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Artemisia jacutica Drob. essential oil as a source of chamazulene: primary introduction and component analysis

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Abstract:
Artemisia jacutica Drob. is a valuable source of chamazulene, which has anti-inflammatory and antioxidant properties. We experimentally introduced this plant in the climatic conditions of Buryatia and compared the compositions of the essential oils produced from both cultivated and wild plants.
The reserves of *A. jacutica* and the laboratory/field germination of seeds were assessed by standard methods. Macro- and microscopic features were determined in line with general pharmacopoeia monographs. The composition of the essential oil obtained by hydrodistillation was analyzed by gas chromatography–mass spectrometry. The resulting data were processed by the principal component method. The antiradical activity was measured by the DPPH test.
The reserves of *A. jacutica* were determined in the Yeravninsky district of Buryatia. The laboratory germination of *A. jacutica* seeds was 75.00 ± 5.35%, while the field germination was only 11–23%. Planting with seedlings showed a good survival rate of 67–80%. In the first year of cultivation, *A. jacutica* plants had similar macro- and microscopic features to those of wild plants. The soils from the experimental plots were superior to the soils of *A. jacutica*'s natural habitat in terms of fertility. The essential oils from cultivated and wild plants contained 51 components. The content of chamazulene, the dominant component, was 59.22–66.60% in the cultivated plants and only 15.98–47.77% in the wild plants. The essential oil of *A. jacutica* exhibited high antiradical activity (IC_{50} = 49.47 μL/mL).
The primary introduction of *A. jacutica* showed good prospects for its cultivation in Buryatia. The macro- and microscopic features and dominant components found in the essential oil of *A. jacutica* grown on the experimental plots were similar to those found in the wild plants. Two chemotypes of *A. jacutica*, Yakutian and Buryatian, were identified according to the oil composition, with the chemotypes preserved in the cultivated plants. The oil's high antiradical activity and a high content of chamazulene make *A. jacutica* a valuable material for the cosmetic, pharmaceutical, and agricultural industries.

Keywords: *Artemisia jacutica* Drob., cultivation, laboratory and field germination, essential oil, chamazulene, antiradical activity, chemotype

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INTRODUCTION

Traditional healing systems (Chinese, Tibetan, Japanese, etc.) have been in the focus of international science in recent years. These systems are based on the use of natural bioactive substances, primarily of plant origin. Scientific advances in this area highlight the need for using secondary metabolites to create effective drugs [1–4]. Russia's Pharma-2030 Program aims to increase the market of domestic innovative pharmaceutical products, including those based

on natural compounds. In addition, the National Technological Initiative's Healthnet Roadmap intends to involve more regions in cultivating medicinal plants and creating a whole medicinal plant sector.

The Republic of Buryatia is part of the Baikal unique ecosystem with rare and endemic plant species. Among them are the medicinal plants of the *Artemisia* L. (*Asteraceae* family) genus used as ethnopharmacological poly-target agents. For example, the antimalarial drug Artemisinin, which is based on *Artemisia annua* L., exhibits antiparasitic, antitumorous, anti-inflammatory, antioxidant, antiangiogenic, and immunomodulatory effects. Another example is the anticancer drug Arglabin based on *Artemisia glabella* L. [5].

The aromatic and pharmacological properties of *Artemisia* plants are largely due to their essential oils based on mono- and sesquiterpenoids. Multiple components of plant essential oils determine their antioxidant and anti-inflammatory properties. For example, the essential oil of *Matricaria chamomilla* L. contains chamazulene with anti-inflammatory action. In addition, chamazulene or chamazulene-containing oils have an apoptotic effect on the A375 human malignant melanoma cells, as well as strong antioxidant properties and a photoprotective effect [6–8]. Other sources of chamazulene-containing essential oils are the plants that are systematically close to the pharmacopoeial species *Artemisia absinthium* L., including *Artemisia sieversiana* L., *Artemisia jacutica* Drob., *Artemisia macrocephala* L., and others. Among these species only *A. sieversiana* and *A. jacutica* grow within the territory of Buryatia, the latter having the highest content of chamazulene [9].

