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REDUCING THE IMPACT OF DROUGHT ON PRODUCTIVITY BY CULTIVATING RESISTANT VARIETIES OF MEDICINAL AND AROMATIC PLANTS

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Rezumat

Schimbările climatice din ultimele decenii impun cultivarea soiurilor de plante adaptate condițiilor de secetă, temperaturilor critice ridicate şi care asigură productivitate şi calitate înaltă. Consecințele secetei pot fi diminuate substanțial prin cultivarea soiurilor rezistente la secetă de plante medicinale şi aromatice, cum ar fi *Salvia sclarea, Lavandula angustifolia, Salvia officinalis, Silybum marianum* etc. Soiurile Ambra Plus, Balsam, Parfum Perfect etc. de *S.sclarea* în anii secetoşi acumulează un conţinut înalt de ulei esențial, asigură o producție de 15,1-22,4 t/ha de inflorescențe în doi ani de exploatare a plantației și garantează obţinerea a 41.1-77.4 kg/ha de ulei esențial în funcție de soi, eficienţa, randamentul, fiind de la 2,8 până la 3,6 kg de ulei esenţial din tona de materie prima. La soiurile de lavandă Moldoveanca 4, Vis Magic 10, Alba 7 etc. în anii secetoşi conţinutul de ulei esențial este mai ridicat (5.103-6.164%) decât în anii obişnuiţi (4,318-5,915%), producţia de inflorescenţe, fiind înaltă (7-12 t/ha), precum şi cea de ulei esențial - 132-245 kg/ha, eficiența constituind 16-21.5 kg/t, în funcţie de soi. Soiul de *S.officinalis* Miracol asigură o producție de 850-990 kg/ha de frunze uscate în anii secetoşi şi 960-1070 kg/ha în anii obişnuiţi. Producția de ulei esențial, fiind de 18,7-18,9 kg /ha în

condiţii de secetă şi 17,2-17,6 kg /ha în anii obişnuiţi.

Cuvinte cheie: plante medicinale şi aromatice, ulei esential, productivitate, secetă, soi rezistent.

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Introduction

The importance of medicinal and aromatic plants is indisputable in view of the revival of phytopharmacy and herbal treatments, the development of perfumery, cosmetics, etc. [1,2,7,8, 10, 12,13,14]. Thus, the share of drug products from medicinal and aromatic plants and their derivatives has been constantly growing. More than 50% of drugs prescribed are chemicals derivatives identified for the first time in medicinal plants. An estimated 50-70 thousand plant species is used in medicines throughout the world [11]. On the other hand they provide important source of income year in rural areas. All of these have influenced constantly the studies on the chemical composition, qualities and benefits of the using flowers, leaves, essential oil and other derivatives of medicinal an aromatic plant. A particular area researches includes the studies carried out to develop new hybrids and varieties that are resistant to abiotic factors that would ensure an enhanced production of raw materials with a higher content of essential oil and a quality that corresponds to the purpose proposed for utilization. Such studies have evidently intensified during the last decades as a consequence of the climatic changes, slow but steady processes of global warming, transformation of some zones into a desert including in south-eastern Europe where farm crops are affected by drought and scorching heat more and more frequently. Simultaneously, our researches show that the cultivars of medicinal and aromatic plants (*Lavandula angustifolia, Salvia sclarea, Salvia officinalis* etc.) provide an enhanced production of raw material and high quality essential oil in dry years. Some of these cultivars such as lavender accumulate a content that is even higher in dry years than in the years with common atmospheric depositions.

