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The use of various types of hybridization in developing high-performing hybrids of *Salvia sclarea* L. with high essential oil content

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Abstract. For the development of different types of hybrids of *Salvia sclarea* L., hybridization was used. As a result of hybridization, hybrid seeds were obtained in 26 types of hybridization: 12 – simple, 3 – triple, 1 – double, 4 – stepped, and 6 – complex. It was demonstrated that very valuable F_1 hybrids were created due to the high content of essential oil, which in the first year of vegetation constituted 0.732–1.906% and 0.836–2.286% in the second year. Nine high-performing hybrids were highlighted, including: 3 – simple, 1 – double, 1 – stepped, and 4 – complex, with a very high content of essential oil (1.499–2.286%).

Keywords: essential oil, hybrid, inbred line, parental forms, quantitative characters, *Salvia sclarea* L.

Utilizarea hibridărilor de diferite tipuri în elaborarea hibrizilor performanți de *Salvia sclarea* L. cu conținut înalt de ulei esențial

Rezumat. Pentru elaborarea hibrizilor de diferite tipuri de *Salvia sclarea* L., a fost utilizată hibridarea. În rezultatul hibridărilor au fost obţinute seminţe hibride în 26 tipuri de hibridări: 12 simple, 3 triple, 1 dublă, 4 în trepte, 6 complexe. S-a demonstrat că au fost creaţi hibrizi F_1 foarte valoroşi prin conţinut ridicat de ulei esenţial, care în primul an de vegetaţie a constituit 0,732–1,906% şi 0,836–2,286% în anul al doilea. Au fost evidenţiaţi 9 hibrizi performanţi, inclusiv: 3 simpli, 1 dublu, 1 în trepte, 4 complecşi, cu conţinut foarte înalt de ulei esenţial (1,499–2,286%).

Cuvinte-cheie: ulei esențial, hibrid, linie consangvinizată, forme parentale, caractere cantitative, *Salvia sclarea* L.

1. Introduction

Salvia sclarea L. (clary sage) is a valuable aromatic and medicinal species, known for the essential oil it contains in its inflorescences. The essential oil extracted by steam distillation from fresh inflorescences is used in aromatherapy and has shown promising effects in the treatment of hypertension [5, p. 218], osteoarthritis and rheumatoid arthritis

[9]. This oil has been extensively studied for its antioxidant, antibacterial and anti-inflammatory properties, being used in the treatment of diabetes [8]. It is also widely used in the perfumery, cosmetics [2], pharmaceutical [7], and food industries, particularly in the manufacture of muscat wines [5, p. 218].

Due to the diverse applications of clary sage essential oil, this species has gained considerable popularity in recent years. At the Institute of Genetics, Physiology and Plant Protection of the Moldova State University (MSU), a series of research activities has been conducted in order to create new genotypes, which would synthesize and accumulate the highest possible content of high-quality essential oil.

To create new hybrid genotypes, various hybridization techniques are used, including crosses between varieties, between varieties and lines, between lines, between lines and hybrids. Through hybridization, hybrids with a genetic potential supported by characters transmitted by each parental form can be obtained. Through subsequent selections of the descendants, genotypes exhibiting the desired traits and properties can be obtained. This initial breeding material includes genotypes of different genetic and geographical origin, with high-performing quantitative traits, blooming in the first year of vegetation and producing high quantities of essential oil in the raw material [1], [3], [5, p. 218]. The purpose of this research was to create the initial breeding material for *Salvia sclarea* L. and to develop new hybrids with high essential oil content.

2. Materials and Methods

The biological material used consists of 26 simple, double, triple, stepped and complex F_1 hybrids of *Salvia sclarea* L. As parental forms for the creation of F_1 hybrids, the following were used: 18 inbred lines with appropriate quantitative and qualitative characters and 4 simple, 4 triple, 3 stepped and 3 complex hybrids.

During the growing season, phenological observations, biometric measurements and visual assessments were performed in accordance with the methodological indications [6]. Prior to hybridization, inflorescences were prepared and the flowers emasculated. Pollination was performed one or two days later using freshly harvested pollen [13].

The essential oil content was determined through steam distillation, from freshly harvested inflorescence samples (100 g inflorescences), processed for 60 minutes using a Ginsberg apparatus [11]. The data obtained were recalculated to dry matter to avoid errors caused by the difference in moisture of the samples analyzed by each genotype.

Statistical analysis of the experimental data was performed according to the established methods [12].

3. Results and Discussions

In the hybridization schemes, inbred lines from higher generations, unaffected by inbreeding degeneration, of different origin, with high general and specific combining ability determined in previous years, were included as parental forms [4]. Prior to hybridization, the initial forms were evaluated for quantitative traits that directly influence productivity, as well as for the correlations between these traits [10].

