the use of a small amount of genetic material, which significantly limits flax breeding. Therefore, it is difficult to achieve significant results in terms of yield and product quality using only intraspecific hybridization (Zhang et al., 2020). Interspecific hybridization between cultivated and wild species can be important in increasing the economic efficiency of the crop.

Cytogenetic studies have shown that cultivated flax (*L. usitatissimum*) can be crossed with various wild species of the *Linum* family (Qi et al., 2022; Schulz, 2022; Raut et al., 2025). However, the most successful are crosses with annual homostylous species that have the same number of chromosomes as cultivated flax (n = 15), and the resulting interspecific hybrids produce fertile offspring (Kumar et al., 2016; Mhiret, 2019).

Wild flax species have great genetic diversity in many valuable traits, such as early maturity, resistance to salinity, alkalinity, cold and drought, dietary and nutritional properties of seeds (Sveinsson et al., 2014; Plaha et al., 2023). And interspecific crosses can provide a high-quality gene pool for flax breeding through valuable germplasm, which enriches the genetic basis of many economically valuable traits, increases resistance to abiotic and biotic environmental factors (WangYu-Fu et al., 2018; Qi et al., 2022; Kaur et al., 2023; Tork et al., 2023). Therefore, the effective use of these genetic resources can expand the genetic background of flax, which is useful for creating high-yielding varieties.

The aim of the study was to determine the effectiveness of using interspecific hybridization in creating breeding material with altered plant habit.

***Materials and Methods.*** The research was conducted at the Institute of Oilseed Crops of the NAAS in 2023-2025. The material was five flax lines (ML 43, ML 74, ML 102, ML 233, ML 282), created by interspecific hybridization in the diallel crossing system, with subsequent individual selection from hybrid combinations: L 6 × *L. angustifolium*, *L. angustifolium* × L 5 (*L. crepitans*), *L. hispanicum* × M 32/2, M 32/2 × *L. angustifolium*, L 6 × *L. hispanicum*, as well as the promising line ML 515 (variety Romance) and its parental forms – a sample of cultivated flax M 32/2 (Ukraine) and the wild species *L. angustifolium*.

The establishment of breeding nurseries and the study of the obtained material were carried out according to methodological recommendations (Lyakh et al., 2023). The samples were analyzed for morphological characteristics (flower and seed color, flower and boll diameter, boll cracking at maturity) and economically valuable characteristics (plant height, number of stems, number of lateral shoots, number of bolls per plant, seed weight per plant, weight of 1000 seeds, seed oil content, fatty acid composition of oil). Before harvesting, the plants with boll cracking, very late-ripening, low-growing, with a small number of bolls were evaluated and rejected. Structural analysis of the samples was carried out on 20 plants. The oil flax variety Pivdenna nich was used as a control.

The oil content in the seeds was determined on a laboratory NMR analyzer AMV-1006, the fatty acid content in the oil was determined by gas-liquid chromatography on a Selmichrome-1 device. The significance of the deviations of the lines from the control for the studied traits was determined using analysis of variance (ANOVA) at $p = 0.05$.

Weather conditions during the flax growing season were characterized by the hydrothermal coefficient (HTC), which was calculated by dividing the amount of precipitation (ΣR) in mm for the period with temperatures above 10 °C by the sum of active temperatures ($\Sigma t > 10$) for the same time. Hydrothermal conditions are divided

© T. G. Tovstanovska, V. O. Lyakh

into groups by the level of the HTC: < 0.5 – a sharp lack of precipitation, severe drought; 0.6-0.7 – insufficient moisture (very dry); 0.8-0.9 – dry (not intense drought); 1.0-1.2 – insufficient moisture; 1.3-1.6 – moderate moisture; > 1.7 – excessive moisture (Shevchenko, Balabukh, 2024).

In general, hydrothermal conditions during the years of research at the HTC level were marked by severe drought due to insufficient precipitation and abnormally high air temperatures in the summer (Table 1).

Table 1

**Hydrothermal conditions of the growing season of oilseed flax during the years of research**

| Indicator/ Year | Amount of precipitation | Sum of temperatures | HTC | Growing season conditions |
|---|---|---|---|---|
| 2023 | 216.4 | 2091 | 0.10 | severe drought |
| 2024 | 83.5 | 2540 | 0.03 | severe drought |
| 2025 | 133.3 | 2089 | 0.06 | severe drought |

**Notes:** HTC – hydrothermal coefficient.
**Source:** developed by the author T. G. Tovstanovska.

***Results and Discussion***. It is known that the high yield of a variety depends on its genetic potential. Therefore, at the first stages of the breeding process, we conducted a detailed analysis of hybrid material obtained from interspecific crosses in order to predict the potential of the selected combinations for further use in the breeding process for increased branching. As a result of research on breeding and genetic parameters (heterosis effect and heritability coefficient) promising interspecific hybrid combinations with a complex of valuable traits were identified. The use of breeding and genetic parameters allows for more effective individual plant selection, reduce the loss of valuable genotypes, and reduce time spent by rejecting low-value material in early generations, when new homozygous and heterozygous genotypes for different traits appear (Gaballah et al., 2022; Tovstanovska and Lyakh, 2021).

