

Heterotic hybrids of lavender (*Lavandula angustifolia* Mill.) with valuable quantitative characteristics

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Abstract. The evaluated lavender hybrids exhibit heterosis compared to the maternal form across a series of quantitative traits assessed over several years. The manifestation of the heterosis effect was recorded in the quantitative traits related to the inflorescence: the length of the floral spike, which varied from +21.8% to +65.6% and the number of whorls per floral spike +11.1 to 44.6%. As for the essential oil content, this index showed values ranging between +51.5% and +85.2%. The hybrid genotypes 7Cr.13S-6-12-27 and 7Cr.13S-6-12-28, descendants of the maternal form Cr.13, were of particular interest, exhibiting the highest heterosis indices for the studied characters and accumulating the highest essential oil content, over 5% (dry matter).

Keywords: lavender, hybrids, genotype, heterosis effect, essential oil, quantitative characteristics, inflorescence.

Hibrizi heterotici de lavandă (*Lavandula angustifolia* Mill.) cu caractere cantitative valoroase

Rezumat. Hibrizii de lavandă evaluați manifestă heterozis în raport cu forma maternă la un șir de caractere cantitative evaluate pe parcursul mai multor ani. Manifestarea efectului heterozis a fost înregistrată la caracterele cantitative ce vizează inflorescența: lungimea spicului floral, care a variat de la +21,8% până la +65,6%, și numărul de verticile pe spicul floral, +11,1% la +44,6%. La conținutul de ulei esențial, acest indice a demonstrat valori cuprinse între +51,5% și +85,2%. Un interes deosebit au manifestat genotipurile hibride 7Cr.13S-6-12-27 și 7Cr.13S-6-12-28, descendenți ai formei materne Cr.13, care au înregistrat cei mai înalți indici ai heterozisului la caracterele studiate, acumulând și cel mai mare conținut de ulei esențial, peste 5% (s.u.).

Cuvinte-cheie: lavandă, hibrizi, genotip, efect heterosis, ulei esențial, caractere cantitative, inflorescență.

1. INTRODUCTION

In the breeding of many medicinal and aromatic plant species, heterosis is utilized to develop varieties and hybrids with enhanced productivity of raw material and essential oil. In *Lavandula angustifolia* Mill., heterosis is successfully applied, as this phenomenon leads to increased vigor and productivity in first-generation hybrids [1, 11]. Consequently,

productivity indices have shown significant increases, by 30-40% compared to the parental forms [8].

The wide use of lavender in medicine, phytotherapy, pharmacology, and perfumery is primarily due to its main product—the essential oil obtained through steam distillation of fresh inflorescences. This essential oil is also widely used in the perfume and cosmetics industry, in the production of various hygiene and sanitary products, and in pharmaceutical preparations with calming, antidepressant, antibacterial, and antimicrobial properties, as well as a fragrance component in topical ointments [3, 4, 5, 6, 7]. Lavender essential oil may also be applied topically to treat burns, frostbite, and allergic skin reactions. The lavender oil produced in the Republic of Moldova is of superior quality, due to a high concentration of active compounds, derived from high-performance varieties that ensure both high raw material yields and elevated essential oil content.

The aim of this research was to evaluate several promising hybrid genotypes of *L. angustifolia* and to identify those combining optimal values of key biological and agronomic traits, including high essential oil content, tolerance to frost, overwintering ability, and drought resistance, as indicated by the expression of heterosis [1, 11]. To achieve this objective, the following goals were pursued: the assessment of quantitative traits directly influencing hybrid productivity, the selection of elite hybrids with superior essential oil content, and the determination of the heterosis effect. Most of the hybrids studied over multiple years demonstrated superior agronomic indices compared to their maternal forms.

2. MATERIALS AND METHODS

The study was conducted on 196 F₁ lavender hybrids, created using four maternal forms of different genetic and geographical origin. Each maternal form was assigned a code: Fr.1, Fr.5, Fr.8, and Cr.13. The maternal forms Fr.1, Fr.5, and Fr.8 are of French origin, while Cr.13 is a generative descendant of the Ukrainian cultivar Crâmceanca. The experimental trials were carried out at the experimental field of the Institute of Genetics, Physiology and Plant Protection, Moldova State University. Frost and winter hardiness were assessed in early spring according to standard methods, using a scoring scale from 1 to 5 points [9, p. 63].