A. jacutica Drob. is an East Siberian endemic used in Yakut traditional medicine to treat gastrointestinal diseases. In addition, this species has selective antifungal activity and is used for helminthic invasions in cattle. Previously, the essential oil of *A. jacutica* was shown to exhibit a wound-healing effect on the napalm-caused burn. *A. jacutica* was first introduced in the Yakutsk Botanical Garden. From 1991 to 1998, scientists studied the agrotechnical methods of growing *A. jacutica* in the Siberian Botanical Garden [10]. Kucharova *et al.* were the first to obtain strains of *A. jacutica* callus cells with stable growth parameters *in vitro* [11].

We aimed to assess a possibility of introducing *A. jacutica* in the natural and climatic conditions of Buryatia and to compare the essential oil of cultivated plants with the oil of wild plants.

STUDY OBJECTS AND METHODS

We studied the aerial parts and seeds of *Artemisia jacutica* Drob. collected in the flowering and fruiting phases, respectively, in Yeravninsky district of Buryatia in 2018–2019. The voucher samples are kept in the herbarium of the Institute of General and Experimental Biology (*A. jacutica* – UUH019308).

The yield was determined on specific thickets by the quadrat method. Fifteen plots of 1 m^2 were evenly distributed over the thickets. The area of the thickets was calculated in m^2. The method's error did not exceed 15% [12].

To determine the germination of *A. jacutica* seeds in the laboratory conditions, we used four samples of 100 seeds. The seeds were spread evenly on moistened filter paper in Petri dishes and germinated at 29–30°C. The filter paper was checked for moisture on a daily basis and, if necessary, wetted with water at room temperature to prevent overwetting. The lids of the Petri dishes were opened for several minutes every day for ventilation. The samples were protected from direct sunlight during seed germination. The germinated seeds were counted during 12 days. The seeds with primary leaves were classified as germinated, whereas hard seeds that had not swelled or changed in appearance were classified as non-germinated.

The macro- and microscopic features of raw materials were determined by standard methods in line with the General Pharmacopoeia Monographs (General Pharmacopoeia Monograph.1.5.3.0003.15 and General Pharmacopoeia Monograph.1.5.1.0002.15).

The essential oil was obtained from *A. jacutica*'s aerial parts by hydrodistillation according to the GPhA (General Pharmacopoeia Monograph.1.5.3.0010.15) using a modified Clevenger nozzle. The oil's components were determined by gas chromatography–mass spectrometry (GC-MS) on an Agilent 6890 gas chromatograph (Agilent Technologies, USA) equipped withan HP 5973N mass selective detector (Hewlett-Packard, USA) and an HP-5MS capillary column (30 m×0.25 mm×0.2 μm; Hewlett-Packard) [13].

For visualization, the data on the oil's composition were processed by the principal component method (PCM analysis, Sirius version 6.0, Pattern Recognition Systems, a/s, Norway).

The antiradical activity of the essential oil was determined by the DPPH test (using 2,2-diphenyl-1-picrylhydrazyl). For this, a solution of DPPH (0.006% in 95% ethanol) was added to *A. jacutica* oil (3.9–31.25 μL/mL in ethanol) and incubated for 30 min in the dark at room temperature. The antiradical activity (% inhibition) was measured spectrophotometrically on a ClarioStar Plus multimodal plate reader at 517 nm and calculated as:

$$\% \text{ inhibition of DPPH-radicals} = (A_0 - A_1)/A_0 \times 100 \quad (1)$$

where A_0 is the absorbance in the control and A_1 is the absorbance of the samples [14, 15].

The IC_{50} index was determined by regression analysis.

RESULTS AND DISCUSSION

Determination of *Artemisia jacutica* Drob. reserves. The reserves of *A. jacutica* were determined in the vicinity of Shiringa village (Yeravninsky district, Buryatia) in 2019. The plant's recovery period is 2 years.

Table 1 Laboratory and field germination (survivability) of *Artemisia jacutica* Drob. seeds

Laboratory germination of seeds				
Sample No.	No. 1	No. 2	No. 3	No. 4
Number of germinated seeds in 12 days, pcs.	71	76	79	74
Field germination (survivability) of seeds				
Experimental plot No.	No. 1		No. 2	
Seed sowing, %	23		11	
Seedling planting, %	80		67	

A thicket of *A. jacutica* occupies a small area of only 500 m^2. According to standard estimations, the average mass of *A. jacutica* collected from one plot was 26.38 g, the dispersion of the result was 209.01 g, and the standard deviation was 3.77 g. Thus, the yield of *A. jacutica* was estimated as 26.38 ± 3.77 g/m^2, its biological reserve was 16.92 kg, the operational reserve was 9.46 kg, with a possible annual harvest of 3.15 kg.