Material and methods

The biological material comprises *S. sclarea, S. officinalis, Silybum marianum* and *L.angustifolia* cultivars of hybrid origin [3,4,5]. Thus, the *Salvia sclarea* varieties are hybrids with fixed, constant heterosis [6] of different complexity: simple (Dacia-50, Dacia-99, V. Junior, Victor), three linear (Nataly-Clary, Parfum Perfect), backcross (Ambra Plus) and stepwise (Balsam, Ambriela) hybrids. The *Lavandula angustifolia* varieties Moldoveanca 4, Vis magic 10, Alba 7 and Aroma Unica as well as new varieties in the testing process (Fr.8-5-15V; VM-18V; Fr.5S8-24) are first-generation hybrids with a high heterosis effect on a number of quantitative traits including essential oil content [6]. The varieties of *Salvia officinalis* (Miracol) and *Silybum marianum* (Argintiu) are also of hybrid origin [4]. The validation of the quantitative traits and productivity of all varieties was carried under legal methods. The essential oil content was assessed in fresh inflorescences at the stage of industrial maturity through hydrodistillation in the Ginsberg apparatus and recalculated for dry matter. The varieties' efficiency was

expressed in kg of essential oil in tonne of raw material (inflorescences).

Results and discussions

The previous researches have shown that intraspecific hybridization is an efficient method to develop valuable genotypes through pronounced variability of the indices of bio morphological character values including the content and components of essential oil in *L.angustifolia, S. sclarea* and *S. officinalis* [3,4,5,6]. Importantly, hybrids, our varieties are strongly resistant to drought [5,6]. In contrast to other *S. sclarea* varieties, the ones we have developed begin flowering in the first year of vegetation providing both production of 3-6 t/ha of inflorescences and 9-30 kg/ha of essential oil. The cultivar Ambra Plus is distinguished by abundant flowering and, the yields of inflorescences make up to 4.4 -11.7 t/ha and 17.1 - 40.9 kg/ha of essential oils in the first year depending on the cultivation conditions and weather conditions of the year (tab.1,2,3; fig.1,2).

Under acute drought conditions in 2012, in the second year of vegetation, all *S.sclarea* varieties recorded high yields of raw material from 9.6 to 11.7 t / ha with very high content of essential oil (1.179-1.494%). The production of essential oil was also very higher (37.0-46.5kg/ha) ensuring exceptional efficiency – 3.46-4.47 Kg of essential oil of each ton of inflorescences (tab.1).

Table 1. Productivity of raw material and essential oil for varieties of *Salvia sclarea* in first and second year of vegetation, 2011-2012*.

Variety	Raw material yield, t/ha			Essential oil content, % (dry matter)		Essential oil production kg/ha			Efficiency, kg/t	
	I year	II year	Σ	I year	II year	I year	II year	Σ	I year	II year
Early varieties										
Dacia-50, st.	3.3	11.2	14,5	0.926	1.143	9.0	38.6	47.6	2.73	3.46
Ambra Plus	9.0	11.0	20,0	0.825	1.179	22.3	39.1	61.4	2.48	3.55
Balsam	6.3	10.4	16,7	1.009	1.494	18.9	46.5	65.4	3.00	4.47
Middle ripening varieties										
Dacia-99	3.9	10.4	14,3	1.003	1.411	11.7	44.1	55.8	3.00	4.24
Late varieties										
Victor	4.8	11.7	16,5	0.833	1.253	12.1	43.9	55.9	2.75	3.75
Nataly Clary, st.	4.0	9.6	13.6	0.880	1.291	10.5	37.0	47.5	2.63	3.85

DL $_{005}$ ***1,7 2,5*** ****dry year*** ***P, % 4, 3 5,8***

In the dry 2015 year in first year of vegetation all the cultivars produced between 3 and 8 t/ha of raw material in dependence on the cultivar. The content of essential oil was higher in the cultivar Balsam (1.286 %). The production of essential oil varied between 5.7 kg/ha in the cultivar Nataly Clary and 11.6 and 12.5 kg/ha in the cultivars Ambra Plus and Balsam, respectively (fig. 1) [4]. Also, in the second year of vegetation, all the varieties produced high quantities of raw material (12.1- 18.7 t/ha) and essential oil (32.5-58.8 kg/ha) (fig. 1, tab.2.). In the two years of exploitation (2014-2015), the yields of raw material made 15.1 t/ha – 22.4 t/ha, the essential oil production varies between 41.1 n 77.4 kg/ ha depending on the variety. The efficiency under drought conditions were very high and varied from 2.41 to Dacia 99 to 3.6 kg / ha in Parfun

Perfect and Balsam varieties (tab. 2).