Inbred lines S_4–S_{12} with high essential oil content, from different origins, were evaluated. These lines had previously been used in hybridization in generations S_3–S_9, resulting in valuable hybrids. Out of 18 selected lines, 12 originated from the early-season variety Ambra Plus (AP), 3 from the late-season variety Natali Clary (NC), both created at the Institute of Genetics, Physiology and Plant Protection. Two additional lines were selected from the variety Moldavschi 69 (M-69), developed in the Republic of Moldova, and one from line V-24, derived from the variety Voznesenskii 24, created in the Krasnodar region. As a result of the evaluation, lines with different vegetation periods were selected for hybridization:

- **Late-season:** AP 112-11 S_4, M-69 489 S_{14}, NC 27-11 S_4
- **Early-season:** AP 2-11 S_4, AP 33-11 S_4, AP 73-11 S_4, AP 114-11 S_4, NC 77-11 S_4, V-24-86 844 S_{12}, M-69 489 S_{12}
- **Middle-season:** AP 26-11 S_4, AP 32-11 S_4, AP 70-11 S_4, AP 77-11 S_4, AP 89-11 S_4, AP 113-11 S_4, AP 115-11 S_4, NC 60-11 S_4

The differences in growth and development phases were evident, from the formation of the leaf rosette to the technical ripening of the seeds. The early-season parental forms (97–106 days) reached full flowering 18–20 days earlier than the late-season forms (115–117 days).

The selected initial breeding material is also characterized by high productivity. This is attributed to quantitative traits that directly influence productivity, such as plant height, inflorescence length, number of inflorescence branches, and essential oil content. The lines included in the hybridizations formed plants with heights ranging from 90.2 cm (NC 77-11 S_4) to 121.3 cm (AP 33-11 S_4), as shown in Figure 1, no. 15, 4.

The inflorescence length of the evaluated parental forms ranged from 49 to 60 cm. The lines with the most vigorous panicles were AP 70-11 S_4 and AP 89-11 S_4, with lengths of 60.1 and 60.6 cm, respectively (Figure 1, no. 5, 8). The number of first-order inflorescence branches varied from 13.8 in the inbred line AP 26-11 S_4 to 17.2 in AP 70-11 S_4. The number of second-order branches ranged from 17.9 in AP 73-11 S_4 to 32.8 in V-24-86 844 S_{12} (Figure 2, no. 6, 17, 2, 5).

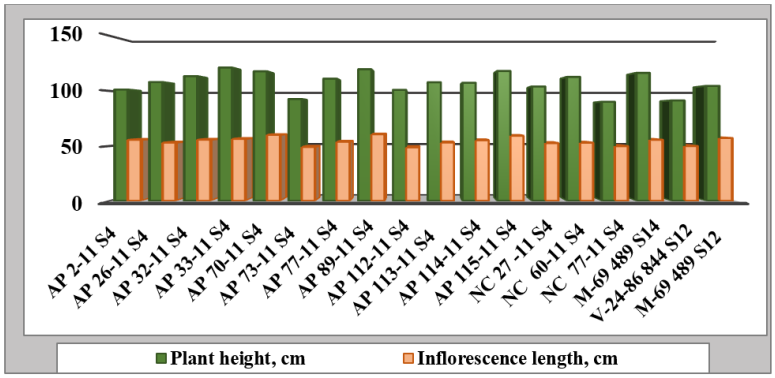

Figure 1. Quantitative characteristics of the plant in the parental forms (inbred lines) of *Salvia sclarea* L.

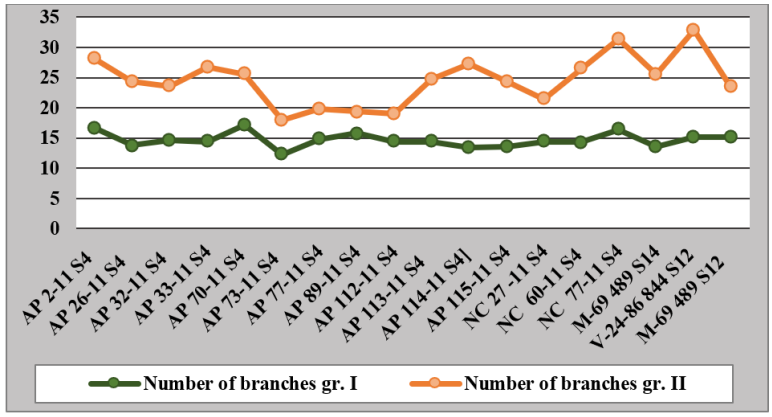

Figure 2. Quantitative characteristics of the inflorescence in the parental forms (inbred lines) of *Salvia sclarea* L.

The essential oil content in the first year of vegetation ranged between 0.770% (AP 114-11 S_4) and 2.159% (AP 2-11 S_4), and in the second year between 0.829% (AP 73-11 S_4) and 1.871% (AP 2-11 S_4) (Figure 3, no. 11, 1, 6, 1). The lines AP 2-11 S_4 (2.159–1.871%) and AP 77-11 S_4 (2.112–1.041%) showed the highest values.