Phenological observations and biometric measurements were performed during the growing season. A set of biomorphological (quantitative) characteristics that directly influence productivity were evaluated for the hybrid genotypes, including *plant height and diameter, number of flower stalks per plant, inflorescence length, spike and flower stalk length, and number of whorls per spike* [3, 9, p. 543, p. 60]. Essential oil content

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in the raw material was determined by steam distillation using Ginsberg apparatuses, conducted twice per season—at the beginning of flowering and at full flowering stages [9, 10, p. 65, p. 326]. The results were recalculated as dry matter values to correct for humidity differences between hybrid samples. Following distillation, lavender essential oil was dried using sodium sulfate (Na_2SO_4). The heterosis effect was calculated as a percentage relative to the maternal form for each hybrid and trait evaluated, using the formula:

$$H = \frac{F_1 - P}{P} \times 100$$

where H is the heterosis index, F_1 is the trait value of the hybrid, and P is the trait value of the maternal form.

The statistical analysis of the experimental data was performed using standard procedures with the STATISTICA 7 software package.

3. RESULTS AND DISCUSSIONS

The evaluation of 196 F_1 lavender hybrids was continued in the seventh year of vegetation, during which frost and winter hardiness were assessed. Results showed that 103 hybrids exhibited high resistance (5 points), 36 showed above-average resistance (4 points), 24 exhibited average resistance (3 points), and 33 hybrids were completely damaged and thus eliminated from further trials. The assessment of quantitative traits revealed the following variation: plant height ranged from 63.5 to 85.0 cm, crown diameter from 80.0 to 145.0 cm, and the number of flower stalks per plant ranged from 650 to 2100.

Breeding programs for *L. angustifolia* focus on developing and evaluating hybrids with elevated essential oil content in the raw material and improved quality. This trait varied depending on both the hybrid and its maternal origin. Data collected between 2019 and 2023 [2] indicated that 40 hybrids derived from the maternal form Fr.8 accumulated essential oil content between 2.543% and 5.834% (dry matter); 8 hybrids originating from Cr.13 showed values ranging from 4.438% to 5.987%, while 8 hybrids from Fr.1 registered between 4.434% and 5.980%.

The selected F_1 hybrids consistently demonstrated higher essential oil content compared to their respective maternal forms. In 2019 (third year of vegetation), essential oil content ranged from 3.848% to 6.255%. Notably high values were recorded in hybrids originating from: Fr.1 (1Fr.1-3-2-30V – 5.042%), Fr.8 (14Fr.8-5-15-18V – 5.321%), and Cr.13 (7Cr.13S-6-12-27 – 5.091%; 7Cr.13S-6-12-28 – above 6%), as shown in Table 1. In contrast, essential oil content in the maternal forms was significantly lower, ranging from 3.378% (Cr.13) to 3.912% (Fr.5).

In the fourth year of vegetation (2020), the essential oil content varied from 4.214% (5Cr.13S-6-7-2) to 6.344% (7Cr.13S-6-12-28), both hybrids descended from the Ukrainian cultivar Crâmceanca (Cr.13). Maternal forms recorded lower oil concentrations during this period, ranging from 2.508% to 3.435% (dry matter). Most hybrids exceeded 5% essential oil content, including: 1Fr.1-3-2-21V, 1Fr.1-3-2-30V, 13Fr.8-5-23-8V, 14Fr.8-5-15-18V, 4Fr.5S-8-54-5, 7Cr.13S-6-12-27, and 7Cr.13S-6-12-28.

Throughout the 2019–2023 observation period, the essential oil content of the studied hybrids ranged from 3.445% (5Cr.13S-6-7-2) to 6.344% (7Cr.13S-6-12-28V). Most hybrids exhibited a consistent increase in essential oil concentration over time, while in others the values remained stable. In contrast, the maternal forms consistently recorded lower values: Fr.1 (2.978–3.421%), Fr.8 (3.115–3.845%), Fr.5 (2.600–3.912%), and Cr.13 (2.508–3.378% dry matter), as detailed in Table 1.

Table 1. The essential oil content of promising hybrids of *L. angustifolia* Mill. (2019-2023)

