INFLUENCE OF SEED HETEROGENEITY ON SOWING AND YIELDING PARAMETERS OF RICE CULTIVARS

Dovbush O.S., Shpak D.V., Shpak T.M., Melnichenko H.V.
Institute of Rice of NAAS, Ukraine

Purpose and objectives. The cultivation technology development was aimed at maximizing the potential productivity of the crop. To accomplish this, studies of heterogeneity are not only of theoretical but also of practical value, as knowledge of this phenomenon can open new opportunities to improve seed quality.

Materials and methods. In 2019–2020, the field and laboratory experiments were carried out in the rice crop rotation of the Institute of Rice of NAAS. The farming technique of the experiment met the requirements for experimentation, as Dospekhov B.A. described.

Results and discussion. This article covers the results on the performance patterns of new rice cultivars and their seed parameters, depending on the matrical heterogeneity. The yield in the field experiments across the study years ranged 8.05 to 11.68 t/ha, depending on a combination of the factors under investigation. It was found that the rice produced high yields in the plots sown with seeds from the upper part of the panicle, regardless of the cultivar. In the plots sown with seeds from the lower part of the panicle, there was a shortfall of planting material from 1.85 to 2.30 t/ha in comparison with the plots sown with seeds from the upper part of the panicle. Therefore, sowing seeds from the lower part of the panicle means irrational use of planting material, resulting in thinned crops and decreased yields, which in turn leads to the production of low-quality seeds.

Conclusions. Thus, the matrical heterogeneity-based selection of rice seeds from the upper part of the panicle in the primary stages of seed production is an important technological approach. This contributes to an increase in the yield and quality of rice seeds, allowing for accelerated implementation of new rice cultivars into production.

Key words:*rice, 1000-seed weight, germination energy, field germinability, yield, heterogeneity.*

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INTRA-POPULATION VARIABILITY OF OIL CONTENT AND FATTY ACID COMPOSITION IN MODERN HEMP CULTIVARS

Laiko[1] I.M., Kobyzeva[2] L.N., Mishchenko[1] S.V., Kyrychenko[1] H.I.
[1]Institute of Bast Crops of NAAS, Ukraine
[2] Plant Production Institute named after V.Ya. Yuriev of NAAS, Ukraine

The intra-population variability of the oil content, selection of plants with the maximum oil content, trait fixing in the selection process, and optimization of the fatty acid composition of oil in hemp seeds were investigated.

Keywords: *breeding, cultivar, inbreeding, oil content, fatty acid composition*

Introduction. Polymathic breeding material, which includes inbreeding lines, inter-line, cultivar-line and line-cultivar tetrahydrocannabinol-free hybrids, has been created. In order to assess their prospects for breeding and production, we studied the intra-population variability of the oil content, selection of plants with the maximum oil content, trait fixing in the selection process, and optimization of fatty acid composition of oil in hemp seeds.

Literature review and problem articulation. Hemps can be used in many industries, in particular textiles, biocomposites, some details for cars, paper, biodiesel, cosmetics, pharmaceuticals, food are made from them; they are used in animal husbandry and as a bioenergy crop, etc. [1]. The following primary purposes and objectives of current hemp breeding have crystallized out in the global practice: increased fiber yield and quality, control of monoecy and cannabinoid content, stabilization of the growing period length and creation of pest-resistant starting material [1]. Both classical [2, 3, 4] (mass and individual selections, crossbreeding, inbreeding and hybridization) and biotechnological [4, 5] methods of breeding as well as molecular technologies (genetic markers of breeding traits) are used, however development the latter is still underway and at initial stages of implementation [6, 7, 8, 9, 10]. We believe that the current avenues of hemp economic use and breeding are a traditional one (fiber) and innovative ones (energy, seed and medicine). Breeders are faced with a priority task of expanding the hemp diversity, in particular for innovative areas of economic use.

The main value of hemp oil is that the vast majority of its components are unsaturated fatty acids. They make cannabis an important source of physiologically active substances, which are essential for treating diabetes, arthritis, skin diseases, and atherosclerosis. However, unsaturated acids cause a rapid oxidation of hemp oil; it loses its nutritional properties and becomes rancid. As significant amounts of peroxides and hydroperoxides are accumulated, the oil turns toxic, and accumulated intermediates of lipid peroxidation have a lot of different negative biochemical and physiological effects [11, 12, 13].

