Erfolgen führen, könnten dadurch eine Reihe von aktuellen Problemen gelöst werden. Bislang sind im Rahmen dieser Untersuchungen der Bayerischen Landesanstalt für Landwirtschaft, Institut für Pflanzenanbau und Pflanzenzüchtung (Prof. Bomme, Dr. Heuberger) 16 Arten aus Fernost aufgrund der Bedarfsmenge, Schwierigkeiten bei der Beschaffung und des aktuellen Drogenpreises ausgewählt worden. Untersucht wurde in der Folge, ob das Inhaltsstoffmuster dieser Drogen mit denen der chinesischen Handelsdrogen vergleichbar ist und ob die in Deutschland kultivierten Drogen den Anforderungen des Chinesischen Arzneibuchs resp. in Zukunft der EP entsprechen.
Die derzeitigen Schlussfolgerungen aus diesen Versuchen waren durchweg positiv und resultierten in der Bereitstellung von TCM-Drogen in hoher Qualität, insbesondere im Bereich der geforderten Reinheitskriterien. Es lagen bei diesen Drogen aus heimischem Anbau keine Kontaminierungen mit Schwermetallen, Pestiziden, Mycotoxinen und anderen Schadstoffen vor. Daneben konnte eine optimale Sicherheit hinsichtlich der Identität des kultivierten und daraus resultierenden Pflanzenmaterials garantiert werden. Schließlich wurde eine gute Konstanz der spezifischen Drogeninhaltsstoffe nachgewiesen, was auf streng kontrollierte Anbau- und Produktionsbedingungen zurückzuführen ist . Mit diesem begrüßenswerten kontrollierten TCM-Drogenanbau können sicher einige, aber nicht alle Probleme der aktuellen, in Europa gehandelten TCM-Drogen gelöst werden.
Es bleibt festzustellen, dass mit der voraussichtlich anwachsenden Entwicklung der Traditionellen Medizin, insbesondere der aus Fernost, der Bedarf an entsprechenden Arzneien und damit auch an TCM-Drogenmaterialien steigen wird, wobei anzunehmen ist, dass die damit verbundenen Probleme ebenfalls zunehmen werden.

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Importance and quality of roseroot (*Rhodiola rosea* L.) growing in the European North

Introduction

At present, the development of the modern concept of healthy life style among various population groups in the northern areas of the nordic “Archipelago” (indigenous people such as the Inuits, Lapps, Eskimos, etc., guest-workers in nordic oil fields, elderly people, etc.) has become not only a medical, but a social and economic problem as well. In the prevention and treatment of various diseases among the population of the North, much attention is paid to application of medicinal plants, vitamins and natural, biologically active supplements. The results of medico-biological research concerning the problem of human adaptation to the extreme natural conditions of the North testify to the urgency of this issue (11). When considering this problem, it is important to take into account the traditions of the indigenous population and people’s experience of medicine in order to ensure protection from unfavourable conditions and contribute to achievement of a longer life-span, which is crucial for the survival of the different northern ethnic groups.
The indigenous populations of the European North (i.e. of the Archangelsk region, Komi Republic and Nenets Okrug in Russia, Lapps in the Norwegian or Finnish Lapland) made extensive use of plants in the treatment of many diseases, as is known from the memoirs of the famous English botanist John Tradescant the Elder (1570-1638), who visited the North of Russia in 1618. Among plants mentioned by him are sorrel, angelica, silverweed, wild marjoram and others which were used in folk medicine. Tradescant took with him living samples of bird cherry tree and prickly rose, seeds of cloudberries and dwarf cornel. Outstanding Russian researchers like I. Molchanov (1813), academician P. Pallas (1787), I. Kostylev (1862), N. Kuznetsov (1888) and M. Kuklin (1922) also conducted investigations into the use of medicinal plants among northern people in Russia (39).
About 150 plant species are known to have been used from ancient times in the folk medicine of the Komi, Finnish and Norwegian nations. Plants intended for the general support of the body and protection against diseases have been of particular importance for the local populations. The most important plants from the Komi flora are *Rhodiola rosea* (Komi name “dzurtanturun” – crunching herb), *Cypripedium calceolus* (L.) (Komi name “adamglava turun” – herb of Adam’s head), *Pulsatilla patens* (L.) Mill. (Komi name “charom-petam turun” – herb growing from under the snow). The Komi people believed these plants to be great remedies possessed of magical properties, they called them “a remedy for a hundred diseases” (37).
Roseroot belongs to the group of so-called adaptogen medicinal plants. Well-known classical adaptogenic

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plants of the ginseng-like group include ginseng (*Panax ginseng* C. A. Mey.), aralia (*Aralia mandshurica* Rupr. Et Maxim.), eleutherococcus (*Eleutherococcus senticosus* Rupr. Et Maxim.) and Chinese magnolia vine (*Schizandra chinensis* Baill.) which are officially registered and recognized in the pharmacopoeia of many European countries.

Nowadays golden root (*Rhodiola rosea* L.) and maral root (*Leuzea carthamoides* DC.), presently: *Stemmacantha carthamoides* (Willd.) M. Dittrich [*Rhaponticum carthamoides* (Willd.) Iljin], have also been attracting more and more attention from official medicine as a source of potent adaptogenic remedies (14, 79). In spite of the differences in chemical composition, the medical action of the majority of adaptogenic plants is similar. Salidroside and glycosides of cinnamalcohol (rosin, rosavine and rosarine) are found to be the active components of roseroot. The structural elucidation and pharmacological activity of these compounds have been started during the eighties by Russian authors (46,74,82). 20-hydroxyecdysone, which belongs to the class of phytoecdysteroids, is the active component of *Rhaponticum carthamoides*.