As parental forms, simple, triple and complex hybrids were included in the hybridization process. Hybrids, like inbred lines, differ in the duration of the growing season. Early-season hybrids [(S-1122 528 S_3 × (Rubin × S-786)F_1 × (0-33S_3 × L-15)F_7)F_7 × M-69 655 S_9]F_5 reach the full flowering stage 17 days earlier than the late-season hybrids. The genotypes (M-69 487-82 S_3 × Rubin 115 b 77)F_{11} and (0-32S_3 × 0-41S_5)F_{11} are included in Table 1.

Table 1. Vegetation period and quantitative plant traits in hybrids (parental forms) of *Salvia sclarea* L.

Hybrids	Plant height, cm	Inflorescence length, cm	Inflorescence length report/plant height, %	Vegetation period, days
Simple hybrids				
[(0-32 S_3 x 0-41 S_5)F_{11}	102.0±3.7	50.8±4.2	49.8	115
(0-57 S_5 x 0-20 S_5)F_{11}	97.9±5.8	48.0±5.9	49.0	104
(Cr.p. 1 S_1 x M-69)F_{14}	114.8±4.4	56.9±5.7	49.6	108
(M-69 487-82 S_3 x Rubin 115 b 77)F_{11}	98.6±3.4	54.1±4.2	54.8	117
Triple hybrids				
[NC34-11S_2x (S-1122528S_3x S.s.Tien-Shan/sud)F_6]F_2	115.0±6.4	60.4±6.8	52.5	104
[[M-69 655 S_9 x (M-69 429-82 S_3 x 0-40 S_5)F_7]F_6	108.4±4.0	59.6±5.4	55.0	101
[(S-1122 60 S_{10} x (M-69 10S_4 x L-15)F_9)]F_5	120.3±7.4	63.5±7.8	52.8	97
(0-42 x Rubin)F_1 x S-786)F_9	102.4±2.1	55.8±6.5	54.5	105
Steps hybrids				
[(S-3 x H_2S_3)F_2 x 0-32 S_3)F_8 x NC 11 - 11 S_2]F_2	122.7±9.9	55.2±7.8	45.1	108
[[M-69 655 S_9 x (K-36 x 0-41)F_2 x 0-19)B_5]F_5	90.0±5.3	48.6±6.9	54.0	109
[(S-1122528S_3x(Rubin x S-786)F_1 x (0-33 S_3 x L-15)F_7)]F_{12}	117.7±7.9	62.8±4.6	53.3	104
Complex hybrids				
[[(V-24-86 809 S_3 x 0-33 S_6)F_7 x (M-55+ 130) S_4 x (K-44 x L-15)F_2x 0-47)F_1]F_7]F_5	109.0±6.0	56.9±6.7	52.2	105
[[(M-69 655 S_9 x (S-1122 528 S_3 x (Rubin x S-786)F_1 x (0-33 S_3 x L-15)F_7)]F_6	111.0±5.5	54.2±6.4	49.0	103
[(S-1122 528 S_3 x (Rubin x S-786)F_1 x (0-33S_3 x L-15)F_7)F_7 X M-69 655 S_9]F_5	99.3±4.7	54.6±3,7	55.0	99

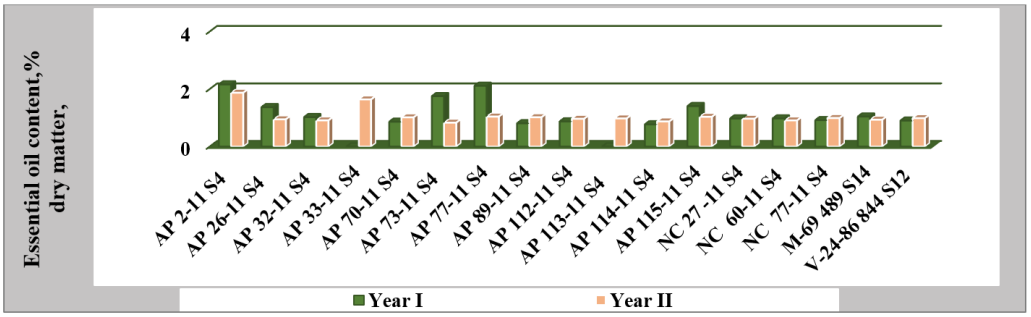

Figure 3. Essential oil content of parental forms (inbred lines) of *Salvia sclarea* L. in the first and second year of vegetation.