Hemp oil is especially valued due to contents of linoleic, linolenic and gamma-linolenic acids. The ratio of glycerides of these acids in hemp oil is 3:1 (56% of linoleic acid and 19% of linolenic acid) puts the hemp among the most valuable crops [14, 15].

Purpose and objectives. To identify new promising material with high seed productivity, oil content and optimal fatty acid composition

Material and methods. Our study was based on modern Ukrainian hemp cultivars with highly stable populations in terms of cannabinoid content compared to foreign cultivars. The study was performed by breeding, biochemical and statistical methods: individual selection, thin layer and gas-liquid chromatography (HP 6890 Series Hewlett Packard chromatograph) with internal references. The oil content was determined by S.V. Rushkovskiy's method; the fatty acid composition of oil was determined by gas-liquid chromatography (Peisker's method) on a Selmichrome 1 chromatograph at the Plant Production Institute named after V.Ya. Yuriev of NAAS. Data were statistically data processed in OSGE application package (P. Litun, A. Belkin, A. Belyanskiy, 1992) in compliance with field experimentation methods, as B.A. Dospekhov described.

Results and discussion. The importance of oil content and uniqueness of fatty acid composition should also be based on the high seed productivity of a cultivar, ensuring the development of food use of hemp seeds. In this regard, all breeding material was evaluated for seed productivity; the best cultivars were screened for oil content; and the oil content variability within the best populations of elite plants was determined.

Analysis of the oil content in inter-line, cultivar-line and line-cultivar F_1 hybrids showed that this trait ranged from 32.0% (I_3 Hlesiia / Hlukhivski 58) to 39.5% (Hlesiia / I_5 Zolotoniski 15). High oil content was recorded in reciprocal hybrids Hlesiia / I_5 Zolotoniski 15 and I_5 Zolotoniski 15 / Hlesiia (39.5 and 39.0%, respectively). Slightly lower content was obtained in hybrids I_3 Hlesiia / Zolotoniski 15 (37.0%), Hlesiia / I_5 Hlukhivski 58 (36.0%), I_3 Hlesiia / I_5 Hlukhivski 58 (36.0%), and Zolotoniski 15 / I_3 Hlesiia (36.0%). In F_2, inter-line hybrids had relatively low oil content (31.0–34.0%), and the selected promising variants – high (39.2 and 38.6%, respectively).

Thus, high oil content was recorded in hybrids derived from crossing cultivars and self-pollinated lines of Central European eco-geographical type with cultivars and self-pollinated lines of the southern type, although the original forms of the first type contained more oil. We believe that in this case, the Central European type was a source and donor of high oil content, while the southern type – of longer seed formation and, accordingly, of a high level of oil accumulation. In addition, there is a heterosis phenomenon as a result of combining distant genotypes in one organism. In this case, cultivar-line and line-cultivar hybrids, but not inter-line hybrids, turned out to be the most successful ones (oil content of 36−39%). They were also noticeable for high seed productivity (11.7 g and 12.6 g, respectively) (Table 1).

Table 1

Oil content in F_1 and F_2 inter-line, cultivar-line and line-cultivar hybrids of hemp

Hybrid	Oil content, %	
	F_1	F_2
Hlesiia / I_5 Hlukhivski 58	36.0	–
I_5 Hlukhivski 58 / Hlesiia	32.8	–
Hlukhivski 58 / I_3 Hlesiia	34.0	–
I_3 Hlesiia / Hlukhivski 58	32.0	–
I_5 Hlukhivski 58/ I_3 Hlesiia	32.2	31.7
I_3 Hlesiia / I_5 Hlukhivski 58	36.0	33.0
Hlesiia / I_5 Zolotoniski 15	39.5	39.2
I_5 Zolotoniski 15 / Hlesiia	39.0	38.6
Zolotoniski 15 / I_3 Hlesiia	36.0	–
I_3 Hlesiia / Zolotoniski 15	37.0	–
I_5 Zolotoniski 15 / I_3 Hlesiia	33.5	31.0
I_3 Hlesiia / I_5 Zolotoniski 15	35.5	34.0
LSD_{05}	2.0	–

In 2016, the best elite plants from cultivars of different genetic origins, Hlesiia and Mykolaichyk, as well as from cultivars of hybrid origin, Artemida and Harmoniia, were selected by high seed productivity, cannabinoid absence and sex type. All elite plants had the largest seed weight of 59.1 g (minimum − 35.6 g; maximum − 100.2 g). In addition, it was found that the population variability of oil content was within 33.99−46.98%. In the process of breeding for increased oil content, a gradual increase in the oil content in seeds was observed.