In this review paper we present some data on the traditional use of roseroot in northern Lapland and the northern and sub-arctic Urals together with some analytical results of its roots collected from these two regions. Additionally, we describe the present status of the adaptogenic research carried out with roseroot and the efforts made to introduce it to field cultivation.

Description of roseroot

Taxonomy and Geography

Rhodiola, a relatively advanced group of the Crassulaceae family, has been interpreted (mostly in Eurasia) as a separate genus, or (particularly in North America) as a section of the genus *Sedum* L. In North America, *Rhodiola* subgenus includes at least five North American taxa of the *S. rosea* complex (73). In 1963, Hegi identified more than 50 species of *Rhodiola* and re-established it as a separate genus (30). In the former Soviet Union, 21 species of the *Rhodiola* genus have been specified (40).

Rhodiola rosea in the broad sense is an extremely variable circumpolar species of cool temperate and subarctic areas of the northern Hemisphere, including North America, Greenland, Iceland and Eurasia. The Asian distribution includes the Arctic, the Altai Mountains, Eastern Siberia, Tien-Shan and the Far-East and south to the Himalayan Mountains. The European distribution includes northern Europe, the Ural Mountains and most of the mountains of central Europe, south to the Pyrenees, Central Italy and Bulgaria (10) (*Fig. 1*).

Morphology

The species of *Rhodiola* genus are perennials with woody, robust, usually branching multicipidal caudices covered with congested appressed leaves. Some of the species are quite difficult to separate due to their close similarity. The plants have from a few to numerous stems, unbranched or somewhat flexuous. The leaves are alternate. Usually a dioecious plant (64), but hermaphrodite individuals were also reported from Greenland and the Northern and sub-arctic Urals (22). The dioecious flowers (corolla) are variable in colour: the male flowers are yellow, the female flowers yellow to red (yellow, yellowish green, cream-coloured, whitish pink or red). Inflorescences are 3-6 cm in diameter. The height of the flowering stems is 5–35 cm and 2–6 mm thick. The flowering time is May-June. The fruits forming in the female flowers are 6–12 mm long, deep brown capsules, with many small seeds in them. The seeds are lanceo-

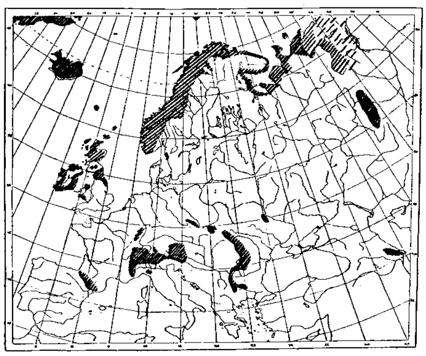

Fig. 1: Incidence of *Rhodiola rosea* L. in Europa (30)
Abb. 1: Verbreitung von *Rhodiola rosea* L. in Europa (30)

Abstract
In this paper, the importance and traditional use of roseroot (*Rhodiola rosea* L.) among the peoples of Lapland and the northern and sub-arctic Urals have been reviewed. Additionally, some phytochemical characteristics of roseroot plants of Finnish and Komi origin have been studied. About 150 plant species are known to have been used from ancient times in the folk medicine of the Komi, Finnish and Norwegian nations. *Rhodiola rosea* L. (roseroot, golden root, arctic root) is a perennial species which grows in sub-arctic areas of the northern hemisphere. Its traditional role was quite important among people living in Greenland, Iceland, Northern Scandinavia and the sub-arctic Urals. In Norway, several historical documents have been found telling of its use for food, as a remedy for scurvy, for washing hair and even grown on house roofs as a protection against fire. Golden root was one of the most valuable medicinal plants among the Komi people living near the northern and sub-arctic Urals and in the upper stream of the Pechora and Vishera rivers. In these regions the tincture from dried roots was used as a general reinvigorating tonic in all illnesses as well as for fatigue and nervous diseases. Its application was most effective for hunters who lived for months far from home in the extreme conditions of the northern taiga. It was considered that golden root encourages an organism and gives new vigour.

Modern clinical trials have demonstrated the favourable adaptogenic effects of roseroot and studies have been started on the introduction of this wild plant into cultivation. For phytochemical characterisation, roseroot roots were collected in two subarctic climatic zones in North Finland and the sub-arctic Urals close to the nordic latitude. The results obtained indicate that the phytochemical profile of roseroot grown in these areas is quite similar. The salidroside content of the roots ranged between 0.4–2.0%, the rosavin content varied between 0.5–2.8%, the rosin content between 0.10–0.54% and the cinnamic alcohol between 0.028–0.16%. The essential oil content was typically low for the species studied. The main compounds of the oil were geraniol (21.3–65.1%), octanol-1 (18.4–29.2%) and myrtenol (5.4–8.3%). The cultivated roots contained nearly equal quantities of sterols (campesterol 5.5–11.4%, sitosterol 21.6–34.2%). Due to its high phenylpropanoid content, the plant population grown in the Kozhym river basin in the sub-arctic Urals should be preferred for further introduction and selection studies.