F1 Hybrids	2019	2020	2021	2022	2023
Fr.1.♀	3.421	2.978	3.212	3.320	3.386
1 Fr.1-3-2-21V	3.911	4.226	5.079	5.177	5.232
1Fr.1-3-2-30V	5.042	5.101	5.309	-	5.321
Fr.8.♀	3.845	3.435	3.378	3.115	3.268
13Fr.8-5-23-8V	4.207	4.688	5.186	3.817	5.518
13Fr.8-5-23-11V	3.907	4.422	4.808	5.536	5.322
13Fr.8-5-23-14V	3.849	4.675	4.7	3.806	4.975
14Fr.8-5-15-18V	5.321	5.453	5.536	-	5.352
Fr.5.♀	3.912	2.600	3.520	3.105	3.365
4Fr.5S-8-54-5	4.821	5.212	5.719	-	5.097
4Fr.5S-8-54-10	3.956	3.988	4.586	4.993	5.272
Cr.13.♀	3.378	2.508	3.224	3.126	3.240
7Cr.13S-6-12-27	5.091	5.226	6.032	-	5.998
7Cr.13S-6-12-28	6.255	6.344	5.851	-	5.879
5Cr.13S-6-7-2	3.445	4.214	4.465	4.769	4.856
5Cr.13S-6-7-11	4.458	4.526	4.632	4.978	4.983

The detailed evaluation of the hybrids researched during the period 2019–2023 demonstrates that they possess a high content of essential oil, as shown in Figure 1. The maternal forms Fr.1, Fr.8, Fr.5, and Cr.13 were characterized by lower essential oil content during the research years.

Summarizing the results obtained while evaluating the most promising lavender hybrids, it was found that the essential oil content in the 7th year of vegetation increased

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considerably. Most of the studied genotypes accumulated a content higher than 5% (dry matter). The highest content was recorded in hybrids originating from the maternal form Cr.13: 7Cr.13S-6-12-27 (5.998%) and 7Cr.13S-6-12-28 (5.879%), compared with 3.240% accumulated by the maternal form.

They were followed by the hybrids originating from Fr.8: 13Fr.8-5-23-8V (5.518%), 14Fr.8-5-15-18V (5.352%), and 13Fr.8-5-23-11V (5.322%); from Fr.1: 1Fr.1-3-2-30V (5.321%) and 1Fr.1-3-2-21V (5.232%); and from Fr.5: 4Fr.5S-8-54-10 (5.272%) and 4Fr.5S-8-54-5 (5.097%) (dry matter).

The results obtained for this trait over five years of evaluation are illustrated in Figure 1.

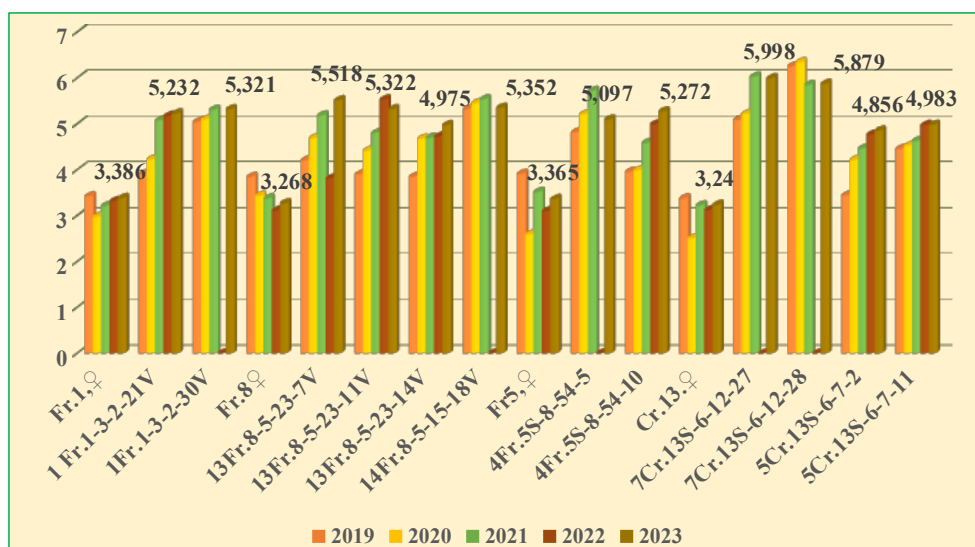


Figure 1. Hybrids of *L. angustifolia* Mill. evaluated by oil content.

The data presented above are characteristic of promising hybrids of *L. angustifolia* Mill., which represent valuable breeding material for the creation of new clone varieties with increased essential oil content in the raw material. The increased essential oil content is due to the heterosis effect, expressed in the first-generation F₁ lavender hybrids.

The results obtained over several years have demonstrated that the created F₁ lavender hybrids are valuable and exhibit heterosis in a number of quantitative traits, which directly influence productivity.

Higher values for essential oil content were observed, particularly in hybrid genotypes originating from Cr.13, which show a high accumulation of essential oil in the inflorescences. The hybrids evaluated in 2022 surpass the maternal form in terms of essential oil content. The lowest essential oil content in the raw material was recorded in the genotypes originating from the maternal form Fr.8, with values of 3.806% (13Fr.8-5-23-14V) and

3.817% (13Fr.8-5-23-8V, dry matter). The indices obtained in the 6th year of vegetation in lavender hybrids are shown in Figure 2.