In order to increase the practical value of a cultivar, the seed productivity was raised through breeding techniques. Analysis of Mykolaichyk plants (harvested in 2017) for seed productivity showed that there were plants with high seed weight and short stems. Thus, 37% of 238 selected plants had an increased seed weight of 33.3–94.0 g (the mean was 33.3 g per plant). The oil content in seeds from the best plants (50 plants) ranged 30.0% to 47.7% (Fig. 1). There were 46% of plants with an oil content of > 39% (Fig. 1). According to the 2017 data, the oil content variation limits were 34.3−37.8% in Mykolaichyk, 33.8–41.6% in Artemida, and 35.5−38.9% in Harmoniia. Artemida and Harmoniia were also noticeable for high seed weight.

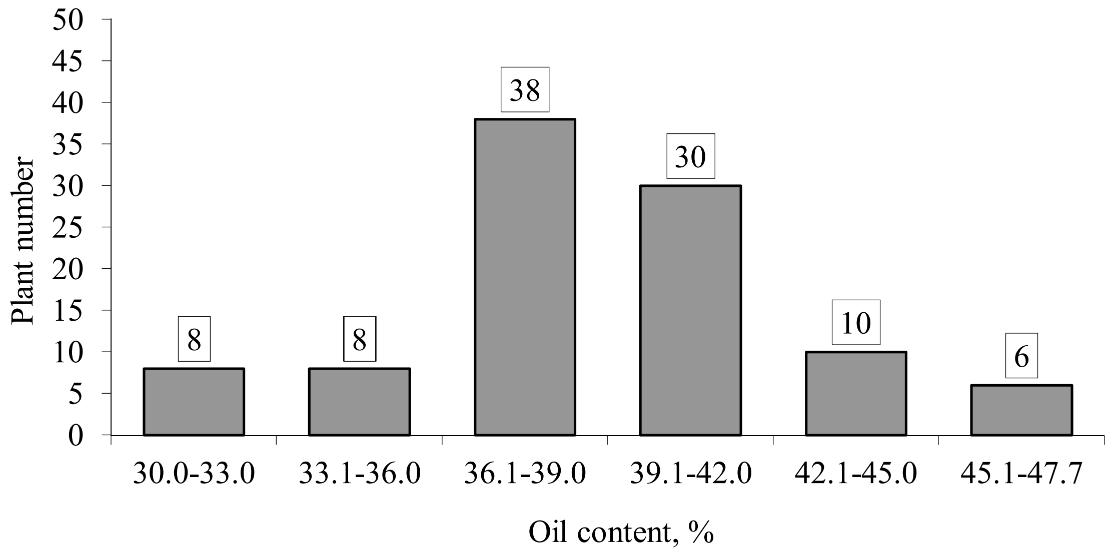

Fig. 1. Distribution of Mykolaichyk plants by oil content

Oil of all cultivars had the optimal ratio of omega-3 to omega 6 fatty acids of 1:3.1−1:3.9 (2016-2017). In 2018–2019, the omega-6/omega-3 ratio was 4.0:1−4.8:1. The linoleic acid contentrangedfrom 55% to 58%; and linolenic acid content − from 12.58% to 18, 23% (Tables 2 and 3). Mykolaichyk and Artemida were distinguished by gamma-linolenic acid level. These results allow us to assert the uniqueness of the fatty acid composition of hemp seeds and its constancy in breeding for increased oil content.