Keywords
Essential oils, Lapland, phenylpropanoids, phytochemical study, *Rhodiola rosea*, Russian sub-arctic Urals, sterols, traditional use

Review articles

late, 1–2 mm long. 2n = 22. The leaves are 2–4 cm long and 1–1.5 cm wide, orbicular – ovate to linear – oblong, usually dentate, rather glaucous. The annual stems die after every summer. The thick rhizome is developed during some years of ontogeny. During the first two years of growth, the young plants have mainly hairy roots with a small, bean-like rhizome. After three or four years, the roseroot develops its typical habit and root formation. The above-ground parts consist of flowering or non-flowering stems, while 10–25 cm long roots and a rhizome 50–20 cm in diameter are formed underground.

Ecology

Roseroot is found on moist cliffs, ledges, taluses, ridges and dry tundra. It typically occurs in crevices or among mats of moss and other vegetation, often near shores, sometimes in rather rich substrates. Southern plants tend to grow on north-exposed cliffs in alpine regions. The arctic forms are lower in growth and have fewer flowers (73). Russian authors have reported a single plant from an Altai natural population with a total fresh weight of 7.8 kg. Its age was estimated to be about 80 years (52). In cultivation the growth dynamic is faster and the roots reach commercial size (0.5–1.0 kg) during four growing years (27).

Use of roseroot

Traditional use of roseroot in Lapland

Due to the quite small distribution area in Finnish Lapland, there are not many written observations on its traditional use. Around the municipality of Kittilä, in the Olostunturi and Pyhätunturi fjelds, plants have been found close to human dwellings, indicating its use among people as a decorative plant (81). The greater abundance of the plants in North Scandinavia, especially in Norway and Sweden, means that one can find more written historical observations there. The importance of roseroot among the Norwegian people is described by Alm (3) in his extensive ethnobotanical survey. The main uses of roseroot were as a source of vitamin C for curing scurvy, as food and as a natural cosmetic for washing hair.

The oldest report on the use of roseroot is connected to a journey made by the Norwegian King Christian IV who travelled to Finnmark and Kola in 1599 (28). According to this report, the plant was used against scurvy both by the Lapps and the Russians. The last report on the use of roseroot against scurvy in Norway was made in 1766 by Gunnerus in which the root was named as “Radix Scorbuticis salutaris” (2). Roseroot is not the plant richest in vitamin C. It was found that the leaves contain 33 mg vitamin C per gram, while the rhizomes contain only 12 mg per gram, but its importance is in the fact that it is the first vitamin C source available after the snow melts.

In Alaska, the Eskimos have used roseroot as a vegetable and it may still be used as such. It is cooked or mixed in different meals and the leaves are eaten as a salad. The Eskimos in Greenland have eaten roseroot, and the priest Herman Ruge from Valdres in Norway wrote in 1762: “I have myself eaten it, both fried and roasted as well as boiled. And I have either in taste or in effect found it disagreeable” (29). “The leaves were ground and mixed with the ingredients to make bread. The children eat the leaves raw.” reported Hoeg (36).

The plant has been used extensively in folk medicine especially against wounds from fire burns, but also internally against scurvy and lung inflammation and as a remedy for urinating. The rhizome contains substances which help relieve pain. Sometimes the rhizome was also used as food. On the West Coast of Norway, the whole plant was used as fodder for calves early in spring (48). Roseroot has been used as a shampoo to wash one’s hair as well. It gave a good smell and was supposed to be good for the

Bedeutung und Qualität von nordeuropäischer Rosenwurz (*Rhodiola rosea* L.)

Zusammenfassung

Der Artikel gibt einen Überblick zu Bedeutung und traditioneller Nutzung der Rosenwurz (*Rhodiola rosea* L.) durch die Bevölkerung Lapplands und des nördlichen und subarktischen Uralgebietes. Außerdem erfolgt die phytochemische Charakterisierung von Rosenwurzherkünften aus Finnland und der russischen Teilrepublik Komi. Etwa 150 Pflanzenarten wurden seit Alters her in der Volksmedizin der Republik Komi, Finnlands und Norwegens genutzt. Die Rosenwurz ist eine ausdauernde Art, die in subarktischen Gebieten der nördlichen Hemisphäre wächst. Sie spielt eine ziemlich wichtige Rolle bei der Bevölkung von Grönland, Island, Nordskandinavien und dem subarktischen Ural. Verschiedene in Norwegen gefundene historische Dokumente belegen den Gebrauch der Rosenwurz als Nahrungsmittel, Arzneimittel gegen Skorbut und Haarwaschmittel. Sie wurde sogar auf Hausdächern als Schutz gegen Feuer angebaut. Rosenwurz war eine der wertvollsten Arzneipflanzen der Komi, die im Gebiet des nördlichen und subarktischen Urals und an den Oberläufen der Flüsse Pechora and Vishera lebten. In diesen Regionen diente die Tinktur aus trockenen Wurzeln als allgemeines Stärkungsmittel bei allen Krankheiten, insbesondere bei Müdigkeit und nervlichen Erkrankungen.

Ihre Anwendung war besonders wohltuend für Jäger, die monatelang unter extremen Bedingungen weit entfernt von ihren Wohnungen in der nördlichen Taiga lebten. Man ging davon aus, dass die Rosenwurz den Organismus belebt und neue Lebenskräfte verleiht.