The parental forms studied for the characteristic "plant height" developed floral stalks ranging in height from 90.0 cm to 122.7 cm. The inflorescences were large and compact, most of them having a large number of branches. The longest inflorescences were recorded in the trilinear hybrids [M-69 655 S_9 × (M-69 429-82 S_3 × 0-40 S_5)F_7]F_6 and [NC 34-11 S_2 × (S-1122 528 S_3 × S.s.Tien-Shan/sud)F_6]F_2, as well as the stepped hybrid [(S-1122 528 S_3 × (Rubin × S-786)F_1 × (0-33 S_3 × L-15)F_7)]F_{12} – 59.6, 60.4 and 62.8 cm, respectively. The triple hybrid combination achieved great results for this character [(S-1122 60 S_{10} × (M-69 10 S_4 × L-15)F_9)]F_5, with 63.5 cm, included in Table 1.

The proportion of inflorescence length/plant height in some simple hybrids (M-69 487-82 S_3 × Rubin 115 b 77)F_{11}, as well as in triple [M-69 655 S_9 × (M-69 429-82 S_3 × 0-40 S_5)F_7]F_6, and complex hybrids [(S-1122 528 S_3 × (Rubin × S-786)F_1 × (0-33 S_3 × L-15)F_7)F_7 × M-69 655 S_9]F_5 was on average 55.0%, as shown in Table 1.

The selected hybrids are characterized by compact inflorescences, due to the large number of branches: 12.8–16.4 of the first order, and 20.6–35.1 of the second order, respectively. The highest number of branches was found in: the step hybrid [(S-3 × H_2S_3)F_2 × 0-32 S_3)F_8 × NC 11-11 S_2]F_2, the triple hybrid (0-42 × Rubin)F_1 × S-786)F_9, as well as the complex hybrid [[(M-69 655 S_9 × (S-1122 528 S_3 × (Rubin × S-786)F_1 × (0-33 S_3 × L-15)F_7)]F_6], their sum being 45.2, 47.6 and 51.5, respectively, as shown in Figure 4, no. 8, 7, 13.

These compact inflorescences consistently result in high essential oil content. In the first year of vegetation, the essential oil content, recalculated to dry matter, ranged from 0.845% to 2.431%. In the second year, it ranged from 0.827% to 1.657%. The best results at this index were achieved by the simple hybrids (0-57 S_5 × 0-20 S_5)F_{11} (1.631–1.394%), (Cr.p. 1 S_1 × M-69)F_{14} (1.379–1.043%) and (M-69 487-82 S_3 × Rubin 115 b 77)F_{11} (2.431–1.004%), as well as the stepped hybrid combination [(S-1122 528 S_3 × (Rubin ×

S-786)F_1 × (0-33 S_3 × L-15)F_7)]F_{12} (1.352–1.657%), which are shown in Figure 5, no. 2, 3, 4, 11.

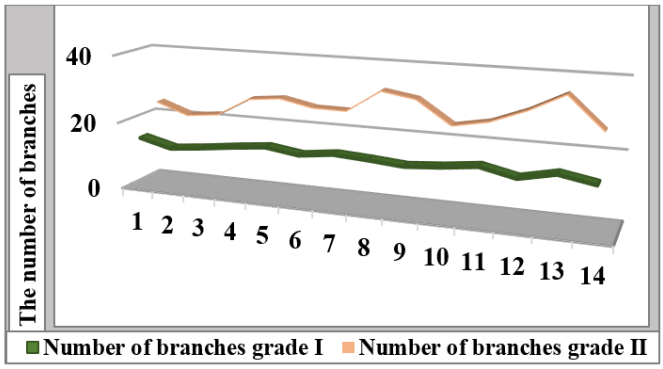

Figure 4. Number of first and second degree branches of the inflorescence in hybrids (parental forms) of *S. sclarea*.

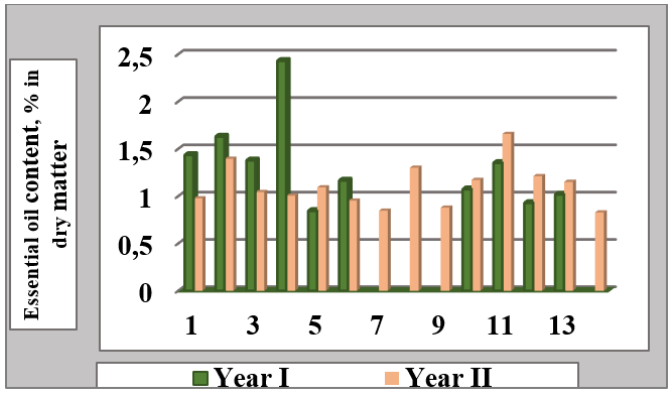

Figure 5. The essential oil content of hybrids, % in dry matter (parental forms) of *S. sclarea.*

From the above, we can conclude that simple, trilinear, stepped and complex hybrids, as well as the inbred lines described above, can be successfully used as parental forms, as sources of valuable genes in various hybridization schemes.

The method of intraspecific hybridization was used for the creation of new hybrid genotypes of *Salvia sclarea* L. Fertile maternal forms, which did not require flower emasculation, were used in all types of hybridizations. A total of 2256 flowers were emasculated, of which 1671 were suitable for pollination, and thus were pollinated. They produced 2938 hybrid seeds, the seed setting rate being 43.8%, as presented in Table 2.