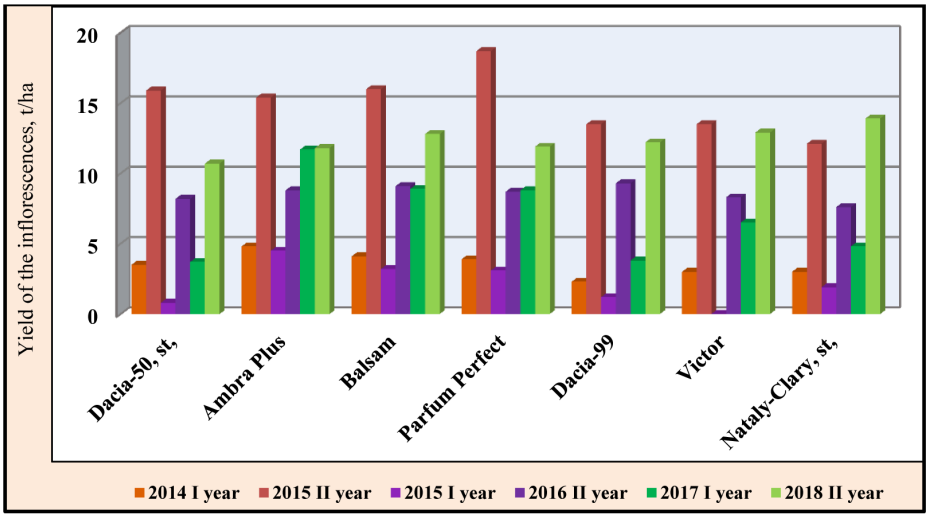

Fig. 1. The yield of inflorescences on *Salvia sclarea* varieties to 3 test cycles, t/ha (2014-2015; 2015-2016; 2017-2018).

The inflorescence yields, the content and production of essential oil are supported by a number of quantitative traits. The indices of their values were remarkable in the dry 2015 year: the plants formed a great number of floral stems per m^2 and the plant's height of 117.7-125.1cm, long inflorescences (56.7-64.3 cm) with a large number of ramifications, high content of essential oil, which shows excellent development under drought conditions.

Table 2. Productivity of raw material and essential oil for varieties of Salvia sclarea, first &second years, 2014&2015*.

Varieties	Raw material yield, t/ha			Essential oil content, %		Essential oil production, kg/ha			Efficiency, kg/t	
	I year	II year	Σ	I year	II year	I year	II year	Σ	I year	II year
Early varieties										
Dacia-50 st.	3.5	15.9	19.4	1.220	0.972	11.7	45.3	58.0	3.34	2.85
Ambra Plus	4.8	15.4	20.2	1.188	1.192	17.1	55.1	72.2	3.56	3.60
Balsam	4.1	16.0	20.1	1.581	1.205	19.6	57.8	77.4	4.78	3.61
Parfum Perfect	3.7	18.7	22.4	1.271	1.049	14.3	58.8	73.1	3.86	3.14
Middle ripening varieties										
Dacia-99	2.3	13.5	15.8	1.225	0.803	8.6	32.5	41.1	3.74	2.41
Late varieties										
Victor	3.0	13.5	17.7	1.204	0.918	10.7	37.2	47.9	3.57	2.76
Nataly Clary st.	3.0	12.1	15.1	1.008	1.154	9.2	41.9	51.1	3.1	3.46