In the $F_1$ generation, combinations in which heterosis for this trait was manifested within two years were particularly valuable for the selection of genotypes with a large number of lateral shoots on the plant. These were the combinations M 32/2 × *L. angustifolium* and M 32/2 × *L. hispanicum*. Combinations in which the effect of heterosis was manifested simultaneously for two traits of habit were also valuable: plant height and the number of lateral shoots – L 5 (*L. crepitans*) × *L. angustifolium*, *L. angustifolium* × L 6, L 6 × *L. hispanicum*, *L. hispanicum* × L 6; the number of stems and the number of shoots – M 32/2 × *L. hispanicum* (Tovstanovska and Lyakh, 2021).

In the $F_2$ generation, combinations with high heritability coefficients (H > 0.66) were selected. For breeding improvement of the branching trait in the direction of increasing the number of stems on a plant, combinations with the wild species *L. hispanicum* were promising. These were the combinations *L. hispanicum* × L 6 – 0.69-0.78; L 6 × *L. hispanicum* – 0.66-0.81; *L. hispanicum* × M 32/2 – H = 0.78; M 32/2 × *L. hispanicum* – 0.81; *L. hispanicum* × L 5 (*L. crepitans*) – 0.78; L 5 (*L. crepitans*) × *L. hispanicum* – 0.72.

According to the characteristic “number of lateral shoots per plant” with high coefficients for creating forms with increased branching in the process of further selection, four combinations were selected: *L. angustifolium* × M 32/2 – 0.66; M 32/2

© T. G. Tovstanovska, V. O. Lyakh

× *L. angustifolium* – 0.72; *L. hispanicum* × M 32/2 – 0.68; M 32/2 × *L. hispanicum* – 0.70-0.71. Interspecific combinations *L. hispanicum* × M 32/2 and M 32/2 × *L. hispanicum* stood out with high coefficients of heritability for two characteristics – the number of stems and the number of lateral shoots per plant (Tovstanovska and Lyakh, 2021).

These developments became the basis for breeding work aimed at creating highly productive starting material with no cracking of the bolls and useful new formations, such as multi-stemmed and multi-shoot habit.

The genetic diversity of the breeding material obtained on the basis of plasma of wild species provided a broad form-forming process in the generations of hybrids. The material we obtained was characterized by a wide variety of genotypes by the vegetation period (early, mid-season, late-season); plant height (low, medium, tall); stem leafiness (low, medium, high); length and shape of the inflorescence (spreading, drooping, compact, elongated, thyroid, short, low, upper, etc.); number of stems and shoots on the plant (multi-stem and multi-shoot forms); size and shape of the bolls and the degree of their cracking during maturation; color of the corolla and buds (white, pink, pale blue, violet-blue, purple, inky, lilac); the shape and degree of opening of the flower (open, open-divided, star-shaped, bell-shaped, semi-collapsed, etc.) and its size (large, medium, small); the size of the boll (small, medium, large); the color of the seeds (yellow, mustard, yellow-mustard, olive, dark brown, spotted, etc.).

The parental wild forms (*L. angustifolium* and *L. hispanicum*), which we involved in the crossing, were characterized by such valuable traits for breeding as a large number of stems on the plant (5.6-6.5 pcs. vs. 1.4-2.9 pcs. in cultivated flax samples), a large number of lateral shoots (16.8-17.9 pcs. vs. 5.7-10.0 pcs.), a large number of bolls (48.9-61.2 pcs. vs. 15.5-29.2 pcs.). In wild species, the number of bolls was 2.1-3.2 times greater than in cultivated parental forms (Tovstanovska and Polyakov, 2023).

Interspecific hybrids had genes for increased branching. Their variability, due to the large contrast of habit in the parental components, was significantly higher than in populations from intraspecific crosses, which made it possible to select forms with a modified plant habit (Fig. 1).

a large number of side shoots | a large number of stems on a plant | wide leaf blade

Fig. 1. **Altered plant habit in specimens obtained from interspecific crosses**
**Source:** developed by the author T. G. Tovstanovska.

© T. G. Tovstanovska, V. O. Lyakh

In addition to valuable traits, wild species also have traits that are negative for breeding, such as short stature (25.8-34.4 cm versus 41.6-52.2 cm in cultivated flax samples), very small seeds (1.3-1.6 g versus 5.3-10.6 g), low oil content (25.9-33.2 % versus 45-50 % in oil flax), as well as severe cracking the bolls during ripening, which significantly complicates breeding work with interspecific hybrids (Tovstanovska and Polyakov, 2023). Therefore, for many years we have purposefully carried out individual selections of plants from interspecific hybrids, starting with the $F_2$ generation, according to such criteria as the absence of cracking bolls, optimal plant height, the presence of a large number of stems, lateral shoots and bolls. In laboratory conditions, samples with very small seeds and low oil content were lacking.