Table 2

Fatty acid composition of oil from hemp seeds of different cultivars, 2016

Fatty acids	Content, %					
	Mykolaichyk		Artemida		Harmoniia	
	$\bar{x} \pm s_{\bar{x}}$	V	$\bar{x} \pm s_{\bar{x}}$	V	$\bar{x} \pm s_{\bar{x}}$	V
Palmitic	7.38 ± 0.079	5.2	7.16 ± 0.248	8.5	6.98 ± 0.059	2.8
Palmitoleic	0.56 ± 0.033	28.4	0.63 ± 0.046	17.8	0.57 ± 0.041	23.4
Stearic	2.71 ± 0.065	11.5	3.56 ± 0.146	10.0	3.62 ± 0.103	9.4
Oleic	13.73 ± 0.279	9.8	13.72 ± 0.359	6.4	13.45 ± 0.296	7.3
Linoleic	57.60 ± 0.286	2.4	56.84 ± 0.330	1.4	56.70 ± 0.323	1.9
Gamma-linolenic	2.66 ± 0.159	28.6	1.98 ± 0.088	10.9	1.78 ± 0.149	27.7
Linolenic	14.62 ± 0.229	7.5	15.27 ± 0.489	7.8	15.94 ± 0.423	8.8
Eicosenoic	0.52 ± 0.049	44.6	0.64 ±0.037	14.3	0.65 ± 0.043	21.9
Behenic	0.20 ± 0.015	35.7	0.20 ± 0.020	25.3	0.30 ± 0.039	42.5
Omega 6/omega 3	3.9:1		3.7:1		3.7:1	

Table 3

Fatty acid composition of oil from hemp seeds of different cultivars, 2017

Fatty acids	Content, %					
	Mykolaichyk		Artemida		Harmoniia	
	$\bar{x} \pm s_{\bar{x}}$	V	$\bar{x} \pm s_{\bar{x}}$	V	$\bar{x} \pm s_{\bar{x}}$	V
Palmitic	6.57 ± 0.066	3.2	6.62 ± 0.100	3.0	6.72 ± 0.038	1.4
Palmitoleic	0.23 ± 0.016	21.2	0.30 ± 0.078	51.1	0.32 ± 0.023	17.4
Stearic	2.82 ± 0.035	3.9	3.38 ± 0.090	5.3	3.13 ± 0.055	4.3
Oleic	12.43 ± 0.346	8.8	13.15 ± 0.376	5.7	13.55 ± 0.161	2.9
Linoleic	56.69 ± 0.481	2.7	58.15 ± 0.097	0.3	56.10 ± 0.494	2.2
Gamma-linolenic	1.82 ± 0.077	13.4	2.00 ± 0.087	8.7	1.38 ± 0.170	30.0
Linolenic	18.23 ± 0.294	5.1	15.45 ± 0.812	10.5	17.75 ± 0.465	6.4
Eicosenoic	0.85 ± 0.043	15.8	0.76 ± 0.012	3.2	0.61 ± 0.079	32.0
Behenic	0.36 ± 0.035	31.0	0.45 ± 0.086	38.3	0.44 ± 0.057	32.1
Omega 6/omega 3	3.1:1		3.7:1		3.1:1	

The selection stabilized the oil content in the cultivar populations. The modern cultivars were ranked in order of decreasing oil levels in seeds as follows: Mykolaichyk, Artemida, Harmoniia, Hlesiia (Fig. 2).

Continuous breeding selection gradually widens the expression range of the “oil content” trait from medium to maximum. In the check cultivar, Hliana, which was not bred for increased oil content in seeds, the oil content remained 28-30% over the years, while in Mykolaichyk populations, it gradually increased and stabilized at a level of 33, 35, or 37.8% without changes in the fatty acid composition of oil in the breeding process. This proves the high efficiency of the developed methods of breeding to create cultivars with high seed productivity and targeted selection to increase the oil content in hemp seeds. Thus, the importance of a cultivar combining high seed yield and high oil output increases.