DL005 1.3 3.6 **** 2015, dry year*** ***P, % 5.1 4.1***

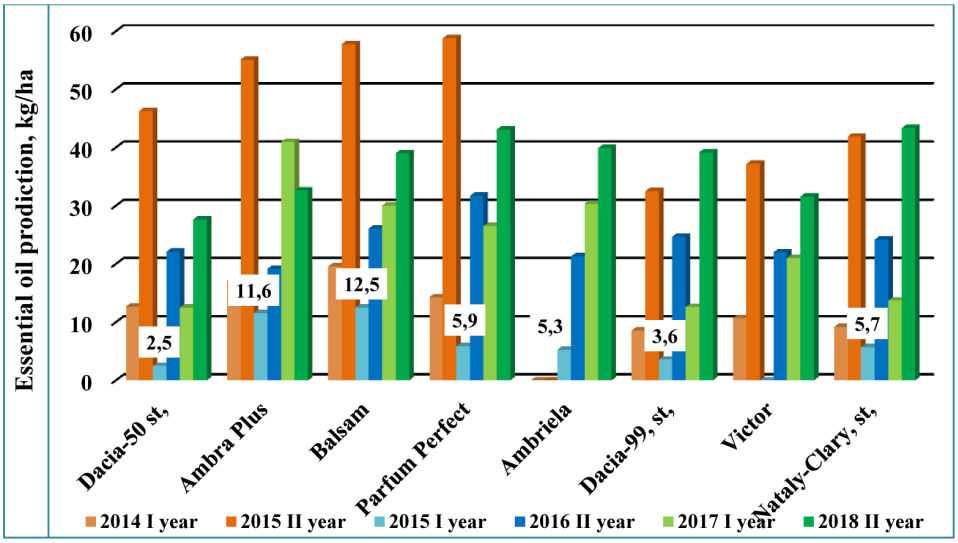

Fig.2. The production of essential oil on *Salvia sclarea* varieties to 3 test cycles, kg/ha (2014-2015; 2015-2016; 2017-2018).

The high productivity of these varieties is sustained, influenced by the values of the quantitative characters of plants. In drought conditions (2018), the tested varieties formed a large number of floral stems (44.4-69.1/m^2), long inflorescences (52.7-70.0 cm) with large number of branches, which shows excellent plant development. All of this has resulted in high content (0.858-1.202%) of essential oil (tab. 3) and high productivity (tab. 4). In the second year of vegetation varieties formed high yields (10.7-13.9 t/ha) of the inflorescences with high content of essential oil (0.859-1.202%). The production of essential oil in the second year of vegetation consisted of 27.6 to the standard variety up to 43.1 kg/ha at variety Ambriela (tab.4).

Table 3. The values of some productivity indices in *Salvia sclarea* varieties in competitive crops, 2018.

Variety	Floral stems/m^2	Plant height, -cm-	Inflorescence length, -cm-	Inflorescence branches, number		Essential oil content, %
				First degree	Second degree	
		X ± Sx	X ±Sx	X ± Sx	X ± Sx	
Early varieties						
Dacia-50 st.	46.5	138.6±7.4	66.9±7,9	16.0±2.1	25.4±6.2	0.858
Ambra Plus	54.7	137.1±8.0	67.9±6,7	15.8±1.7	25.9±8.0	0.916
Balsam	46.4	138.2±7.2	66.4±6.4	15.4±1.8	21.7±4.8	1.015
Parfum Perfect	60.0	143.2±8.8	69.2±6.7	15.0±1.9	23.0±6.4	1.086
Ambriela	54.6	141.0±7.8	70.0±7.9	16.1±2.7	22.6±5.7	1.202
Middle ripening varieties						
Dacia-99	55.7	135.7±9.9	63.4±8.3	15.5±2.3	24.3±8.2	1.070
Late varieties						
Victor	69.1	138.8±9.5	64.4±7.9	15.6±2.1	25.0±6.8	0.815
Nataly Clary, st.	58.6	120.9±6.0	52.7±5.3	14.4±1.9	20.1±4.4	1.036

In two years of plantation operation, the yield of raw material was from 14.4 t/ha to standard variety Dacia 50 to 23.2 t/ha for Ambra Plus variety. Essential oil production ranged from 51.8 kg/ha attested for Dacia 99 to 73.6 kg/ha for Ambra Plus variety. The efficiency of all varieties is very high: 3.3-3.6 kg/t in the first year of vegetation and 2.7-3.6 kg/t in the second year that was dry (fig. 2, tab.3).