Table 2. Results of hibridizations of *Salvia sclarea* L., in 2020

Parental forms	The number of flowers		Bound seeds	
	Demas culinized	Polle nated	Num ber	%
Simple hybrid combinations				
[AP 26-11 S_4]♀x [AP 115-11 S_4♂]	94	66	87	32.9
[AP 113-11 S_4]♀x [M-69 489 S_{14}♂]	95	74	107	36.1
[NC 77-11 S_4]♀x [AP 89-11 S_4♂]	68	45	148	82.2
[V-24-86 844 S_{12}]♀x [NC 77-11 S_4♂]	67	53	87	41.0
[AP 2-11 S_4]♀x [NC 60-11 S_4♂]	92	66	149	56.4
[NC 60-11 S_4]♀x [AP 115-11 S_4♂]	89	61	184	75.4
[AP 115-11 S_4]♀x [AP 112-11 S_4♂]	87	69	37	13.4
[AP 32-11 S_4]♀x [AP 33-11 S_4♂]	99	74	151	51.0
[AP 32-11 S_4]♀x [AP 26-11 S_4♂]	101	79	183	57.9
[AP 112-11 S_4]♀x [NC 27-11 S_4]	77	51	101	49.5
[AP 73-11 S_4]♀x [AP 77-11 S_4♂]	101	76	162	53.3
[AP 114-11 S_4]♀x [NC 77-11 S_4♂]	88	69	185	67.0
Triple hybrid combinations				
[(0-57 S_5 x 0-20 S_5)F_{11}]♀x [AP 115-11 S_4♂]	83	58	35	15.1
[M-69 489 S_{14}]♀x [(Cr.p. 1 S_1 x M-69)F_{14}♂]	83	61	50	20.5
[AP 26-11 S_4♀x [(M-69 487-82 S_3 x Rubin 115 b 77)F_{11}♂]	108	77	106	34.4
Duble hybrid combinations				
[(0-32S_3 x 0-41S_5)F_{11}]♀x(M-69 487-82S_3 x Rubin 115 b 77)F_{11}♂]	87	68	41	15.1
Stepped hybrid combinations				
[M-69 489 S_{12}]♀x [(S-1122 60 S_{10} x(M-69 10S_4 x L-15)F_9)]F_5♂]	83	71	82	28.9
[AP 70-11 S_4]♀x [(S-1122 528 S_3 x (Rubin x S-786)F_1 x (0-33 S_3 x L-15)F_7)]F_{12}♂]	83	67	72	26.8
[(0-32 S_3 x 0-41 S_5)F_{11}]♀x (0-42 x Rubin)F_1 x S-786)F_9♂]	91	68	216	79.4
[(0-57 S_5 x 0-20 S_5)F_{11}]♀x (0-42 x Rubin)F_1 x S-786)F_9♂]	88	59	80	33.9
Complex hybrid combinations				
[(S-1122 528 S_3x(Rubin x S-786)F_1x(0-33S_3 xL-15)F_7)F_7 X M-69 655 S_9]F_5♀x M-69 489 S_{12}♂]	98	79	87	27.5
[[(V-24-86 809 S_3x 0-33 S_6)F_7 x (M-55+130)S_4 x (K-44xL-15)F_2x 0-47)F_1]F_7]F_5]♀x [M-69 655 S_9 x(K-36 x0-41)F_2 x 0-19)B_5]F_5♂]	84	62	56	22.6
[[(M-69 655 S_9 x (S-1122 528 S_3 x (Rubin x S-786)F_1 x(0-33 S_3 x L-15)F_7)]F_6]♀x [M-69 655 S_9 x (K-36 x 0-41)F_2 x 0-19)B_5]F_5♂]	79	51	156	76.4
[[(S-1122 528 S_3 x (Rubin xS-786)F_1 x (0-33 S_3 x L-15)F_7)F_7 X M-69 655 S_9]F_6]♀x [M-69 655 S_9 x(K-36 x 0-41)F_2 x 0-19)B_5]F_5♂]	66	39	94	60.2
[[M-69 655 S_9 x (M-69 429-82 S_3 x 0-40 S_5)F_7]F_6]♀x [NC 34 - 11S_2 x(S-1122 528 S_3 x S.s.Tien-Shan/sud)F_6]F_2♂]	84	61	112	45.9
[[M-69 655 S_9 x (M-69 429-82 S_3 x 0-40 S_5)F_7]F_6]♀x [(S-3 x H_2S_3)F_2 x 0-32 S_3)F_8 x NC 11 -11 S_2]F_2♂]	81	67	170	36.4
Total	**2256**	**1671**	**2938**	**43.8**

The highest seed setting rate was recorded in the hybrid combinations: [AP 115-11 S_4 × AP 112-11 S_4] – 75.4%; [[(M-69 655 S_9 × (S-1122 528 S_3 × (Rubin × S-786)F_1

× (0-33 S_3 × L-15)F_7))]F_6] × [M-69 655 S_9 × (K-36 × 0-41)F_2 × 0-19)B_5]F_5] – 76.4%; [(0-32 S_3 × 0-41 S_5)F_{11} × (0-42 × Rubin)F_1 × S-786)F_9] – 79.4%; [NC 77-11 S_4 × AP 89-11 S_4] – 82.2%. Therefore, as shown above, hybrid seeds were obtained through 26 types of hybridizations: 12 simple, 3 triple, 1 double, 4 stepped, and 6 complex, as detailed in Table 2.