Thus, we proposed to introduce *A. jacutica* into the culture taking into account its limited potential reserves in Buryatia and high medicinal value as a source of bioactive compounds.

Laboratory and field germination. At the first stage, we determined the germination of *A. jacutica* seeds in the laboratory. The seeds were obtained from wild intact plants collected in the fruiting phase in 2018–2019. The oblong, dark brown achenes were 1.0–1.2 mm long, 0.4–0.5 mm wide, and covered with a golden film. The seeds began to germinate in 2–4 days. The primary introduction of *A. jacutica* was carried out on two experimental plots: in Oreshkovo settlement, the Republican Ecological and Biological Center (plot No. 1) and in Sotnikovo settlement (plot No. 2), the Republic of Buryatia (Table 1).

As can be seen, the laboratory germination of *A. jacutica* seeds was 75.00 ± 5.35%, with a standard deviation of 8% [12]. Our results were consistent with the previous studies [16, 17], where this indicator amounted to 70–100% without primary dormancy. The authors classified *A. jacutica* seeds as slow germination seeds with a maximum number of germinated seeds at the beginning of germination.

Since we did not use fertilizers or artificial irrigation on the experimental plots, the differences between the cultivated and the natural plants were associated with soils. The plots had a chestnut soil type. Nothing was grown on them before the experiments and no chemicals (pesticides) were used. The plots were periodically plowed up to get rid of weeds. The main agrochemical indicators of soil fertility were analyzed by standard methods. The reaction of the soil solution was determined in an aqueous extract. The soil samples were analyzed for carbon and humus contents by the Tyurin spectrophotometric method (The Standard Operating Procedure for Soil Organic Carbon. The Tyurin spectrophotometric method), for total nitrogen by the Kjeldahl method (General Pharmacopoeia Monograph.1.2.3.0011.15), for mobile phosphorus and potassium by the Chirikov method (State Standard 26204-91), and for exchangeable calcium and magnesium by the complexometric method (trilon method) (State Standard 26487-85). The results are presented in Table 2.

The acidity of the soils from Buryatia's Yeravninsky district (natural habitat of *A. jacutica*) and from the experimental plots was close to neutral. However, the pH of the water extract of the experimental soil was in the alkaline region of 7.3–7.6, compared to 6.5 for the soil from the natural habitat. However, the soils from the experimental plots were superior to the soils from the natural habitat in the main indicators of fertility.

As we know, soil formation is largely determined by organic matter. The activity of plants, animals, and microorganisms leads to the accumulation of organic carbon in the form of humus. The processes of humus formation and accumulation are significantly affected by climatic conditions. Humic substances contribute to an optimal soil structure for plants and are an important reserve of ash elements. Thus, they determine a number of soil's physical and chemical characteristics. Soil organic matter contains nitrogen. The accumulation of nitrogen, along with carbon, is part of soil formation determined by the cycle of matter. Organic nitrogen is taken as total nitrogen in the soil since mineral nitrogen is found in insignificant amounts. Our analysis showed that plot No. 1 had the most fertile soil rich in easily digestible nutrients. Plot No. 2 was only superior in the content of mobile phosphorus P_2O_5.

A. jacutica was planted with seeds and seedlings (Table 1). The seeds were sowed in early June in strips of 100 seeds. Shoots appeared in mid-June. The seedlings

Table 2 Agrochemical indicators of soils from the experimental plots and places of *Artemisia jacutica* Drob. natural growth

Sample	Plot No. 1	Plot No. 2	Shiringa village, Yeravninsky district
pH of water extract	7.3	7.6	6.5
Total carbon, %	1.58 ± 0.05	1.36 ± 0.05	0.58 ± 0.03
Total humus, %	2.72 ± 0.09	2.35 ± 0.08	0.99 ± 0.04
Total nitrogen, %	0.140 ± 0.006	0.120 ± 0.003	0.040 ± 0.001
Mobile phosphorus P_2O_5, mg/kg	58.03 ± 2.88	76.10 ± 2.37	9.73 ± 0.52
Mobile potassium K_2O, mg/kg	525.7 ± 24.9	244.3 ± 12.7	120.8 ± 5.2
Exchange cation Ca^{2+}, mgEq/100 g	22.67 ± 1.03	15.60 ± 0.66	5.89 ± 0.28
Exchange cation Mg^{2+}, mgEq/100 g	3.97 ± 0.14	3.90 ± 0.25	1.60 ± 0.11

(208 plants) were planted in rows (10 plants per 1 m^2) with a 50 cm distance between them.