Moderne klinische Untersuchungen haben die günstige adaptogene Wirkung der Rosenwurz gezeigt und es wurden Versuche zur Inkulturnahme dieser Wildpflanze begonnen. Zur Charakterisierung der phytochemischen Eigenschaften wurden Rosenwurzwurzeln in zwei subarktischen Klimazonen in Nordfinnland und im subarktischen Ural im Bereich des nördlichen Verbreitungsgebietes gesammelt. Die Ergebnisse zeigen, dass das phytochemische Profil der Pflanzen aus diesen beiden Gebieten ziemlich ähnlich ist. Der Salidrosidgehalt der Wurzeln betrug 0,4–2,0 %, der Rosavingehalt 0,5–2,8 %, der Rosingehalt 0,10–0,54 % und der Gehalt an Zimtalkohol 0,028-0,16 %. Der niedrige Ätherischölgehalt ist typisch für die untersuchte Pflanzenart. Die Hauptkomponenten des ätherischen Öls waren Geraniol (21,3–65,1 %), Octanol-1 (18,4–29,2 %) und Myrtenol (5,4–8,3 %). Die Wurzeln angebauter Pflanzen enthielten nahezu gleiche Mengen an Sterolen (Campesterol 5,5–11,4 %, Sitosterol 21,6–34,2 %). Angesichts ihres höheren Phenylpropanoidghealtes sollte der in der Ebene des Koshym-Flusses im subarktischen Uralbereich wachsenden Population bei zukünftigen Untersuchungen zur Inkulturnahme und Selektion der Vorzug gegeben werden.

Schlagwörter

Rhodiola rosea, Lappland, russisches subarktisches Uralgebiet, traditionelle Nutzung, phytochemische Studie, Phenylpropanoide, ätherische Öle, Sterole

hair (67). Roseroot was believed to provide fire protection and was grown on house roofs for that purpose (3).

Use and importance of roseroot among the Komi people in the North Urals

According to Klavdij Popov (61), the Zyrjane (an historical name of the Komi people) knew many special means against diseases and "they could notably use those means given by nature". Nikolaj Ivanitsky (38) mentioned that "the Komi prepared their most important remedies from herbs".

As mentioned above, *Rhodiola rosea* L. ("dzhurtan turun") and *Cypripedium calceolus* L. ("Adam's head herb") play a special role in the folk medicine of the Komi which is connected to their unusual properties. *Adonis sibiricus* Patr. (Komi name "uraznoy turun" – herb for bruises) and *Paeonia anomala* L. (Komi names: "marjamol", "marjatus" – Maria's berry, "marjavuzh" – Maria's root) are the other examples of medicinal herbs thought to possess magic properties (37).

In Komi folklore, they were all characterized as herbs for "twelve illnesses" or even "seventy-seven illnesses", and the gathering of these plants was accompanied by special rituals right up to the end of the twentieth century. The locations of these plants were kept secret and absolute silence was required during plant gathering. The Komi people believed that plants could not be seen by just any picker. According their belief there had to be a "similarity of blood" between the plant and the person for whom the magic plant was intended. Otherwise the plant disappeared.

Roseroot was a rare and valuable plant among the Komi people since it grows in very remote places. The people who hunted in the Ural Mountains, in the upper part of the stream of the Pechora river, the Vishera and the Vym rivers, were the main pickers of this plant. The roots collected were washed, sliced, then usually dried in the stove, and kept in small birch-bark boxes. The hunters and members of their families used tincture or broth of a root as a general fortifying remedy for weariness, nervous diseases and even "for any illness". Its application was most effective for the hunters living for months far from home in the extreme conditions of the northern taiga. It was considered that the "golden root" encourages an organism and gives new vigour.

It is necessary to explain a special feature of the manner in which the Komi people prepared remedies from the herbs. The Komi did not have precise recipes but instead they adhered to the rule "Every person needs his own handful". Skilled female herbalists explained that all people are different - big and small, thick and thin – so the remedy would benefit if a person drinks his own limit, and this limit is defined by his own handful. Therefore, as a rule, remedies were prepared individually for each patient. A handful of the dried roots was steeped in half a litre of vodka or boiled water and kept in a warm place. Broth could be also be evaporated on the stove in a vessel covered with dough. Picking golden root in such remote places was extremely difficult in the past, so the Komi people tried to cultivate plants near their houses, but their attempts were generally unsuccessful (37).

Studies on the adaptogen effects

The concept of adaptogens was developed by Prof. Nikolai V. Lazarev in 1961, based on his physiological and clinical experiences (6). The theory was first published in 1968 (13).

Since roseroot was used in the traditional medicine of Russia and Scandinavia for centuries, modern pharmacological studies have focused on its adaptogenic effects. Following extensive medical and pharmacological tests in the former Soviet Union, in 1975 its alcohol-based extract (Rhodiola Extract Liquid) was officially registered as a medicine and tonic. Numerous pharmacological effects of roseroot extract are described in Russian literature by A. Saratikov and E. Krasnov (68). The new stage in the phytochemical investigations of *Rhodiola rosea* have been started by a research group lead by Kurkin A.V. (46, 47, 74, 82). In an extensive phytomedicinal survey, nearly a hundred research papers published in the former Soviet Union up to 2000 were reviewed by Brown et al. (14).