After a comprehensive evaluation of the breeding material obtained from interspecific crosses, five lines with the absence or weak cracking the bolls and a changed plant habit were isolated: ML 43 (L 6 × *L. angustifolium*), ML 74 (*L. angustifolium* × L 5 (*L. crepitans*)), ML 102 (*L. hispanicum* × M 32/2), ML 233 (M 32/2 × *L. angustifolium*), ML 282 (L 6 × *L. hispanicum*). All lines were characterized by increased branching and exceeded the control variety Pivdenna nich both in the number of stems per plant (2.8-3.2 pcs. vs. 1.2 pcs. in the control), and in the number of lateral shoots (12.9-14.0 pcs. vs. 8.1 pcs.). According to these indicators, they approached the wild parental forms.

Due to the increased bushiness, the lines were also distinguished by a large number of bolls per plant. This indicator was high in all lines (29.7-34.9 pcs. versus 19.4 pcs. in the control). The excess was 10.3-15.5 pcs. bolls.

In terms of the duration of the growing season, two lines (ML 43 and ML 282) were distinguished by early maturity and ripened earlier than the control by 2.8-3.2 days, the other lines were on a par with the control, with a growing season duration of 87.6-88.3 days.

The plant height of all lines was optimal. Two lines – ML 102 (*L. hispanicum* × M 32/2) and ML 233 (M 32/2 × *L. angustifolium*), in which one of the parental forms was the tall specimen M 32/2, were characterized by plant heights of 77.4 cm and 72.2 cm and exceeded the control by 12.9-18.1 cm. The lowest height (54.5 and 53.8 cm) was in the lines ML 43 (L 6 × *L. angustifolium*) and ML 282 (L 6 × *L. hispanicum*), in which both parental forms were short-growing. The plant height of the line ML 74 was on a par with the control and was 58.0 cm.

In terms of the weight of 1000 seeds, the best, i.e. closest to cultivated flax, were two lines – ML 74 (6.5 g) and ML 102 (6.4 g). Other lines had a lower weight of 1000 seeds – 4.8-5.7 g. Selection for this trait in interspecific hybrids was difficult, since the wild species *L. hispanicum* and *L. angustifolium* are characterized by very small seeds (1.3-1.6 g), which are inherited in the hybrid generation. In terms of the weight of seeds per plant, all lines exceeded the control by 0.36-0.58 g.

In terms of seed oil content, the lines ML 102 (45.4%) and ML 233 (44.6%) were on a par with the control, the oil content of which was 44.7%. The content of linolenic acid in the oil of all lines was high, which is typical for oil flax and was 52.3-56.7% (Table 2).

The lines had distinctive morphological characteristics of the flower and seeds. Sample ML 43 (L 6 × *L. angustifolium*) – lilac flower with a diameter of 23.5 mm and brown seeds; ML 74 (*L. angustifolium* × L 5 (*L. crepitans*)) – violet-blue flower with a diameter of 25.2 mm and brown seeds; ML 102 (*L. hispanicum* × M 32/2) – violet-blue flower with a diameter of 23.7 mm and spotted yellow-brown seeds; ML 233 (M 32/2 × *L. angustifolium*) – white flower with a diameter of 24.6 mm and mustard seeds;

© T. G. Tovstanovska, V. O. Lyakh

ML 282 (L 6 × *L. hispanicum*) – dark lilac flower with a diameter of 22.8 mm and dark brown seeds.

Table 2

**Economically valuable traits of flax lines with altered plant habit created by interspecific hybridization (2023-2025)**

| Trait / Line | ML 43 | ML 74 | ML 102 | ML 233 | ML 282 | Control |
|---|---|---|---|---|---|---|
| Duration of the growing season, days | 83.7 | 87.7 | 88.3 | 87.6 | 83.3 | 86.5 |
| ± *to control* | *-2.8* | *+1.2* | *+1.8* | *+1.1* | *-3.2* | - |
| Plant height (cm) | 54.5 | 58.0 | 77.4* | 72.2* | 53.8 | 59.3 |
| ± *to control* | *-4.8* | *-1.3* | *+18.1* | *+12.9* | *-5.5* | - |
| Number of stems per plant (pcs.) | 3.1* | 2.8* | 2.9* | 3.2* | 3.1* | 1.2 |
| ± *to control* | *+1.9* | *+1.6* | *+1.7* | *+2.0* | *+1.9* | - |
| Number of side shoots per plant (pcs.) | 13.4* | 13.7* | 14.0* | 13.5* | 12.9* | 8.1 |
| ± *to control* | *+5.3* | *+5.6* | *+5.9* | *+5.4* | *+4.8* | - |
| Number of bolls per plant (pcs.) | 34.9* | 30.2* | 34.3* | 34.6* | 29.7* | 19.4 |
| ± *to control* | *+15.5* | *+10.8* | *+14.9* | *+15.2* | *+10.3* | - |
| Weight of 1000 seeds (g) | 5.4 | 6.5 | 6.4 | 4.8 | 5.7 | 7.1 |
| ± *to control* | *-1.7* | *-0.6* | *-0.7* | *-2.3* | *-1.4* | - |
| Seed weight from one plant (g) | 1.43* | 1.37* | 1.52* | 1.46* | 1.30* | 0.94 |
| ± *to control* | *+0.49* | *+0.43* | *+0.58* | *+0.52* | *+0.36* | - |
| Oil content, % | 40.7 | 43.1 | 45.4 | 44.6 | 40.2 | 44.7 |
| ± *to control* | *-4.0* | *-1.6* | *-0.7* | *-0.1* | *-4.5* | - |
| Linolenic acid content in oil, % | 53.5 | 56.7 | 55.6 | 52.3 | 56.5 | 56.0 |
| ± *to control* | *-2,5* | *+0,7* | *-0,4* | *-3,7* | *+0,5* | - |

**Notes:** * – significant excess of lines over the control variety at $p = 0.05$.
**Source:** developed by the author T. G. Tovstanovska.