The laboratory germination of *A. jacutica* seeds reached 75.00 ± 5.35%, while the field germination on both plots was very low, ranging from 11 to 23%. Further planting with seedlings showed a good survival rate: 80% on plot No. 1 and 67% on plot No. 2. The highest germination of seeds and the best survival of seedlings was observed in the plot with more fertile and less alkaline soil (pH 7.3). Thus, planting with seedlings is the best way to cultivate *A. jacutica* under the natural and climatic conditions of Buryatia.

Macro- and microscopic features of *A. jacutica*. Macro- and microscopic features were determined for both the wild and the cultivated plants of *A. jacutica*. We found that the morphological features of the plants did not change during cultivation, so the cultivated plants had most macro- and microscopic features similar to those of the wild plants. *A. jacutica* stems were under 25 cm long and had whole or leafy tops. Some plants had ribbed stems, simple or branched. Basal and middle stem leaves had long petioles, half the length of the leaf blade, with simple or pinnate ears at the base. The leaves had narrowly linear, or almost filiform, pointed terminal lobes. Dense hairs gave them a gray felt color. The stems were grayish-brown or greenish-gray, and leaves were grayish-green. The plants had a strong, peculiar smell. The water extract had a spicy and bitter taste (Fig. 1).

The microscopic analysis of the leaf revealed slightly sinuous cells of the upper epidermis and strongly sinuous cells of the lower epidermis. Both the upper and the lower epidermis had an anomocytic stomatal apparatus. The hairs were of two types: T-shaped and capitate. The leaves were densely covered with T-shaped thin-walled hairs, consisting of a multicellular stalk and a long transverse cell with narrowed ends. There were also some capitate hairs consisting of a unicellular stalk and a multicellular oblong head. Numerous essential oil glands consisted of 6–8 excretory cells arranged in 2 rows and 3–4 tiers. Above were glands with a septum, covered with a cuticle (Fig. 2).

Figure 1 *Artemisia jacutica* Drob. on experimental plot No. 1

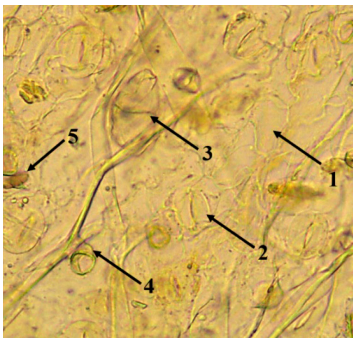

Figure 2 Microscopy of the leaf epidermis: 1 – epidermal cells; 2 – stomata; 3 – essential oil gland; 4 – T-shaped hair; and 5 – capitate hair

***A. jacutica* essential oil composition**. Essential oils were isolated from the aerial parts of the cultivated and wild plants of *A. jacutica* collected in late July of the same year. They were dark blue liquids with a characteristic odor. The oil yield was determined in terms of air-dry raw material. From the cultivated plants (aerial parts), the yield was 0.6 and 0.5% from plot No. 1 and plot No. 2, respectively. From the wild plants, the oil yield was 0.9, 1.4, and 0.7% in the budding, flowering, and fruiting phases, respectively. The composition of essential oils was studied by GC-MS (Table 3).

Table 3 The composition of the essential oils from wild and cultivated *Artemisia jacutica* Drob. plants

Component	Retention index	Wild plants			Cultivated plants	
		Budding	Flowering	Fruiting	Plot No. 1	Plot No. 2
Acyclic monoterpenoids						
β-myrcene	991	0.32	0.18	–	0.98	0.32
geranyl butanoate	1456	–	–	6.37	–	–
Monocyclic monoterpenoids						
α-phelandrene	1004	0.35	0.03	–	0.44	–
α-terpinene	1010	0.27	–	–	0.13	–
p-cymol	1024	0.41	0.11	–	0.26	–
γ-terpinene	1058	0.58	0.18	–	0.37	0.07
terpineol-4	1177	1.14	0.59	0.58	0.36	0.07
α-terpineol	1191	0.89	0.63	0.70	0.40	0.12
β-ionone	1488	–	–	–	0.31	0.22