Roseroot is one of the most promising adaptogen species for its positive pharmacological properties. The roots and rhizome contain phenylpropanoids (rosavin, rosin, rosarin), phenylethanol derivatives (salidroside, tyrosol), flavonoids, essential oils, etc. (14, 68).

During the last decade, roseroot and its preparations were the subjects of several phytochemical and pharmacological studies in different countries. The most intensive research activity was conducted in Sweden, in the Swedish Herbal Institute. Starting in 1976, numerous modern experiments were carried out aiming to understand better and more deeply the mechanism of the adaptogenic action (53, 54, 55, 56, 58, 59).

In the Swedish Herbal Institute, several clinical experiments have been carried out with roseroot preparations in collaboration with Russian scientists (9, 18, 60, 72, 75). For instance, the results of recent double-blind placebo controlled clinical trials on roseroot supported an improved definition of adaptogens as a separate group of anti-fatigue and anti-stress metabolic regulators that increase mental and physical working performance against a background of fatigue or stress. The results obtained showed that roseroot extract has potential use in geriatrics to maintain the health status of elderly people on the normal level and prolong life span (58).

Essential oil content

Carl Linnaeus named this species *Sedum rosea* because of the rose-like smell of the roots and rhizomes. The quantity and composition of the root oil has been the subject of several studies in Norway (66), Switzerland (51) and in Bulgaria (78). Although the plant is not endemic in Hungary, experiments on its introduction have been started in the coolest climatic region of West-Hungary and several papers have been published on the essential oil composition of the roseroot accessions cultivated in South-Finland (32, 33, 34). The most recent study is from Mongolia (70). The essential oil contents of roseroot roots and rhizomes reported in these studies are relatively low (0.05 – 0.20 % DW). A total of 86 compounds were identified, the most abundant constituents being geraniol (12 – 59 %), myrtenol (5 – 36 %) and E-pinocarveol (4 – 16 %).

Present Status

Based on the documented pharmacological effects and safety of use,

Tab. 1. Content of phenylpropanates (%) of roseroot from Finland (2003, 2006) and Komi (2003) (according to 25, 41, 50)
Tab. 1. Phenylpropanatgehalt (%) der Rosenwurz aus Finnland (2003, 2006) und aus Komi (2003) (nach 25, 41, 50)

Country/year (Land/Jahr)	Places of origin (Herkunftsorte)	Coordinates (Koordinaten)	Drying at (Trocknung bei) (C°)	Content (Gehalt) (%)			
				Salidroside	Rosavin	Rosin	Cinnamic alcohol
Finland, 2003	Kilpisjärvi I	69°05′ N, 20°45′ E	35	0.62	1.08	0.23	0.067
	Kilpisjärvi II	69°02´ N 20°58` E	35	0.86	1.27	0.17	0.028
	mean:			0.74	1.17	0.20	0.048
	Kilpisjärvi I	69°05′N, 20°45′ E	75	0.37	2.20	0.23	0.11
	KilpisjärviII	69°02´N 20°58` E	75	0.66	0.92	0.10	0.036
	mean:			0.51	1.56	0.17	0.073
Mean (Mittel)				0.63	1.36	0.19	0.060
Finland, 2006	Kilpsisjärvi I	69°05′ N, 20°45′E	45	2.06	1.55	0.25	0.16
	Kilpisjärvi II	69°02´ N 20°58` E	45	1.84	1.33	0.18	0.14
	Utsjoki *	69°55′ N, 26°35′ E	45	1.28	1.23	0.23	0.15
Mean				1.73	1.37	0.22	0.15
	Utsjoki **	69°55′ N, 26°35′ E	45	1.08	0.49	0.16	0.08
Finland, 2006	Mikkeli ***	61°44′N, 27° 18′ E	45	0.80	1.11	0.14	0.10
Komi, 2003	Pachvov river	65°78′ N, 61°13′ E	50	1.26	1.99	0.17	0.095
	Pachvov river	65°78′ N, 61°13′ E	50	1.63	2.08	0.17	0.072
	mean:			1.44	2.03	0.17	0.083
	Kozhym-V. river	65°10′ N, 60°57′ E	50	1.82	2.79	0.53	0.12
	Syktyvkar ***	61°38′N, 50°43′E	50	0.56	2.73	0.55	0.16
	mean:			1.19	2.76	0.54	0.14
Mean (Mittel)				1.31	2.39	0.36	0.11

* = alive parts (* lebende Teile), ** = dead parts (abgestorbene Teile), ***= cultivated (angebaut)

commercial interest in roseroot-based products has quickly increased worldwide. According to a recent overview, currently there are 46 companies worldwide using roseroot in their products and there are 30 companies listed as ingredient suppliers for roseroot (5). Presently, one of the biggest problems is to meet the raw material requirement for the increasing industrial demand.

The intensive geological exploration and extraction of minerals during the period of socialism in the twentieth century led to the exhaustion of roseroot in the natural populations of the Northern and sub-arctic Urals. Now roseroot is included in the Red Book of the Komi Republic (77) and is also included in the Red Book of the Russian Federation (12) as well as in the Red Books of the Central Urals, Arkhangelsk, the Nenetz and Khanty Mansiysk Autonomous Area of the Russian Federation and the Republic of Karelia (42). In Europe, roseroot is listed as a threatened plant in Great Britain (16), the Czech Republic, Bosnia-Herzegovina and Slovakia (49).