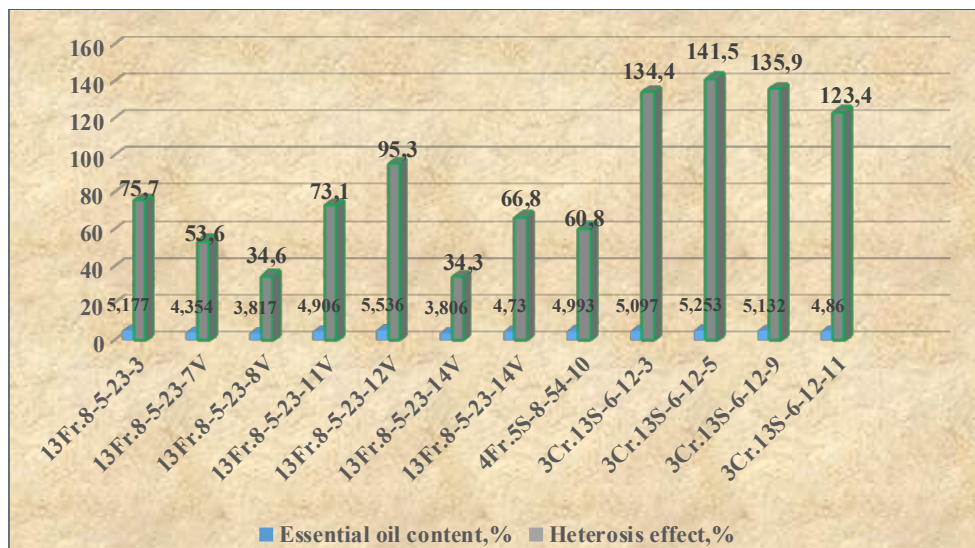


Figure 2. The extent of heterosis for the essential oil content, % (year 2022).

The heterosis effect on this trait had positive values ranging from +34.3% in the hybrid 13Fr.8-5-23-12V, which comes from the maternal form Fr.8, to +141.5% in the genotype 3Cr.13S-6-12-5, a descendant of the Cr.13 form.

The highest heterosis effect (over 100%) was recorded by four hybrids that are offspring of the maternal form Cr.13, highlighted in Figure 2:

- 3Cr.13S-6-12-11 – 4.860% (dry matter) essential oil, heterosis effect +123.4%.
- 3Cr.13S-6-12-9 – 4.923% (dry matter) essential oil, heterosis effect +135.9%.
- 3Cr.13S-6-12-3 – 5.097% (dry matter) essential oil, heterosis effect +134.4%.
- 3Cr.13S-6-12-5 – 5.536% (dry matter) essential oil, heterosis effect +141.5%.

We can conclude that the results obtained during the study years 2019–2023 have demonstrated that most lavender hybrids originating from different maternal forms are well developed and exhibit positive heterosis in the quantitative characteristics of the inflorescence. The evaluated characteristics: *the length of the floral spike, the number of whorls per floral spike, and the essential oil content in the raw material*, are shown in Table 2.

The length of the floral spike in the selected hybrids varied from 7.8 to 10.6 cm, and the highest positive index of heterosis for this character was +65.6% in the 7Cr.13S-6-12-27 hybrid, followed by the 1Fr.1-3-2-30V genotype with +65.0%, and 7Cr.13S-6-12-28 with

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+61.0%. The mentioned hybrids are also characterized by the best developed floral spikes – longer than 10 cm.

The number of whorls per floral spike in lavender is an index that characterizes the essential oil content. For this characteristic, the evaluated hybrids had values ranging from 6.2 to 8.1 whorls per floral spike. All the evaluated hybrids showed heterosis with positive indices, the highest index was recorded in the genotypes 7Cr.13S-6-12-27 of +44.6% and 7Cr.13S-6-12-28 of +39.3%.

Table 2. The extent of heterosis for inflorescence characteristics and essential oil content in lavender hybrids, 2023.