The bolls of the lines were significantly larger in size than those of the wild species (6.6-7.6 mm versus 4.2-5.0 mm) and approached the control variety, in which this indicator was 7.5 mm.

All lines were characterized by the absence or weak cracking the bolls during ripening (Table 3).

The result of our work was the creation of a highly productive variety called Romance for technical use (with a high content of linolenic acid in the oil) and marker traits of the flower and seeds based on the germplasm of the wild species *L. angustifolium*. The ancestor of the variety was an elite plant selected from the interspecific hybrid combination M 32/2 × *L. angustifolium*, with the absence of cracking the bolls and their large number on the plant.

© T. G. Tovstanovska, V. O. Lyakh

Table 3

Table 3. **Morphological characteristics of flax lines with altered plant habit created by interspecific hybridization**

| Trait / Line | ML 43 | ML 74 | ML 102 | ML 233 | ML 282 | Control Pivdenna Nich |
|---|---|---|---|---|---|---|
| Flower diameter, mm | 23.5±0.31 | 25.2±0.27 | 23.7±0.21 | 24.6±0.24 | 22.8±0.29 | 25.3±0.31 |
| Boll diameter, mm | 6.9±0.11 | 7.2±0.11 | 7.0±0.12 | 6.6±0.11 | 7.6±0.13 | 7.5±0.11 |
| Flower color | lilac | violet-blue | violet-blue | white | dark purple | blue-violet |
| Seed color | brown | brown | yellow-brown spotted | mustard | dark brown | brown |
| Cracking bolls | absent | weak | absent | weak | слабка weak | absent |

**Source:** developed by the author T. G. Tovstanovska.

In terms of the duration of the growing season, plant height, seed productivity and plant habit, the promising line ML 515 (Romance variety) had intermediate indicators between the cultivated and wild parental forms, and in terms of the mass of seeds per plant it exceeded both the parental forms and the control variety. It ripened 3.2 days earlier than the control variety; in terms of plant height, it was on a par with the control (57.8 cm versus 59.3 cm).

In terms of the number of stems per plant, it exceeded the control variety by 2.5 pcs., lateral shoots by 6.2 pcs., bolls by 16.8 pcs., and seed mass per plant by 0.65 g.

In terms of yield in arid growing conditions, it significantly exceeded the control variety by 0.5 c/ha. According to biochemical indicators, it was characterized by an average oil content in seeds at the same level as the control – 44.5%, and by the content of linolenic acid in the oil, it significantly exceeded the Pivdenna Nich variety by 5.4% (Table 4).

According to morphological features, the ML 515 line differed from the wild and cultivated parental forms. The maternal form M 32/2 (Ukraine) is a «mezheumok» plant type, the plant is dark green, the flower is white, with a diameter of 27.7 mm; the boll is medium, with a diameter of 7.1 mm; the seeds are medium (6.5 g), yellow. The wild annual homostyle species *L. angustifolium* was characterized by very small flowers (16.0 mm), bolls (5.1 mm) and seeds (1.6 g). The flower is pale lilac, with separate petals, the seeds are light brown. The bolls crack strongly when ripe.

In the ML 515 line (Romance variety), the flower and bolls are of medium size with a diameter of 24.8 mm and 7.2 mm, respectively. The flower is open, the color of

© T. G. Tovstanovska, V. O. Lyakh

the corolla petals is white with bright purple veins and a pink bud. The seeds are light mustard with a mass of 1000 seeds of 5.6 g (Table 3, Fig. 2).

Table 4

**Characteristics of the promising line ML 515 (variety Romance) created by interspecific hybridization, and its parental forms** (2023-2025)