The estimated quantity of dry roseroot exported from Russia is approximately 20–30 tons per year (Ramazanov, pers. comm.). At present there are numerous ongoing agronomical and biochemical studies in different countries to develop effective cultivation and post-harvest processing methods for roseroot (24).

Domestication of roseroot

During the last decade, an increasing number of papers have been published on phytochemical and agronomical questions in countries where roseroot is an endemic plant.

In Poland, the following questions were studied: seed biology and germination (45, 62) plant age, yield and accumulation of secondary metabolites (4,15, 63).

In Russia, papers were published on seed biology (43), biomass production (43, 64) and the results of fertilization field experiments (20). The bio-morphological potential of this plant species in the territory of the northern and sub-arctic Urals has been discovered, its seed biology has been studied and recommendations for its cultivation have been given (22). Regulation of the biosynthesis of secondary metabolites in golden roots by means of water deficiency in order to obtain plant raw material with high contents of salidrosid and rosavins has been studied (8).

In Northern Italy, field experiments have been carried out with local roseroot strains and results have been reported on seed germination (1) and the accumulation of biomass in relation to active compounds (17).

In Germany, acclimatization observations and cultivation experiments have been started in Thuringia (69).

In Switzerland, phytochemical and agronomical experiments have been started with local Alpine roseroot accessions in the Agroscope Changins-Wädenswill ACW, Centre de Recherche Contheny (51) and the first commercial cultivation has been initiated (http://ilis.ch).

In Bulgaria, phytochemical and cultivation trials have been started with endemic roseroot strains from the Rhodope Mountains (76, 78).

In Norway, the research work has been started by the foundation of a national germplasm collection, including 97 roseroot clones from all regions of the country (19). Field cultivation techniques, composition of essential oil (66) and phytochemical activities of different clones are being studied (31).

In Canada, the phytochemical characterization of the endemic Canadian roseroot population has been started (7, 21). In Alberta, a large development project has been started aiming at rural development with special crops such as roseroot (5).

In Finland, experiments have been carried out for the elaboration of field growing technique for roseroot, and phytochemical characterization of wild and cultivated strains has been carried out (23, 24, 25, 26, 27).

Phytochemical characterization of roseroot from North Finland and the sub-arctic Urals

Since roseroot grows naturally in the same sub-arctic areas of North Finland and the Komi Republic, Russia, at 65°-69° N latitudes, there was increased research interest in comparing the phytochemical characteristics of these two populations.

In this study, we have compared the chemical composition of roseroot plants of Finnish and Ural origin, in connection with the study of the influence of genotype and conditions of growth on the accumulation of

Tab. 2. Chemical composition of the essential oil of the 2003 Finnish samples.
Tab. 2. Chemische Zusammensetzung des ätherischen Öls der finnischen Proben des Jahres 2003

Retention time (Retentionszeit) (min)	Compounds (Komponenten)	Origin (Herkunft)	
		Kilpisjärvi I	Kilpisjärvi II
4.23	alfa-pinen	0.3	0.1
5.56	Octanol-1	18.1	20.9
5.98		0.6	2.2
6.81	trans-pinocarveol	3.6	0.1
7.76	myrtenol	8.6	5.4
8.06		0.3	0.1
8.29		1.9	0.1
8.76	geraniol	31.5	21.3
8.94	cinnamylaldehyd	1.6	3.4
9.24	cumin alcohol	3.9	3.9
9.37	cinnamyl alcohol	1.2	0.1
10.01	cuminaldehyd	13.2	9.6
10.49	unknown (150)	1.1	0.1
Oil content (Äth. Ölgehalt) (%)		0.08	0.08

Tab. 3. Content and composition of the essential oil of the 2006 Finnish and Komi samples.
Tab. 3. Gehalt und Zusammensetzung des ätherischen Öls der Proben des Jahres 2006 aus Finnland und Komi

Retention time (Retentionszeit) (min)	Compounds (Komponenten)	Origin (Herkunft)		
		Kilpisjärvi I+II	Utsjoki	Komi
8.05	1-heptene-6-methyl-1			1.4
8.81	octanol-1	29.7	0.9	31.1
9.41	linalool	3.5	7.7	1.0
10.24	trans-pinocarveol	1.3		5.8
11.34	myrtenol	8.3	6.6	0.7
12.38	geraniol	43.4	65.1	43.7
12.53	unknown (Mw 134)			1.5
12.71	cinnamylaldehyd	2.7	6.1	1.4
13.04	cumin aldehyd	0.9	4.9	7.0
13.30	cinnamyl alcohol			1.8
13.70	unknown (Mw 150)			4.7
Oil content (Äth. Ölgehalt) (%)		0.032	0.027	0.108

Tab. 4. Essential oil content of roots of old roseroot plants from Lapland in 2006.
Tab. 4. Ätherischöl-Gehalt der Wurzeln alter Rosenwurzpflanzen aus Lappland im Jahre 2006.

Compounds (Komponenten)	Alive rhizomes (Lebende Rhizome)		Dead rhizomes (Abgestorbene Rhizome)	
	Kilpisjärvi I+II	Utsjoki	Kilpisjärvi I+II	Utsjoki
octanol	29.7	0.9	18.4	3.7
linalool	3.5	7.7	3.9	5.1
trans-pinocarveol 3,7	1.3		1.1	
unknown	0.6		0.7	
myrtenol	8.3	6.6	5.3	5.9
unknown	0.7			
cuminaldehyd	0.9	4.9	8.9	8.6
geraniol	43.4	65.1	21.6	40.9
cinnamylaldehyd	2.7	6.1	2.2	6.1
cumin alcohol	5	9.7	28.3	25.1
thymol	1.4		3.6	2.9
Oil content (Äth. Ölghalt (%)	0.032	0.027	0.022	0.043

biologically active materials for the purpose of further selection.