Maternal form, F1 hybrid	Flower spike length, cm	The heterosis effect, %	Number of whorls in flower spike	The heterosis effect, %	Essential oil content, % (dry matter)	The heterosis effect, %
Fr.1.♀	6.3±1.2	-	5.2±0.3	-	3.386	-
1 Fr.1-3-2-21V	8.9±1.8	+ 41.3	6.2±0.4	+ 19.3	5.232	+ 54.5
1Fr.1-3-2-30V	10.4±1.6	+ 65.0	7.1±0.3	+ 36.5	5.321	+ 57.2
Fr.8♀	6.4±1.3	-	5.4±1.4	-	3.268	-
13Fr.8-5-23-7V	8.4±1.4	+31.3	6.8±0.7	+ 25.9	5.518	+ 68.8
13Fr.8-5-23-11V	8.2±1.3	+ 28.2	6.2±0.4	+ 14.8	5.322	+ 62.8
13Fr.8-5-23-14V	8.4±1.4	+ 31.3	6.7±0.5	+ 24.1	4.975	+ 52.3
14Fr.8-5-15-18V	7.8±0.7	+ 21.8	6.0±0.6	+11.1	5.352	+ 60.7
Fr.5.♀	5.9±1.2	-	5.1±0.3	-	3.365	-
4Fr.5S-8-54-5	7.9±1.3	+ 33.9	6.7±0.5	+ 31.3	5.097	+ 51.5
4Fr.5S-8-54-10	8.1±1.4	+ 37.3	6.9±0.3	+ 35.3	5.272	+ 56.7
Cr.13.♀	6.4±1.4	-	5.6±0.5	-	3.24	-
7Cr.13S-6-12-27	10.6±1.6	+ 65.6	8.1±0.6	+ 44.6	5.998	+ 85.2
7Cr.13S-6-12-28	10.3±1.7	+ 61.0	7.8±0.5	+ 39.3	5.879	+ 81.4
5Cr.13S-6-7-2	7.8±1.3	+ 21.8	6.4±0.4	+14.3	4.856	+ 49.8
5Cr.13S-6-7-11	8.2±1.1	+ 28.2	6.5±0.7	+ 16.1	4.983	+ 53.8

According to the essential oil content, the evaluated hybrids exceed the maternal form, reaching values of 4.856% in the hybrid 5Cr.13S-6-7-2 to 5.998% in the genotype 7Cr.13S-6-12-27. The heterosis effect on this trait has values ranging between +52.3% and +85.2%, presented in Table 2.

The highest heterosis effect was achieved by the hybrids:

- 7Cr.13S-6-12-27 – 5.998% (dry matter) essential oil, heterosis effect +85.2%.
- 7Cr.13S-6-12-28 – 5.878% (dry matter) essential oil, heterosis effect +81.4%.
- 13Fr.8-5-23-7V – 5.518% (dry matter) essential oil, heterosis effect +68.8%.

Research on the initial lavender breeding material continued in 2024. As a result of the investigations, a new generation of hybrids of the *L. angustifolia* Mill. species was created, characterized by vigorous plants, a large number of well-developed floral stalks, long inflorescences, and an increased content of essential oil in the raw material up to 5.556% in dry matter and 1.822% at standard humidity (60%).

The hybrids included in the research show positive heterosis relative to the maternal form in a number of important biomorphological traits evaluated over several years.

The distinctiveness of the created lavender hybrids, the value of the quantitative characteristics, and the expression of heterosis denote their importance in the creation of high-performance clone varieties of hybrid origin.

4. CONCLUSIONS

Generalizing the results obtained, we conclude that the promising lavender hybrids are resistant to frost, wintering and drought, are vigorous, with long floral spikes and a large number of whorls. These characteristics are of particular importance in the accumulation of essential oil. The essential oil content was determined in 60 hybrids, in the 7th year of vegetation, originating from four maternal forms: Fr.1, Fr.5, Fr.8, and Cr.13, including 40 hybrids (Fr.8) with a content of 2.543-5.834%; 8 hybrids (Fr.1) with 4.438-5.987%; 4 hybrids (Fr.5) with 5.097-6.133% (dry matter); and 8 hybrids (Cr.13) with 2.008-5.512% (dry matter).

The evaluated hybrids show heterosis relative to the maternal form for a number of important quantitative characteristics evaluated over several years. The highest heterosis effect, over 100%, was recorded by four hybrids originating from the maternal form Cr.13 in 2022 (123.4-141.5%).

According to the essential oil content, the hybrids evaluated in the 7th year of vegetation exceed the maternal form, reaching values of 4.856-5.998% (dry matter). The heterosis effect on this trait reaches values ranging from +52.3% to +85.2%.

The hybrids evaluated in 2024 are characterized by vigorous plants, forming a large number of well-developed floral stalks, with an increased content of essential oil in the raw material, reaching up to 5.556% in dry matter.

The evaluated hybrids represent breeding material with valuable quantitative traits for the development of high-performance cultivars of *L. angustifolia* Mill., of hybrid origin.

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