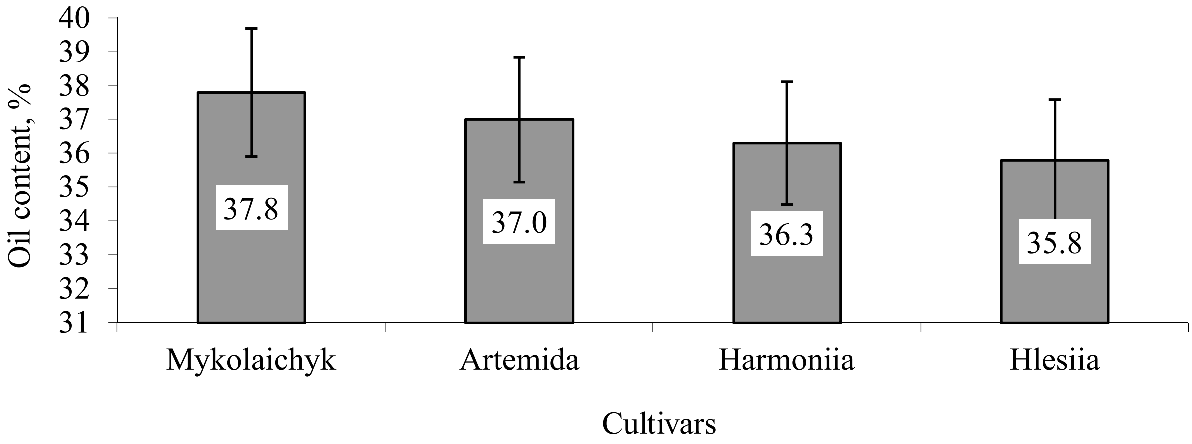

Fig. 2. Ranking of promising hemp cultivars by oil content in seeds (mean, 2017–2021)

Conclusions. We believe that the Central European type is a source and donor of high oil content, while the southern type – of a longer seed formation and, accordingly, of high oil accumulation.

The heterosis phenomenon resulted from combining distant genotypes in one organism was observed. In this case, cultivar-line and line-cultivar hybrids, but not inter-line hybrids, turned out to be the most successful ones (oil content of 36−39%).

New hemp cultivars, Mykolaichyk, Artemida and Harmoniia, have been created; they combine such traits as high seed productivity, high seed oil content and a unique fatty acid composition.

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ВНУТРІШНЬОПОПУЛЯЦІЙНА МІНЛИВІСТЬ ОЗНАК ВМІСТУ ОЛІЇ ТА ЇЇ ЖИРНОКИСЛОТНОГО СКЛАДУ СУЧАСНИХ СОРТІВ КОНОПЕЛЬ

Лайко[1] І.М., Кобизєва[2] Л.Н., Міщенко[1] С.В., Кириченко[1] Г.І.
[1]Інститут луб'яних культур НААН, Україна
[2]Інститут рослинництва ім. В.Я. Юр'єва НААН, Україна

Мета та завдання досліджень. Виявити новий перспективний матеріал з високою насіннєвою продуктивністю, олійністю та оптимальним жирнокислотним складом.

Обговорення результатів. Визначено, що під дією добору збільшується діапазон мінливості ознак вмісту олії та маси насіння. Включення в гібридизацію віддалених генотипів сприяє отриманню високоолійних ліній, які в подальшому є донорі цієї ознаки. Високі показники вмісту олії були зафіксовані в гібридів, отриманих в результаті схрещування сорту і самозапилених ліній середньоєвропейського еколого-географічного типу з сортом і самозапиленими лініями південного типу. При цьому найбільш вдалими виявилися сортолінійні і лінійносортові гібриди (вміст олії 36–39 %), а не лінійні.

Родинно-груповий добір є основа підвищення та подальшої стабілізації ознаки олійності насіння. При проведенні селекційної роботи в напряму підвищення олійності виявлено поступове збільшення олійності насіння. Встановлено, що популяційна мінливість ознаки вмісту олії насіння складає від 33,99 до 46,98%.

Постійний селекційний добір веде до поетапного розширення діапазону прояву ознаки вмісту олії від середнього до максимуму. З метою підвищення практичної цінності сортів селекційними прийомами збільшували також насінну продуктивність. Найбільш перспективними виявлено сорти різного генетичного походження Глесія і Миколайчик і гібридного походження сорти Артеміда, Гармонія. В популяції сорту Миколайчик у процесі відбору вміст олії поетапно підвищується і стабілізується на рівні 33, 35, 37,8% без змін жирнокислотного складу олії.

Результатом добору є стабілізація популяцій сортів за ознакою вмісту олії. Це доводить високу ефективність розроблених методів селекції створення сорту з високою насіннєвою продуктивністю та цілеспрямованого відбору на підвищення олійності насіння конопель. Таким чином, збільшується значимість сорту, що поєднує високу врожайність насіння та вихід олії. За олійністю насіння сучасні сорти можна розташувати в наступному порядку: Миколайчик, Артеміда, Гармонія, Глесія.