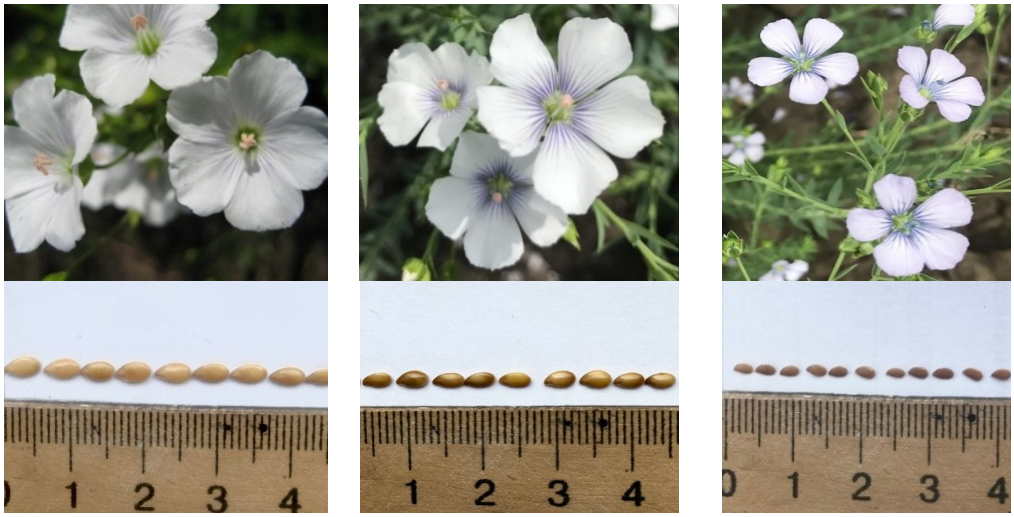
| Trait | M 32/2 | ML 515 (variety Romance) | *L. angustifolium* | Control |
|---|---|---|---|---|
| Duration of the growing season, days | 89.8 | 83.3 | 76.0 | 86.5 |
| *difference (±)* | *-6.5* | *-3.2* | *+7.3* | - |
| Plant height (cm) | 69.3 | 57.8 | 42.3 | 59.3 |
| *difference (±)* | *-11.5* | *-1.5* | *+15.5* | - |
| Number of stems per plant (pcs.) | 1.8 | 3.7* | 4.9 | 1.2 |
| *difference (±)* | *+1.9* | *+2.5* | *-1.2* | - |
| Number of side shoots per plant (pcs.) | 12.6 | 14.3* | 16.7 | 8.1 |
| *difference (±)* | *+1.7* | *+6.2* | *-2.4* | - |
| Number of bolls per plant (pcs.) | 23.1 | 36.2* | 45.3 | 19.4 |
| *difference (±)* | *+13.1* | *+16.8* | *-9.1* | - |
| Weight of 1000 seeds (g) | 6.5 | 5.6 | 1.6 | 7.1 |
| *difference (±)* | *-0.9* | *-1.5* | *+4.0* | - |
| Seed weight from one plant (g) | 1.12 | 1.59* | 0.49 | 0.94 |
| *difference (±)* | *+0.47* | *+0.65* | *+4.1* | - |
| Yield, c/ha | - | 2.2* | - | 1.7 |
| *difference (±)* | - | *+0.5* | - | - |
| Oil content, % | 43.1 | 44.5 | 33.9 | 44.7 |
| *difference (±)* | *+1.4* | *-0.2* | *+10.6* | - |
| Linolenic acid content in oil, % | 57.1 | 61.4* | 55.9 | 56.0 |
| *difference (±)* | *+4.3* | *+5.4* | *+5.5* | - |
| Flower diameter, mm | 27.7±0.32 | 24.8±0.30 | 16.0±0.34 | 25.3±0.31 |
| Boll diameter, mm | 7.1±0.11 | 7.2±0.12 | 5.1±0.11 | 7.5±0.11 |
| Flower color | white | white with bright purple veins | pale lilac | blue-violet |
| Seed color | yellow | mustard yellow | light brown | brown |
| Cracking the bolls | absent | absent | strong | absent |

**Notes:** ± – difference between the ML 515 line and the parental forms and the control;
* – significant excess of the ML 515 line over the control variety at $p = 0.05$.
**Source:** developed by the author T. G. Tovstanovska.

Based on the positive results of three-year tests, the ML 515 line was transferred to the State Variety Testing in 2025.

© T. G. Tovstanovska, V. O. Lyakh

The feasibility of using the method of interspecific hybridization of flax and obtaining genotypes with valuable agronomic traits has been highlighted in scientific works by both domestic and foreign scientists (Zhang et al., 2012; Qu et al., 2018; Poliakova et al., 2024). It has been established that the diversity of alleles of wild species when introduced into hybridization with cultivated flax contributes to an increase in heterozygosity, resulting in a wide spectrum of variability, among which various genotypes with useful neoplasms can be extracted (Zhang et al., 2020).



*L. usitatissimum* (M 32/2) | line ML 515 (M 32/2 × *L. angustifolium)* | *L. angustifolium* (wild species)

Fig. 2. **Morphological characteristics of flower and seed color of the ML 515 line (Romance variety) and its parental forms**

**Source:** developed by the author T. G. Tovstanovska.

An important task of our work was to increase branching (both basal at the soil level and lateral at the inflorescence level). Earlier scientific studies have proven a strong influence of stems and lateral shoots on the number of bolls and biological yield (Kalinina and Lyakh, 2007; Thakur et al., 2020; Paul and Kumar, 2020; Ahmad et al., 2021), which is consistent with our data (Tovstanovska and Lyakh, 2024). We also identified the main trait of plant habit that has a stronger influence on the formation of the number of bolls – "the number of lateral shoots on the plant". This is a more stable trait, unlike basal branching, which is highly dependent on the feeding area. Based on these studies, interspecific hybrid combinations with high correlation coefficients were identified, promising for selection in early generations for increased branching (Tovstanovska and Lyakh, 2024).