Continuation of Table 3

Component	Retention index	Wild plants			Cultivated plants	
		Budding	Flowering	Fruiting	Plot No. 1	Plot No. 2
Bicyclic monoterpenoids						
3-thuyene	926	0.18	0.04	–	0.18	–
α-pinene	932	0.34	0.11	–	0.34	0.06
sabinene	973	0.19	0.05	–	0.18	–
β-pinene	975	–	0.05	–	0.08	–
2-karen	1000	–	0.12	–	–	0.06
1.8-cineole	1031	4.97	2.05	1.19	2.66	1.21
Acyclic sesquiterpenoids						
lavandulyl acetate	1292	–	–	1.17	–	–
β-farnesene	1458	0.38	–	0.63	1.61	0.23
nerylisobutanoate	1492	–	0.11	–	–	–
α-farnesene	1496	–	–	–	0.35	–
neryl-2-methylbutanoate	1579	7.59	3.64	10.45	4.71	3.42
neryl-3-methylbutanoate	1585	13.12	0.69	–	4.40	5.80
geranyl-2-methylbutanoate	1604	1.49	–	–	–	–
geranyl-3-methylbutanoate	1610	3.08	2.08	–	0.80	1.01
nerylpentanoate	1636	–	6.92	14.30	–	0.65
lavandulyl hexanoate	1657	4.33	–	–	1.74	2.70
nerylhexanoate	1721	0.40	1.78	–	–	0.20
Monocyclic sesquiterpenoids						
γ-curcumene	1482	2.33	0.25	–	2.60	1.24
germacrene D	1484	1.30	–	2.06	2.49	0.83
β-curcumen	1513	–	0.05	–	–	–
elemol	1553	–	0.89	–	–	–
α-bisabolol	1688	–	–	1.84	–	–
Bicyclic sesquiterpenoids						
α-bergamotene	1416	–	–	–	0.29	–
caryophyllene	1422	1.17	–	–	1.48	0.20
β-guayene	1441	–	–	1.27	–	–
humulene	1456	–	0.06	–	–	–
9-epi-caryophyllene	1469	–	0.61	–	–	–
dehydrosesquicineol	1471	1.89	0.40	0.63	1.67	0.93
selina-4,11-diene	1488	1.54	0.96	1.56	1.14	0.37
cadina-4,11-diene, cis-	1496	–	0.08	–	–	–
bicyclogermacrene	1500	0.28	0.15	–	0.52	0.20
3,6-dihydrochamazulene	1530	–	–	–	0.76	1.55
Δ-amorphous	1553	–	0.12	–	0.31	–
γ-eudesmol	1633	9.07	25.39	31.66	3.22	0.91
amorph-4-en-7-ol	1636	–	–	–	2.90	–
caryophyll-4-en-13-al	1644	–	0.70	–	1.26	–
chamazulene	**1730**	**41.17**	**47.77**	**15.98**	**59.22**	**66.60**
dehydrochamazulene	1800	0.95	–	–	1.84	1.86
Tricyclic sesquiterpenoids						
β-cubeben	1392	–	0.53	–	–	–
Σ acyclic monoterpenoids		0.32	0.18	6.37	0.98	0.32
Σ monocyclic monoterpenoids		3.64	1.54	1.28	2.27	0.48
Σ bicyclic monoterpenoids		5.68	2.42	1.19	3.44	1.33
Σ acyclic sesquiterpenoids		30.39	15.22	26.55	13.61	14.01
Σ monocyclic sesquiterpenoids		3.63	1.19	3.90	5.09	2.07
Σ bicyclic sesquiterpenoids		56.07	76.24	51.10	74.61	72.62
Σ tricyclic sesquiterpenoids		–	0.53	–	–	–
Σ monoterpenoids		**9.64**	**4.14**	**8.84**	**6.69**	**2.13**
Σ sesquiterpenoids		**90.09**	**93.18**	**81.55**	**93.31**	**88.70**
Unidentified constituents		**0.27**	**2.68**	**9.61**	**–**	**9.17**