Plant material from Finland

The region where roseroot grows naturally is situated in the north-eastern parts of Finnish Lapland. The Kilpisjärvi area in the municipality of Enontekiö is at the meeting point of three Scandinavian countries (Sweden, Norway and Finland) and Utsjoki is the most famous salmon fishing area in Finland. The geographical sites of the collected plants are presented in *Tab 1*. The roseroot plants were collected twice: fresh roots and rhizomes were collected in September from two populations around the Kilpisjärvi area. Kilpisjärvi I. = Jeähkäjärvi is situated on the northern part of Saana fjeld near the Norwegian border, 500–560 m above sea level (69°05'N, 20°45'E). Kilpisjärvi II.= Tsahkaljärvi is situated about 5 km south of area I, on the northern part of Lake Tsahkaljärvi (69°02´N 20°58`E). The age of the plants is unknown, the roots and rhizomes were quite small, their diameter varied between 2–5 cm. Fresh roots and rhizomes were collected on 17 June 2006 in Kilpisjärvi II from the Tsahkaljärvi population, from the same site as in 2003. Additionally, on 19 June 2006 we collected plant material from another population situated in the municipality of Utsjoki, on the banks of the Goahppelasjoki River 110 m above sea level (69°55'N, 26°35'E). In both places we collected only the older and bigger plants.

The cultivated plants were grown in the experimental field of Agrifood Research Finland in Mikkeli, about 800 km south of the natural North-Lapland populations (61°44'N, 27°18' E). The cultivated accession represents close geographical relations to the natural collection populations. The accession originated from seeds from a natural population in Norway, collected close to the Finnish border and grown by Särkä Nursery in North Finland. The plants were six years old at harvest time (20 September 2006) including the one-year seedling period. The growing methods are described in our previous paper (25). Consequently, the Finnish natural samples were roots and rhizomes of plants of an unknown age collected from nature and one sample was from rhizomes of a six-year-old cultivated plantation.

Plant material from Komi (Russia)

The region where the roseroot accessions were collected is situated in the North-East of the Komi Republic in the sub-arctic Urals in the northern part of the Yugyd-Va National Park. In the Komi language Yugyd-Va means "Clean water" and refers to the water collecting area of the Pechora river. Since 1994, the national park has been on the UNESCO World Heritage List and several parts have been described as “the last wilderness of Europe”.

Seeds of plants of the sub-arctic Urals were collected during 1993 at Pachvozh River 500 m above sea level (65° 78 ’N, 61°13’ E). Another accession was collected from Kozhym-Vozh River, 1040 m above sea level (65°10’N, 60°57’E). All seed samples were sown in the experimental plot of the Institute of Biology, Komi Science Centre, Ural Division, RAS (61° 38’ N, 50°43’ E). Plants were cultivated during 1993-2003. Seeds of roseroot from another population in the sub-arctic Urals were collected in 2000. Seedlings were obtained and transplanted into the plot. The plants were cultivated for three years and the roots were collected in 2003. The first three Komi samples in *Tab. 1* were from ten-year-old plants and the fourth sample (Syktyvkar) was from a three-year-old plant. For analyses, only rhizomes were used.

Rhizomes and roots of plants were harvested during autumn 2005 and the rhizomes were dried for analysis of essential oils and sterols carried out in 2007. Before analysis the samples were stored in air-dried form at room temperature. According to the Russian Pharmacopoeia, the dry roseroot can be stored without quality deterioration for three years. Consequently, the plants of sub-arctic Ural origin were cultivated plants either ten or three years old.

Analysis

During 2003, the fresh roots collected in Lapland were transported for further processing after two days of collection. The thicker roots and rhizomes were washed, mixed and dried at 35 °C and 75 °C in a forced-air drier. In 2006, the thick, live and dead rhizomes were separated, washed and dried separately at 40 °C. In Komi, the roots were dug out from the experimental plots, then washed. The roots and rhizomes were separated and the rhizomes were dried at 50 °C in a forced-air dryer.

The phenylpropanoid contents of the samples collected in 2003 were analysed in the laboratory of the Interregional Center “Adaptogen” in St-Petersburg for the contents of phenylpropanoids by the method described earlier (50). The contents of phenylpropanoids in the samples collected in 2006 were analysed in the ILIS Laboratory, Bien, Switzerland, as described earlier (25). The methods for isolation and analysis of volatile oils by GC, GC/MS have been described previously (32). The analytical data presented in tables 2-4 are means of two analyses of one sample per original place. The method for analysis of the sterol contents of the rhizomes from the cultivated plants of Syktyvkar (2005) and Mikkeli (2006) has been described earlier (35).