From the crosses carried out, simple, triple, double, stepped and complex F_1 hybrids were obtained, which exhibited abundant flowering in the first and second years of vegetation, respectively. These hybrids stood out for their height (116–119 cm) and long inflorescences (50–62 cm), as shown in Table 3.

The number of first- and second-degree branches of the inflorescence was quite large, with their total reaching 41 units. In most cases, they consisted of 11–16 first-degree branches and 18–26 second-degree branches. The following hybrids stood out for this trait: the complex hybrid [(0-32 S_3 x 0-41 S_5)F_{11} x (0-42 x Rubin)F_1 x S-786)F_9]F_1, where the sum of the first- and second-degree ramifications constitutes 35–42, the triple hybrid [(0-57 S_5 x 0-20 S_5)F_{11} x AP 115-11 S_4]F_1, as well as 2 simple hybrids [AP 113-11 S_4 x M-69 489 S_{14}]F_1 and [AP 32-11 S_4 x AP 33-11 S_4]F_1, where the total number of branches is 40.0, 39.8 and 39.2, respectively, as presented in Table 3.

As mentioned, clary sage is a species used in medicine, perfumery, cosmetics, pharmaceuticals, etc., due to the essential oil extracted from the raw material. The developed F_1 hybrids synthesize and accumulate a greater amount of essential oil than the parental forms used in hybridization. Thus, in the 1st and 2nd year of vegetation (2021–2022), the essential oil content of F_1 hybrids, in the first year of vegetation, ranged between 0.732 and 1.906% (dry matter) and from 0.836 to 2.286% (dry matter) in the second year, as shown in Figure 6. As a result of the research, it was demonstrated that the following hybrids, distinguished by their very high essential oil content, recalculated to dry matter, stood out during the first and second years of vegetation: [AP 32-11 S_4 x AP 33-11 S_4]F_1 (1.580–1.499%), [(0-32 S_3 x 0-41 S_5)F_{11} x (M-69 487-82 S_3 x Rubin 115 b 77)F_{11}]F_1 (1.424–1.544%), [(S-1122 528 S_3 x (Rubin x S-786)F_1 x (0-33 S_3 x L-15)F_7)F_7 x M-69 655 S_9]F_5 x M-69 489 S_{12}]F_1 (1.906–1.550%), [(V-24-86 809 S_3 x 0-33 S_6)F_7 x (M-55+130)S_4 x (K-44 x L-15)F_2 x 0-47)F_1]F_7]F_5 x [M-69 655 S_9 x (K-36 x 0-41)F_2 x 0-19)B_5]F_5]F_1 (1.508–1.624%), [AP 26-11 S_4 x AP 115-11 S_4]F_1 (1.409–1.701%), [M-69 655 S_9 x (M-69 429-82 S_3 x 0-40 S_5)F_7]F_6 x [(S-3 x H_2S_3)F_2 x 0-32 S_3)F_8 x NC 11-11 S_2]F_2]F_1 (1.552–1.913%), M-69 655 S_9 x (M-69 429-82 S_3 x 0-40 S_5)F_7]F_6 x [NC 34-11 S_2 x (S-1122 528 S_3 x S.s.Tien-Shan/sud)F_6]F_2]F_1 (1.348–1.975%), [M-69 489 S_{12} x [(S-1122 60 S_{10} x (M-69 10 S_4 x L-15)F_9)]F_5]F_1 (1.650–2.202%), [AP 2-11 S_4 x NC 60-11 S_4]F_1 (1.120–2.286%), shown in Figure 6, no. 7, 16, 21, 22, 1, 26, 25, 17, 5).

Table 3. Evaluation of some quantitative characters in F_1 hybrids of *Salvia sclarea* L., 2022.