Currently, varieties of oil flax grown in Ukraine have a characteristic number of stems per plant within 1-3 pieces. Therefore, the creation of genotypes with high branching (multi-stem and multi-shoot) will ensure stable implementation of the potential productivity of the crop in the arid conditions of the East and South of the country, where oil flax is mainly grown. In our breeding work, as a result of selection from interspecific hybrid populations, flax lines with a changed plant habit were obtained, which have a complex of economically valuable traits, distinctive

© T. G. Tovstanovska, V. O. Lyakh

morphological features of the flower and seeds and are promising material for inclusion in breeding work to create high-yielding varieties with increased branching.

***Conclusions.*** The effectiveness of interspecific hybridization, which consists in creating flax lines with a modified plant habit, high seed productivity, distinctive morphological features of the flower and seeds, which are promising material for breeding for high yield, has been determined.

The lines ML 43, ML 74, ML 102, ML 233, ML 282 obtained on the basis of germplasm of wild species exceeded the control variety Pivdenna Nich in terms of plant habit both in the number of stems per plant (2.8-3.2 pcs. vs. 1.2 pcs. in the control), and in the number of lateral shoots (12.9-14.0 pcs. vs. 8.1 pcs.). Lines ML 102 and ML 233 were characterized by high growth and exceeded the control by 12.9-18.1 cm. In terms of seed productivity, they exceeded the control by the number of bolls – by 10.3-15.5 pcs., by the mass of seeds per plant – by 0.36-0.58 g. The best indicators of the mass of 1000 seeds had the lines ML 74 (6.5 g) and ML 102 (6.4 g), and oil content – lines ML 102 (45.4%) and ML 233 (44.6%). All lines were characterized by a high content of linolenic acid in the oil (52.3-56.7%).

The promising flax line ML 515, created by interspecific hybridization, was submitted to the State Variety Testing as the Romance variety due to its high yield (2.2 c/ha) and high linolenic acid content in oil (61.4%), as well as marker traits of flowers and seeds.

***Acknowledgements.*** None.

***References***

Ahmad, E., Ansari, A. M., Singh, D. N. (2021). Estimating gene action and combining ability analysis for yield and yield attributing traits in linseed (*Linum usitatissimum* L.). *Journal of Environmental Biology, 42*(2), 366-370. https://doi.org/10.22438/jeb/42/2(SI)/SI-232

Gaballah, M. M., Attia, K. A., Ghoneim, A. M., Khan, N., El-Ezz, A. F., Yang, B., Al-Doss, A. A. (2022). Assessment of genetic parameters and gene action associated with heterosis for enhancing yield characters in novel hybrid rice parental lines. *Plants*, *11*(3), 266. https://doi.org/10.3390/plants11030266

Golshenas, P. (2023). The usage of flax as biodiesel and biomass. *The Canadian Science Fair Journal*, *5*(1). https://csfjournal.com/archive

Hoque, A., Fiedler, J. D., Rahman, M. (2020). Genetic diversity analysis of a flax (*Linum usitatissimum* L.) global collection. *BMC Genomics,* 21, 557. https://doi.org/10.1186/s12864-020-06922-2

Kaur, V., Singh, M., Wankhede, D. P., Gupta, K., Langyan, S., Aravind, J., Kumar, A. (2023). Diversity of *Linum* genetic resources in global genebanks: from agro-morphological characterisation to novel genomic technologies, a review. *Frontiers in Nutrition*, 10, 1165580. https://doi.org/10.3389/fnut.2023.1165580

Kalinina, O. Yu., & Lyakh, V. O. (2007). Variability and correlations of habit traits in oil flax lines and hybrids. *Agrarian Bulletin of the Black Sea Region*, 41, 3–6. [in Ukrainian]

Kumar, N., Paul, S., Chaudhary, H. K., Jamwal, N S., Singh, A. D. (2016). Wide hybridization and characterization of hybrids of *Linum usitatissimum* for crossability, agromorhological traits and rust resistance. *Sabrao journal of Breeding and Genetics, 48*(2), 136-144. https://sabraojournal.org/wp-content/uploads/2018/01/SABRAO-J-Breed-Genet-48-2-162-171-Kumar-1.pdf

Lyakh, V. O., Tovstanovska, T. G., Polyakova, I. O. (2023) Breeding and primary seed production of oil flax. Methodological recommendations. *Institute of*

© T. G. Tovstanovska, V. O. Lyakh

*Oilseed Crops of the NAAS,* Zaporizhzhia, 41. https://imk.zp.ua/index.php/naukovi-vydannia/rekomendatsii/440-2023-11-15-10-29-48 [in Ukrainian]

Mhiret, W. N. (2019). Association and variation on boll and seed morphology among hybrids between linseed (*Linum usitatissimum* L.) and *Linum bienne* Mill. and their parents. *African Journal of Plant Science, 13*(6), 138-152. https://doi.org/10.5897/AJPS2019.1761

Paul S., Kumar P. S. A. (2020). Genetic variability, correlation and path coefficient analysis of introduced genotypes of linseed (*Linum usitatissimum* L.) in mid-hills of North-West Himalayas. *Journal of Pharmacognosy and Phytochemistry, 9*(1), 1189-1192. https://doi.org/10.22271/phyto.2020.v9.i1t.10618