Results and discussion

The salidroside and phenylpropanoid contents

The contents of the roseroot samples of Finnish and Komi origin are presented in *Tab. 1*. The results indicate that the salidroside content in the rhizomes shows some correlation with the age of the plants. The average salidroside content of the samples collected during 2003 in Finland was low ($\bar{x}$ = 0.63 %). These plants were young and the samples therefore had a high percentage of thin roots. The salidroside content of the roots of the three-year-old cultivated plants in Komi was also low ($\bar{x}$ = 0.53 %), and so was that of the plants cultivated in Mikkeli (0.80 %). On the contrary, the salidroside contents of the older and thicker roots were higher, both for those collected in Finland during 2006 ($\bar{x}$ = 1.73 %) and for those cultivated in Komi (1.26-1.82 %).

It was established that, independent of the plant age and year of collection, the rosavin content in the roots of the Finnish plants was the same: 1.36 % in 2003 and 1.37 % in 2006. The rosavin content in the roots of the plants cultivated in Mikkeli was lower: 1.11 %. The rosin contents in all samples were in the range 0.10-0.20 %.

The average rosavin content in the roots of the plants cultivated in Komi was 75 % higher compared to the Finnish ones. The content of rosavin was double and the rosin content was nearly three times the contents in the plants from the Kozhym-Vozh River site (2.73 %). The content of these substances in the plants from the Patchozh River site were lower and seemed to be at the same level as in the plants of Finnish origin.

The drying temperature had some irregular effect on the content of active metabolites. The salidroside content in samples dried at 75 °C was 0.51 %, while the of salidroside content obtained in those dried at 35 °C was 0.74 %. At the same time, contrary results were observed for rosavin content, i.e. 1.56 % and 1.17 %, respectively. Russian authors have proposed higher drying temperatures for roseroot, 75 – 80 °C (46).

Essential oil content and composition

The results presented here are the first data related to these *Rhodiola* populations. The essential oil content and its composition in the Finnish samples for 2003 are presented in *Tab. 2*. The results of the analysis of the 2006 Finnish and Komi samples are shown in *Tab. 3*. The essential oil content in the rhizomes of the samples of all experimental years was very low, ranging between 0.027 – 0.10 %. The main compounds of the oils were geraniol (21.3 – 65.1 %), octanol-1 (18.1 – 32.4 %) and myrtenol (5.4 – 8.3 %). The geraniol content in the oils obtained from the younger plants collected during 2003 was lower (21 – 31 %), while in the older roots the content was higher (41-65 %).

Some differences were observed in the composition of the oil between plants of the two Finnish populations. The content of geraniol in the Kilpisjärvi population was lower (43 %), while in the Utsjoki population the content of geraniol was the highest (65 %). At the same time the content of octanol-1 showed an opposite trend – its content was very low (0.9 %) in the Utsjoki population and higher in the Kilpisjärvi population (29.7 %). The differences in the content of this compound may be explained by the quite different environmental conditions of these two habitats: in Kilpisjärvi the plants were grown in an alpine meadow, while in Utsoki the plants were grown only in a stony-sandy riverside.

The contents of geraniol and octanol-1 in the Komi sample was 43.7 % and 31.1 %, respectively and the myrtenol contents were very low (0.7 %). Besides the main compounds, the further minor compounds were trans-pinocarveol, linalool, cuminaldehyd, cinnamylaldehyd, cumin alcohol and cinnamyl alcohol.

Quality of the old roseroot roots

Generally the live fresh roots and rhizomes are white in colour when sliced, but after 1–2 hours they became brownish. The rhizomes of the 5–10-year-old plants contain varying proportions of dead parts which are continuously reddish-brownish in colour. They are porous and lighter, although they habe a strong smell. According to our previous report, the dead parts as a proportion of the whole rhizome weights ranged between 23–68% in Utsjoki, but no dead parts were found in the four-year-old cultivated roots (25).

The quality of the dead root parts is inferior. The salidroside content in the dead parts was 45% lower and the rosavin content 75% lower compared to the live rhizome parts. Additionally, the composition of the oil obtained from the dead parts is different due to deterioriation during the decay (*Tab. 4*). The content of geraniol and octanol-1 in the dead parts was only half that in the live parts and the cuminaldehid was 3–5 times higher. Although these quality differences are clear, practically it is quite difficult to separate parts with two quality criteria into old and live roots. The best solution is to harvest the roots at their optimum age.

Conclusion

In this study, some phytochemical features of the dried roots of roseroot of different origins – North Finland and the sub-arctic Urals in Russia were presented. These geographical areas belong to the subarctic climatic zone and their flora is quite similar. Although the number of plants studied was not very large, the results indicate that the phytochemical profile of roseroot grown in these areas is quite similar. The salidroside content of the roots ranged between 0.4–2.0%, the rosavin contents between 0.5–2.8%, the rosin contents between 0.10–0.54% and the cynnamilalcohol between 0.028-0.16%.

The essential oil contents of the roots varied from 0.027% to 0.10% that is typically low for this plant species. The main compounds of the essential oil were geraniol (21.3–65.1%), octanol-1 (18.4–29.2%) and myrtenol (5.4–8.3%). We found similarities in the sterol contents of plants of the two roseroot populations studied. The roots cultivated in Mikkeli, Finland, and Syktyvkar, Komi, Russia, contained campesterol (5.5–11.4%) and sitosterol (21.6–34.2%) in nearly the same quantities. The salidroside and phenylpropanoid contents in the roots of the plants of different origins were relatively low, especially in Finland. Due to their higher phenylpropanoid contents, plants from the population of roseroot on the Kozym river (Prepolar Ural) should be selected for further introduction and selection studies.

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