Hybrids	Plant height, cm	Inflores cence length, cm	Number of branches Grade I	Number of branches Grade II
Simple hybrids				
[AP 26-11 S_4 x AP 115-11 S_4]F_1	104.8±3.1	57.6±5.3	13.6±1.6	16.4±4.7
[AP 113-11 S_4 x M-69 489 S_{14}]F_1	106.6±7.8	60.3±5.4	15.0±3.0	24.8±8.0
[NC 77-11 S_4 x AP 89-11 S_4]F_1	106.8±6.1	58.5±5.5	15.0±2.1	23.4±9.8
[V-24-86 844 S_{12} x NC 77-11 S_4]F_1	101.6±4.2	58.6±5.0	13.8±1.9	18.8±5.5
[AP 2-11 S_4 x NC 60-11 S_4]F_1	93.7±4.4	50.1±3.9	13.6±1.5	18.2±3.1
[NC 60-11 S_4 x AP 115-11 S_4]F_1	96.0±5.9	49.6±2.2	13.2±1.0	17.6±3.2
[AP 115-11 S_4 x AP 112-11 S_4]F_1	104.2±5.6	54.0±3.7	13.4±1.3	18.8±3.2
[AP 32-11 S_4 x AP 33-11 S_4]F_1	113.4±4.0	60.1±4.6	13.4±1.8	25.8±8.1
[AP 32-11 S_4 x AP 26-11 S_4]F_1	108.6±5.0	55.7±4.9	12.4±1.2	18.0±6.1
[AP 112-11 S_4 x NC 27 -11 S_4]F_1	102.4±8.2	51.4±7.8	12.8±1.7	21.6±5.8
[AP 73-11 S_4 x AP 77-11 S_4]F_1	113.9±6.8	57.6±2.2	14.6±1.8	23.7±4.9
[AP 114-11 S_4 x NC 77-11 S_4]F_1	105.6±3.7	56.4±7.4	13.2±2.2	16.8±2.6
Triple hybrids				
(0-57 S_5 x 0-20 S_5)F_{11} x AP 115-11 S_4]F_1	93.9±3.4	55.3±4.9	14.4±2.4	25.6±7.8
[M-69 489 S_{14} x [(Cr.p. 1 S_1 x M-69)F_{14}]F_1	116.2±7.0	57.4±7.2	12.8±1.1	15.2±4.1
[AP 26-11 S_4 x (M-69 487-82 S_3 x Rubin 115 b 77)F_{11}]F_1	118.8±4.1	61.8±7.4	14.0±1.4	21.2±3.8
Double hybrids				
[(0-32 S_3 x 0-41 S_5)F_{11} x (M-69 487-82 S_3 x Rubin 115 b 77)F_{11}]F_1	106.3±9.6	60.4±6,9	15.2±2.8	23.0±5.3
Steps hybrids				
[M-69 489 S_{12} x [(S-1122 60 S_{10} x(M-69 10S_4 x L-15)F_9)]F_5]F_1	110.8±7.4	57.8±5.7	16.4±1.2	18.8±3.2
[AP 70-11 S_4 x [(S-1122 528 S_3 x (Rubin x S-786)F_1 x (0-33 S_3 x L-15)F_7)]F_{12}]F_1	97.0±4.7	54.0±2.6	12.4±0.8	18.8±5.2
[(0-32 S_3 x 0-41 S_5)F_{11} x (0-42 x Rubin) F_1 x S-786)F_9]F_1	114.2±8.1	57.1±7.3	14.6±3.1	26.4±9.2
[(0-57 S_5 x 0-20 S_5)F_{11} x (0-42 x Rubin) F_1 x S-786)F_9]F_1	93.4±3.5	51.1±3.8	12.6±0.9	16.4±3.9
Complex hybrids				
[(S-1122 528 S_3 x (Rubin x S-786)F_1 x (0-33S_3 x L-15)F_7)F_7 x M-69 655 S_9]F_5 x M-69 489 S_{12}]F_1	107.2±5.5	59.1±6.8	13.4±1.8	18.4±9.7
[(V-24-86 809 S_3 x 0-33 S6)F_7 x (M-55+130) S_4 x (K-44 x L-15)F_2 x 0-47)F_1]F_7]F_5 x [M-69 655 S_9 x (K-36 x 0-41)F_2 x 0-19)B_5]F_5]F_1	104.8±3.1	56.2±3.4	11.6±0.8	14.4±2.6
[(M-69 655 S_9 x (S-1122 528 S_3 x (Rubin x S-786)F_1 x (0-33 S_3 x L-15)F_7)]F_6 x [M-69 655 S_9 x (K-36 x0-41)F_2 x 0-19)B_5]F_5]F_1	105.6±6.7	50.6±2.7	12.4±0.8	16.4±5.3
[(S-1122 528 S_3 x (Rubin xS-786)F_1 x (0-33 S_3 x L-15)F_7)F_7 x M-69 655 S_9]F_6 x [M-69 655 S_9 x (K-36 x0-41)F_2 x 0-19)B_5]F_5]F_1	91,8±6.2	49.4±4.9	11.4±2.3	13.8±4.2
[M-69 655 S_9 x (M-69 429-82 S_3 x 0-40 S_5) F_7]F_6 x [NC 34 -11S_2 x (S-1122 528 S_3 x S.s.Tien-Shan/sud)F_6]F_2]F_1	92.2±5.8	50.4±2.7	13.6±2.1	22.8±9.7
[M-69 655 S_9 x (M-69 429-82 S_3 x 0-40 S_5)F_7]F_6] x [(S-3 x H_2S_3)F_2 x 0-32 S_3)F_8 x NC 11-11 S_2]F_2]F_1	96.4±2.4	51.4±1.8	12.4±0.8	25.6±5.7