Table 4 Productivity of raw material and essential oil for varieties of *Salvia sclarea* in first and second year of vegetation, 2017-2018*.

Soiul	Producţia materie primă, t/ha			Essential oil content, % (s.u.)		Essential oil production, kg/ha			Efficiency, kg/t	
	I year	II year	Σ	I year	II year	I year	II year	Σ	I year	II year
Early varieties										
Dacia-50, st.	3.7	10.7	14.4	1.120	0.858	12.5	27.6	40.1	3.38	2.59
Ambra Plus	11.7	11.8	23.5	1.163	0.916	40.9	32.6	73.5	3.49	2.76
Balsam	8.9	12.8	21.7	1.131	1.015	30.1	39.4	70.0	3.38	3.08
Ambriela	8.3	11.9	20.2	1.215	1.202	30.3	43.1	73.4	3.65	3.62
Parfum Perfect	7.8	12.2	20.0	1.132	1.086	26.5	39.9	66.4	3.40	3.27
Middle ripening varieties										
Dacia-99	3.8	12.2	16.0	1.097	1.070	12.6	39.2	51.8	3.31	3.21
Late varieties										
Victor	6.5	12.9	19.4	1.081	0.815	21.0	31.6	52.6	2.70	3.23
Nataly Clary, st.	3.8	13.9	17.7	1.187	1.036	13.7	43.3	57.0	3.60	3.11

DL, 005 1.3, 2.8 ****2018 dry year*** ***P, % 5.2, 5.3***

The hybrids, varieties of lavender accumulate enhanced content of essential oil in drought conditions than in the years that are not affected by drought (Table 3). In the 2015, this important trait ranged from 4.575-6.164% in the cultivar Vis Magic 10 to 6.164% in the cultivar FR.5S8-24.

It is well known that severe drought has a negative effect on perennial species both in the year of major humidity deficiency and in the years that follow. The consequences of the 2015 drought were different in the case of the lavender cultivars. The F_1 hybrids recorded higher content of essential oil in the 2015 than in the 2014, 2016 and 2017 exceeding the maternal form of origin [3]. Similar results were recorded in the years of severe drought 2007 and 2012.

The average producing capacity of the lavender varieties in drought conditions with different vegetation period ranges between 6.9 t/ha of raw material (inflorescences) in the cultivar VM-18V and 8.9-10.8 t/ha in the cultivars Aroma Unica and Moldoveanca 10 (tab. 6). The production of essential oil makes 121.1-182.6 kg/ha depending on the cultivar.

In the years with common atmospheric deposition, the productivity of lavender varieties is 7.4-12.4 t/ha and 132.8-250 kg/ha essential oil, depended of variety [3,4]. These cultivars are also distinguished by high efficiency – one ton of raw material ensures obtaining from 16.8 to 21.5 kg of essential oil with content of linalyl acetate making 28 to 39%.

Table 5. The content of essential oil in the varieties (hybrids) of *Lavandula angustifolia.*

Varieties (hybrids F_1)	Essential oil content, % (s.u.)				
	2014	2015, dry year	2016	2017	2018, dry year
early varieties					
Moldoveanca 4 st.	4.893	5.404	4.318	4.981	4.611
Fr.8-5-15V	4.545	5.803	4.691	5.454	5.624
middle varieties					
Vis Magic 10 st.	4.423	4.575	4.597	4.518	4.741
VM-18V	4.710	5.103	4.924	4.829	4.872
late varieties					
Alba 7st.	5.298	5.762	5.915	5.256	5.624
Fr.5S8-24	5.087	6.164	5.786	5.915	5.656
Aroma Unica	4.901	5.496	4.899	4.961	5.476

This index is 44% in the new cultivars Aroma Unica etc. It should be mentioned that all developed cultivars, and hybrids have a low concentration (0.21-0.27%) of camphor in the essential oil [3,4,5], this component being important as it diminishes the quality and perfumery value of essential oil in high concentrations (more than 2%).