Plaha, N. S., Kaushik, N., Awasthi, S., Singh, M., Kaur, V., Langyan, S., Kalia, S. (2023). Comparison of nutritional quality of fourteen wild *Linum* species based on fatty acid composition, lipid health indices, and chemometric approaches unravelling their nutraceutical potential. *Heliyon*, *9*(11). https://doi.org/10.1016/j.heliyon.2023.e21192

Poliakova, I. O., Nikonova, V. M., Taranets, T. O. (2024). Appearance of economic traits of a new line of oil flax obtained by the method of interspecific hybridization. *Scientific and Technical Bulletin of the Institute of Oilseed Crops of the NAAS*, 37, 66-74. https://doi.org/10.36710/IOC-2024-37-07 [in Ukrainian]

Qi, Y., Wang, L., Li, W., Xie, Y., Zhao, W., Dang, Z., Zhang, J. (2022). Phenotypic analysis of Longya-10× pale flax hybrid progeny and identification of candidate genes regulating prostrate/erect growth in flax plants. *Frontiers in Plant Science*, *13*, 1044415. https://doi.org/10.3389/fpls.2022.1044415

Qu, Z. H., Wang, Y. X., Qiao, H.M. et al (2018). Breeding of new flax (*Linum usitatissimum* L.) variety Jizhangya No.1 by interspecific hybridization. *Plant Fiber Sci China, 40*(1):8-11.

Raut, V. K., Yadav, A., Kaur, V., Rao, M., Pathania, P., Wankhede, D., Singh, G. P. (2025). Pollen–pistil interactions in divergent wide crosses lead to spatial and temporal pre-fertilization reproductive barrier in flax (*Linum usitatissimum* L.). *Scientific Reports*, *15*(1), 6806. https://doi.org/10.1038/s41598-025-90046-8

Schulz, R. (2022). Interspecific crossability study to determine combining ability in perennial *flax*. https://conservancy.umn.edu/items/52dab0ba-cfd4-4df5-8fd6-1a52997d0cd4

Shevchenko, O. V., Balabukh V. O. (2024). The impact of climate change on the natural and agricultural zoning of the territory of Ukraine. *Environmental Sciences*, *5*(56): 222-231. https://doi.org/10.32846/2306-9716/2024.eco.5-56.34 [in Ukrainian]

Sveinsson, S., McDill, J., Wong, G. K. S., Li, J., Li, X., Deyholos, M. K. (2014). Phylogenetic pinpointing of a paleopolyploidy event within the flax genus (*Linum*) using transcriptomics. *Ann. Bot,* 113, 753-761. https://doi.org/10.1093/aob/mct306

Thakur, R., Paul, S., Satasiya, P. (2020). Genetic variability and path analysis for yield and its related traits in linseed (*Linum usitatissimum* L.). *International Journal of Current Microbiology and Applied Sciences, (9)*10, 2579-2586. https://doi.org/https://doi.org/10.20546/ijcmas.2020.910.310

Tork, D. G., Anderson, N. O., Wyse, D. L., Betts, K. J. (2023). Selection of perennial flax (Linum spp.) for yield and reproductive traits for the oilseed ideotype. *Agronomy*, *14*(1), 99. https://doi.org/10.3390/agronomy14010099

Tovstanovska, T. G., Lyakh, V. O. (2021). Estimation of oil flax intra-species hybrids by breeding-genetic parameters for the creation of material with altered

© T. G. Tovstanovska, V. O. Lyakh

habitus. *Scientific and Technical Bulletin of the Institute of Oilseed Crops of the NAAS*, 30, 24-32. https://doi.org/10.36710/ioc-2021-30-03 [in Ukrainian]

Tovstanovska, T. G., Polyakov O.I. (2023) Features of hybridization of oil flax with wild annual species. *Grain Crops*, *7*(2), 217-226. https://doi.org/10.31867/2523-4544/0280 [in Ukrainian]

Tovstanovska, T., Lyakh V. (2024). Influence of plant habitus traits on formation of seed productivity in flax. *Bulgarian Journal of Crop Science*, *61*(1), 21-30. https://doi.org/10.61308/AHFH6013

Vikas, P., Nandan, M. (2016). Genetic diversity assessment of flax (*Linum usitatissimum L.*) germplasm using molecular and morphological markers. *EJPB* 7, 986-995. https://doi.org/10.5958/0975-928x.2016.00135.6

Wang, Y. F., Jankauskiene Zofija, Qiu Cai-Sheng, Gruzdeviene Elvyra, Long Song-Hua, Alexopoulou Efthymia, Guo Yuan, Szopa Jan, Hao Dong-Mei, Fernando Ana Luisa (2018). Fiber flax breeding in China and Europe. *Journal of natural fibers*, *15*(3). 309-324. https://doi.org/10.1080/15440478.2017.1325431

Wang, Y. F., Kang, Q. H., Zhu, X., Zhang, Z., Qiu, H. J., Yao, D. D., Hanipa, H. (2025). Advances in Flax (*Linum usitatissimum* L.). Breeding and biotechnology strategies. *Breeding and Biotechnology of Grass and Bast Fiber Crops,* 463-506.