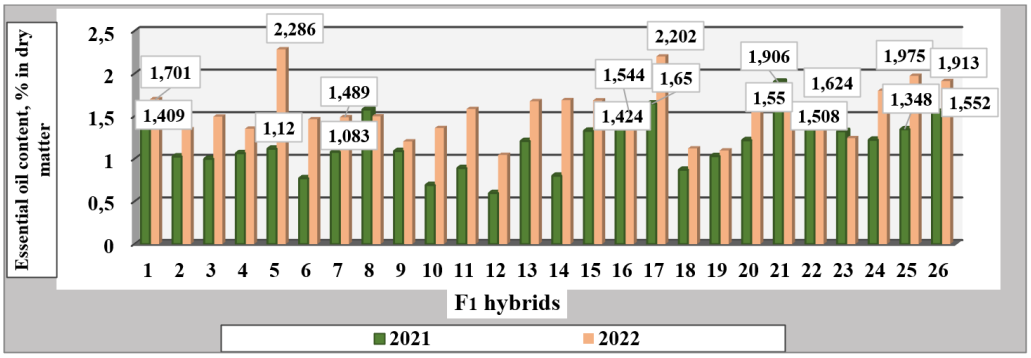

Figure 6. Essential oil content in F_1 hybrids of *S. sclarea* in the 1st and 2nd year of vegetation.

The evaluation of these hybrids (in the second generation (F_2)) continued in 2023–2024, the 1st and 2nd year of vegetation. The plant height increased in the F_2 generation in all studied genotypes. In F_1 it ranged from 91.8 to 116.2 cm, but in F_2 it was 103.2–136.2 cm. The inflorescence length ranged from 52 to 70 cm, and the inflorescence length/plant height ratio is also higher than in the first generation. Thus, an essential oil content greater than 1.0% was accumulated by 78.2% of the evaluated hybrids and 30.4% of these hybrids synthesized and accumulated 1.4–1.7% (dry matter).

4. Conclusions

Through simple, triple, double, stepped and complex crosses, hybrids have been created that bloom from the first and second year of vegetation, produce inflorescences and yield essential oil in the first year of vegetation as well, thus increasing the profitability of the plantation.

The developed hybrids possess valuable quantitative traits, many of them forming long, compact inflorescences with a large number of branches, whorls and flowers, which also results in high inflorescence productivity. It was demonstrated that very valuable hybrids were obtained with a high essential oil content – 1.001-2.286%, but also 5 hybrids in which the essential oil content in inflorescences was less than 1% (0.599-0.893%).

As a result of the research, 9 valuable F_1 hybrids with very high essential oil content were highlighted: simple hybrids [AP 32-11 S_4 x AP 33-11 S_4]F_1, [AP 26-11 S_4 x AP 115-11 S_4]F_1, [AP 2-11 S_4 x NC 60-11 S_4]F_1, in which this index was 1.499, 1.701 and 2.286%, respectively; the double hybrid [(0-32 S_3 x 0-41 S_5)F_{11} x (M-69 487-82 S_3 x Rubin 115 b 77)F_{11}]F_1, which produced 1.544% essential oil; the complex hybrids [(S-1122 528 S_3 x (Rubin x S-786)F_1 x (0-33S_3 x L-15)F_7)F_7 x M-69 655 S_9]F_5 x M-69

489 S_{12}]F_1, [(V-24-86 809 S_3 x 0-33 S_6)F_7 x (M-55+130) S_4 x (K-44 x L-15)F_2 x 0-47)F_1]F_7]F_5 x [M-69 655 S_9 x (K-36 x 0-41)F_2 x 0-19)B_5]F_5]F_1, [M-69 655 S_9 x (M-69 429-82 S_3 x 0-40 S_5)F_7]F_6] x [(S-3 x H_2S_3)F_2 x 0-32 S_3)F_8 x NC 11-11 S_2]F_2]F_1, and [M-69 655 S_9 x (M-69 429-82 S_3 x 0-40 S_5)F_7]F_6 x [NC 34-11S_2 x (S-1122 528 S_3 x S.s.Tien-Shan/sud)F_6]F_2]F_1, as well as the stepped hybrid [M-69 489 S_{12} x [(S-1122 60 S_{10} x (M-69 10S_4 x L-15)F_9)]F_5]F_1, which accumulated 1.550, 1.624, 1.913, 1.975 and 2.202% essential oil, respectively. The created hybrids represent a valuable breeding material for creating varieties of *Salvia sclarea* L., with increased essential oil content.

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