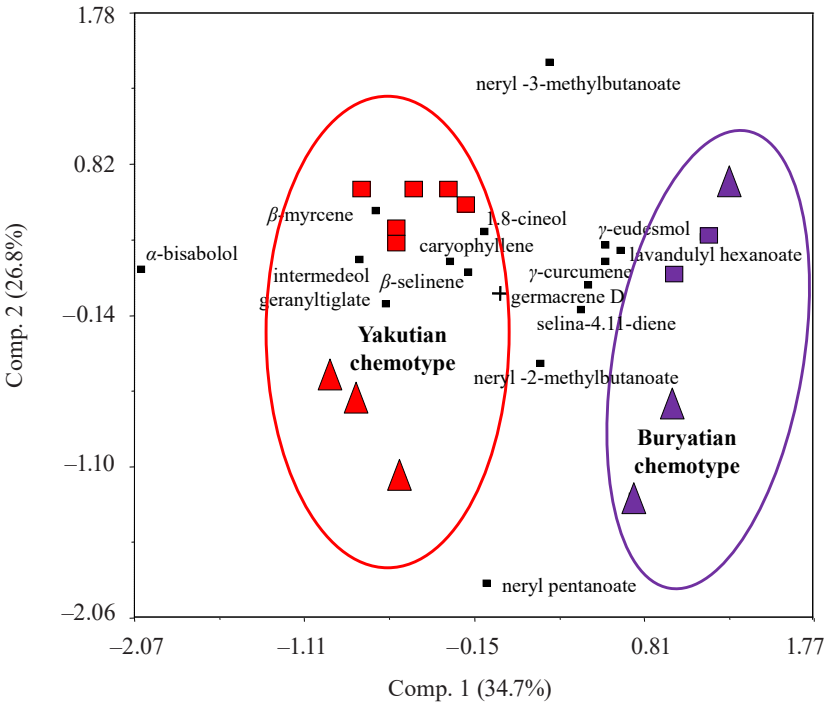

Figure 3 Principal component method. Biplot (PC1-PC2) of the composition of *Artemisia jacutica* Drob. essential oil. In the figure: triangles – wild plants, squares – cultivated plants; purple – experimental data according to Table 3, red – literature data [10]; black squares – oil components

A total of 51 components were identified in the essential oil samples. A number of components (*γ*-terpinene, terpineol-4, *α*-terpineol, *α*-pinene, 1,8-cineol, *β*-farnesene, neryl-2-methylbutanoate, neryl-3-methylbutanoate, geranyl-3-methylbutanoate, *γ*-curcumene, germacrene D, caryophyllene, chamazulene) were found in the oils from both the cultivated and wild plants at all, or almost all, development phases. Several compounds (*β*-ionone, *α*-bergamotene, Δ-amorphene, amorph-4-en-7-ol, and 3,6-dihydrochamazulene) were found only in the oil from the cultivated plants.

The oils from cultivated and wild plants were similar in composition by group. The composition of the oil from wild plants was most diverse in the flowering phase (up to 32 components). In this phase, the oil had the highest content of chamazulene (47.77%), the dominant component, compared to its lowest content in the fruiting phase (15.98%). The oil obtained from wild plants in the budding phase had higher contents of 1,8-cineol (4.97%) and neryl-3-methylbutanoate (13.12%), while in the oil obtained in the fruiting phase, neryl-2-methylbutanoate (10.45%), nerylpentanoate (14.30%), *γ*-eudesmol (31.66%), and germacren D (2.06%) prevailed. Our analysis showed a high content of geraniol and a wide variety of its derivatives, as well as its isomer nerol. However, neryl isobutanoate and geranyl-2-methylbutanoate were found only in the essential oil from wild plants (Table 3).

The highest content of chamazulene was found in the oil from cultivated plants (59.22 and 66.60% on plots No. 1 and No. 2, respectively), which was higher than its content in the oil from wild plants both in the budding (41.17%) or flowering phase (47.77%). The oil from plants cultivated on plot No. 1 was more diverse (33 components) that the one from plot No. 2 (25 components). Despite the higher survival rate of *A. jacutica* in the more fertile plot, the highest content of chamazulene was found in the oil from the less fertile plot with a higher content of mobile phosphorus P_2O_5. Apparently, phosphorus increases the activity of enzymes that control the biosynthesis of proazulene substances [18]. The total content of geraniol derivatives and nerol was also higher in the oil from the plants cultivated on plot No. 2 (11.01%), compared to plot No. 1 (9.91%). In the essential oils of wild plants, it varied from 15.11 to 25.68%, depending on the phase of plant development.