Zhang, L. L., W. Bai, J. Mi, Z. H. Qu, H. M. Qiao, S. F. Li, A. R., Li (2012). Interspecific hybridization between cultivated flax and wild flax. *Acta Agriculturae Boreali-Sinica,* 27. supplement, 57-60.

Zhang, J., Qi, Y., Wang, L., Wang, L., Yan, X., Dang, Z., Liu, T. (2020). Genomic comparison and population diversity analysis provide insights into the domestication and improvement of flax. *Science,* 23(4), 1-11. https://doi.org/10.1016/j.isci.2020.100967

# ЕФЕКТИВНІСТЬ ВИКОРИСТАННЯ МІЖВИДОВОЇ ГІБРИДИЗАЦІЇ У СТВОРЕННІ СЕЛЕКЦІЙНОГО МАТЕРІАЛУ ЛЬОНУ ЗІ ЗМІНЕНИМ ГАБІТУСОМ РОСЛИНИ

**Т. Г. Товстановська[1], В. О. Лях[1,2]**

*[1]Інститут олійних культур Національної академії аграрних наук України,*
*[2]Запорізький національний університет*

**Створення високопродуктивного вихідного матеріалу є одним із стратегічних напрямів селекції льону олійного. У значній мірі це залежить від розширення генетичного різноманіття, зокрема, за рахунок залучення дикорослих видів як джерел багатьох цінних ознак. Мета роботи – визначення ефективності використання міжвидової гібридизації у створенні селекційного матеріалу зі зміненим габітусом рослини. Дослідження проводили в Інституті олійних культур НААН у 2023-2025 рр. Матеріалом були п'ять ліній льону від міжвидових схрещувань: МЛ 43, МЛ 74, МЛ 102, МЛ 233, МЛ 282, а також перспективна лінія МЛ 515 та її батьківські форми – зразок льону культурного М 32/2 (Україна) і дикий вид *L. angustifolium.* Вивчення селекційного матеріалу проводили згідно методичних рекомендацій. Структурний аналіз зразків здійснювали на 20 рослинах. Вміст олії визначали на ЯМР-аналізаторі АМВ-1006, вміст жирних кислот –**

© T. G. Tovstanovska, V. O. Lyakh

**методом газоридинної хроматографії на приладі «Селміхром-1». У результаті досліджень встановлено, що за ознаками габітусу рослини лінії перевищували контроль як за кількістю стебел на рослині (2,8-3,2 шт. проти 1,2 шт. у контролю), так і за кількістю бічних пагонів (12,9-14,0 шт. проти 8,1 шт.). Лінії МЛ 102 і МЛ 233 характеризувалися високорослістю й перевищували контроль на 12,9-18,1 см. За ознаками насіннєвої продуктивності лінії перевищували контроль за кількістю коробочок на 10,3-15,5 шт., за масою насіння з рослини – на 0,36-0,58 г. Кращими показниками маси 1000 насінин характеризувалися лінії МЛ 74 (6,5 г) і МЛ 102 (6,4 г), олійності – МЛ 102 (45,4%) і МЛ 233 (44,6%). Усі лінії характеризувалися високим вмістом ліноленової кислоти в олії (52,3-56,7%). Перспективна лінія МЛ 515 за високими показниками врожайності (2,2 ц/га), вмісту ліноленової кислоти в олії (61,4%), маркерними ознаками передана як сорт Романс до державного сортовипробування. Створені методом міжвидової гібридизації лінії є перспективним матеріалом для селекції на високу врожайність.**

***Ключові слова:*** льон культурний, дикий вид, міжвидове схрещування, габітус рослини, кількість стебел, кількість бічних пагонів, перспективна лінія

## Author Information

**Tovstanovska Tetiana Gryhorivna** – corresponding author, Candidate of Agricultural Sciences, Leading Researcher of the Flax Breeding Laboratory, Institute of Oilseed Crops of the National Academy of Agrarian Sciences of Ukraine (1 Instytutska St., Soniachne settlement, Zaporizhzhia district, Zaporizhzhia region, 69055), tovstanovskat@gmail.com, https://orcid.org/0000-0002-7295-4538).

**Lyakh Viktor Oleksiiovych** – Doctor of Biological Sciences, Professor, Leading Researcher of the Flax Breeding Laboratory, Institute of Oilseed Crops of the National Academy of Agrarian Sciences of Ukraine (1 Instytutska St., Soniachne settlement, Zaporizhzhia district, Zaporizhzhia region, 69055), lyakh@iname.com, https://orcid.org/0000-0002-7385-3157).

**Suggested Citation:**

Tovstanovska, T. G., & Lyakh, V. O. (2026). Effectiveness of the use of interspecific hybridization in creating flax breeding material with altered plant habit. *Scientific and Technical Bulletin of the Institute of Oilseed Crops NAAS*, 40, 71–83. https://doi.org/10.36710/IOC-2026-40-06

© T. G. Tovstanovska, V. O. Lyakh