Олія всіх сортів має оптимальне співвідношення жирних кислот омега-3 і омега-6 на рівні 1: 3,1, 1: 3,9 (2016–2017 рр.). За 2018–2019 рр. співвідношення жирних кислот омега-6 и омега-3 складав 4,0: 1, 4,8: 1. Діапазон мінливості вмісту лінолевої кислоти становить від 55 до 58%, а ліноленової від 12,58 до 18,23% . За вмістом гама-ліноленової кислоти виділяються сорти Миколайчик та Артеміда. Дані результати дозволяють стверджувати про унікальність жирнокислотного складу насіння конопель та його незмінність при проведенні селекції на підвищення олійності.

Висновки. Вважаємо, що середньоєвропейський тип виступає джерелом і донором ознаки високого вмісту олії, а південний – більш тривалого періоду формування насіння і відповідно високого рівня накопичення олії.

Виявлено, що явище гетерозису в результаті поєднання в одному організмі віддалених генотипів. При цьому найбільш вдалими виявилися сортолінійні і лінійносортові гібриди (вміст олії 36–39%), а не лінійні.

Створено нові сорти конопель Миколайчик, Артеміда і Гармонія, які поєднують ознаки високої насіннєвої продуктивності, олійності насіння та унікальний жирнокислотний склад.

Ключові слова: *селекція, сорт, інцухт, олійність, жирнокислотний склад*

INTRA-POPULATION VARIABILITY OF OIL CONTENT AND FATTY ACID COMPOSITION IN MODERN HEMP CULTIVARS

Laiko[1] I.M., Kobyzeva[2] L.N., Mishchenko[1] S.V., Kyrychenko[1] H.I.
[1]Institute of Bast Crops of NAAS, Ukraine
[2] Plant Production Institute named after V.Ya. Yuriev of NAAS, Ukraine

Purpose and objectives. To identify new promising material with high seed productivity, oil content and optimal fatty acid composition

Results and discussion. It was found that the variability ranges of the oil content and seed weight increased under the influence of selections. Use of distant genotypes in hybridization contributed to the generation of high-oil lines, which later become donors of this trait. High oil content was recorded in hybrids derived from crossing cultivars and self-pollinated lines of the Central European eco-geographical type with cultivars and self-pollinated lines of the southern type. In this case, cultivar-line and line-cultivar hybrids (oil content of 36−39%), rather than inter-line ones, turned out to be the most successful results.

Family-group selection is a basis for increasing and further stabilizing the oil content in seeds. The oil content was revealed to gradually increase during the breeding for increased oil content. It was found that the population variability of the seed oil content was from 33.99% to 46.98%.

Continuous breeding selection gradually widens the expression range of the “oil content” trait from medium to maximum. In order to increase the practical value of cultivars via breeding techniques the seed productivity was also increased. The cultivars of different genetic origins, Hlesiia and Mykolaiychyk, as well as the cultivars of hybrid origin, Artemida and Harmoniia, were considered the most promising ones. In Mykolaichyk populations, the oil content gradually increased and stabilized at a level of 33, 35, or 37.8% without changes in the fatty acid composition of oil.

The selections stabilized the oil content in cultivar populations. This proves the high efficiency of the developed breeding methods to create cultivars with high seed productivity and of targeted selection to increase the oil content in hemp seeds. Thus, the importance of a cultivar combining high seed yield and high oil output rises. The modern cultivars were ranked in order of decreasing oil levels in seeds as follows: Mykolaichyk, Artemida, Harmoniia, Hlesiia.

Oil of all cultivars had an optimal ratio of omega-3 to omega 6 fatty acids of 1:3.1−1:3.9 (2016−2017). In 2018−2019, the ratio of omega-6 to omega-3 fatty acids was 4.0:1− 4.8:1. The linoleic acid content ranged from 55% to 58% and the linolenic acid content – from 12.58% to 18.23%. Mykolaichyk and Artemida were noticeable for gamma-linolenic acid. These results allow us to assert that the fatty acid composition of hemp seeds is unique and immutable during the breeding for increased oil content.

Conclusions. We believe that the Central European type is a source and donor of high oil content, while the southern type – of a longer seed formation and, accordingly, of high oil accumulation.

The heterosis phenomenon resulted from combining distant genotypes in one organism was observed. In this case, cultivar-line and line-cultivar hybrids, but not inter-line hybrids, turned out to be the most successful ones (oil content of 36−39%).

The new hemp cultivars, Mykolaichyk, Artemida and Harmoniia, which combine high seed productivity with high seed oil content and unique fatty acid composition, have been created.

Keywords: *breeding, cultivar, inbreeding, oil content, fatty acid composition*