Table 6. Productivity of *Lavandula angustifolia* varieties in drought conditions, 2018.

Variety	Row material yield, t/ha	Essential oil content, %	Essential oil production, kg/ha	Efficiency, kg /t
Early varieties				
Moldoveanca 4, st.	10.8	4.611	181.7	16.8
Fr.8-5-15V	8.5	5.656	161.9	19.0
Middle varieties				
Vis Magic 10, st.	8.3	4.741	143.3	17.3
VM-18V	6.9	4.872	121.1	17.6
Cr.13S-6-7	7.9	4.012	136.4	17.3
Late varieties				
Alba 7, st.	7.6	5.624	134.7	17.7
FR.8-5-15V	8.5	5.624	182.6	21.5
Aroma Unica	8.9	5.476	166.8	19.9

The early ripening variety of *S. officinalis* named Miracol as well as varieties of *L.angustifolia* and *S. sclarea* is resistant to drought, frost and wintering. The variety can be used to produce pharmaceutical raw material of *Folium Salviae*, *Herba Salviae* and essential oil – *Oleum Salviae* [4].

The producing capacity of the variety Miracol is 850-989 kg/ha of dry leaves (13% of humidity) in drought conditions (2012, 2015, 2018) and 960- 1070 in the years with common atmospheric deposition (tab. 7).

Table 7. Yield of *Salvia officinalis* L. variety Miracol.

Years	Yield of raw material, kg/ha		Essential oil content, % (dry matter)	Production of essential oil, kg/ha
	Humidity 60%	Humidity 13%		
2012*	2990	850	2.500	18.7
2013	2930	960	2.240	17.4
2014	3055	1029	2.198	17.6
2015*	2989	920	2.605	18.9
2016	3010	980	2.230	17.5
2017	3090	1070	2.306	17.2
2018*	3025	989	2.608	18.9

**** dry year***

The production of essential oil obtained from steam distillation of fresh raw material constitutes 18.7-18.9 kg/ha in dry years and 17.2-17.6 kg/ha in common years.

Thus, climate changes in recent decades imposed cultivation, and the use of medicinal and aromatic plants varieties that support drought, high critical temperatures, ensure high productivity.

Conclusion

1. The consequences of drought can be substantially diminished by cultivating drought resistant varieties of aromatic and medicinal species.
2. The drought favors the varieties such as *Salvia sclarea, Lavandula angustifolia* and *Salvia officinalis* through the synthesis of essential oil, guaranteeing high productivity and quality.
3. The *Salvia sclarea* varieties Ambra Plus, Balsam, Parfum Perfect, Ambriela, Dacia 99; Victor; Nataly Clary are resistant to drought and accumulate in dry years high content (0.858-1.202 %) of essential oils, provide a production of 15.1-22.4 t/ha of inflorescences and guarantee yields of 41.1-77.4 kg/ha of essential oil depending on the variety. The efficiency of *Salvia sclarea* varieties ranges between 2.7 and 3.6 kg/t of essential oil per tonne of raw material.
4. The essential oil content of *Lavandula angustifolia* cultivars in drought conditions is higher (4.575-6.164%) than in those with common atmospheric depositions (4,318-5,915).
5. The productivity of the lavender cultivars Moldoveanca 4, Vis Magic 10, Alba 7, Aroma Unica etc. in drought conditions ensures yields of 6.9-10.8 t/ha of inflorescences and 121.1-182.6 kg/ha of essential oil depending on the variety. The varieties efficiency varies from 16.8 to 21.5 kg of essential oil per ton of inflorescences.
6. Variety Miracol of *Salvia officinalis* drought-resistant ensures a production of 850-989 kg/ha of dried leaves in the drought conditions and 960-1070 kg / ha of ordinary habitat. The production of essential oil of the variety in the dry years is higher (18.7-18.9 kg / ha) than in the years with normal atmospheric depositions (17.2-17.6 kg/ha).

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