We compared the oils from *A. jacutica* cultivated in Buryatia and in the Siberian Botanical Garden (Tomsk) and found that chamazulene was their main component [10]. However, its content was lower in the plants grown in Tomsk (up to 43.37%), compared to the plants cultivated in Buryatia (up to 66.60%) or wild-growing plants in Yakutia (up to 45.75%) and Buryatia (up to 47.77%). We analyzed our results and literature data by the principal component method and identified two chemotypes, “Yakutian” and “Buryatian”. The chemotypes were preserved in the cultivated plants (Fig. 3).

The components identified in *A. jacutica* essential oil can be divided into three groups:

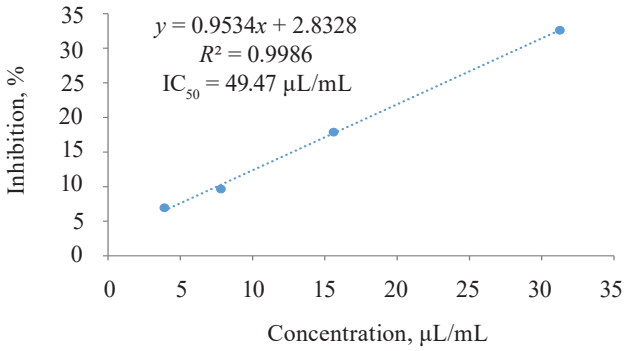

Figure 4 DPPH-antiradical activity of *Artemisia jacutica* essential oil

1) Components found in the essential oils of both wild and cultivated plants, regardless of chemotype. This group includes dominant (chamazulene, γ-eudesmol, neryl-2-methylbutanoate, 1,8-cineol) and minor (β-myrcene, α-terpineol, geranyl-3-methylbutanoate, caryophyllene) components. The acyclic sesquiterpenoid neryl-pentanoate was found in noticeable amounts only in the wild plants of the Yakutian (up to 14.59%) and Buryatian (up to 14.30%) chemotypes, and in small amounts in the cultivated plants of the Buryatian (0.65%) chemotype;

2) Components found in the essential oils of both wild and cultivated plants of either Yakutian or Buryatian chemotype. For example, the Yakutian plants had a noticeable content of α-bisabolol (6.07–24.75%), geranyl tiglat (0.69–3.05%), and intermediol (0.25–2.78%), while the Buryatian plants contained some compounds that were absent in the Yakutian chemotype, namely γ-terpinene, α-pinene, β-farnesene, γ-curcumene, lavandulyl-hexanoate, and others;

3) Components found in the essential oils from cultivated plants of the Yakutian chemotype and from both wild and cultivated plants of the Buryatian chemotype: terpineol-4, neryl-3-methylbutanoate, germacren D, and seline-4,11-diene. Sesquiterpene hydrocarbon β-selinene (0.21–0.41%) was identified only in the introduced plants of the Yakutian chemotype.

Antiradical activity of *A. jacutica* essential oil. The antiradical potential of *A. jacutica* essential oil was determined by the DPPH test (2,2-diphenyl-1-picryl-hydrazyl free radical inhibition). We found that the oil exhibited high antiradical activity (IC_{50} = 49.47 µL/mL) (Fig. 4).

The antiradical potential of *A. jacutica* oil was higher than that of *A. annua* – 50.63 µg/mL, *A. gmelinii* – 2400 µg/mL, or *A. alba* – 1.50 mg/mL [19–21]. It could be due to synergistic and antagonistic interactions between individual components of essential oil as a complex system. Azulenes, including chamazulene, are known to have significant antioxidant activity [22].

CONCLUSION

The primary introduction of *Artemisia jacutica* Drob. showed good prospects for cultivating this plant in the natural and climatic conditions of Buryatia. The macro- and microscopic features and dominant components found in the essential oil of *A. jacutica* grown on the experimental plots were similar to those found in the wild plants. Two chemotypes of *A. jacutica*, Yakutian and Buryatian, were distinguished according to the oil composition. Notably, the chemotypes were preserved in the cultivated plants. The oil's high antiradical activity and a high content of chamazulene make *A. jacutica* a valuable material for the cosmetic, pharmaceutical, and agricultural industries.

CONTRIBUTION

E.P. Dylenova developed the research concept and design, analyzed the data, and wrote the first draft. S.V. Zhigzhitzhapova collected and analyzed the data and edited the article. D.B. Goncharova collected and analyzed the data. Zh.A. Tykheev edited the article. D.G. Chimitov conducted field work and edited the article. L.D. Radnaeva edited the article.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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