

Rhodiola rosea: A Possible Plant Adaptogen

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Abstract

Rhodiola rosea is a popular plant in traditional medical systems in Eastern Europe and Asia with a reputation for stimulating the nervous system, decreasing depression, enhancing work performance, eliminating fatigue, and preventing high altitude sickness. *Rhodiola rosea* has been categorized as an adaptogen by Russian researchers due to its observed ability to increase resistance to a variety of chemical, biological, and physical stressors. Its claimed benefits include antidepressant, anticancer, cardioprotective, and central nervous system enhancement. Research also indicates great utility in asthenic conditions (decline in work performance, sleep difficulties, poor appetite, irritability, hypertension, headaches, and fatigue) developing subsequent to intense physical or intellectual strain. The adaptogenic, cardiopulmonary protective, and central nervous system activities of *Rhodiola rosea* have been attributed primarily to its ability to influence levels and activity of monoamines and opioid peptides such as beta-endorphins. (*Altern Med Rev* 2001;6(3):293-302)

Introduction

Rhodiola rosea (“golden root” or “Arctic root”) is widely distributed at high altitudes in Arctic and mountainous regions throughout Europe and Asia. It is a popular plant in traditional medical systems in Eastern Europe and Asia, with a reputation for stimulating the nervous system, decreasing depression, enhancing work performance, eliminating fatigue, and preventing high altitude sickness.¹ In addition to *Rhodiola rosea*, over 200 different species of *Rhodiola* have been identified and at least 20 are used in traditional medical systems in Asia, including *R. alternata*, *R. brevipetiolata*, *R. crenulata*, *R. kirilowii*, *R. quadrifida*, *R. sachalinensis*, and *R. sacra*.

Rhodiola rosea has been intensively studied in Russia and Scandinavia for more than 35 years. Although the majority of this research on *Rhodiola rosea* is unavailable for review, available literature is supportive of its adaptogenic properties. Similar to other plant adaptogens investigated by Russian researchers, such as *Eleutherococcus senticosus* (Siberian ginseng) and *Panax ginseng* (Korean ginseng), extracts of this plant produce favorable changes in a variety of diverse areas of physiological function, including neurotransmitter levels, central nervous system activity, and cardiovascular function.

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Table 1. Criteria for Defining an Adaptogen

1. An adaptogen produces a non-specific response in an organism; i.e., an increase in power of resistance against multiple stressors including physical, chemical, or biological agents.

2. An adaptogen has a normalizing influence on physiology, irrespective of the direction of change from physiological norms caused by the stressor.

3. An adaptogen is incapable of influencing normal body functions more than required to gain non-specific resistance²

Rhodiola rosea is considered by Russian researchers to satisfy all three criteria.

Rhodiola rosea has been categorized as an adaptogen by Russian researchers due to its observed ability to increase resistance to a variety of chemical, biological, and physical stressors. Origination of the term adaptogen has been dated to 1947 and credited to a Russian scientist, Lazarev. He defined an “adaptogen” as an agent that allows an organism to counteract adverse physical, chemical, or biological stressors by generating non-specific resistance. Inherent in his definition is the concept that administration of the adaptogenic agent allows an organism to pre-adapt itself in a manner that allows it to be more capable of responding appropriately when diverse demands are eventually placed on it. In 1969, Brekhman and Dardymov proposed specific criteria that need to be fulfilled in order for a substance to qualify as an adaptogen (Table 1).

Subjecting animals and humans to a period of stress produces characteristic changes in several hormones and parameters associated with the central nervous system and the hypothalamic-pituitary-adrenal axis (HPA). HPA changes include an increase in cortisol, a reduced sensitivity of the HPA to feedback down-regulation, and a disruption in

the circadian rhythm of cortisol secretion. Central nervous system changes include the stress-induced depletion of catecholamine neurotransmitters such as norepinephrine and dopamine. An acute increase in beta-endorphin levels is also observed under stressful conditions.

To successfully combat stress and stressful situations, adaptation is required. Adaptation might be best thought of as the ability to be exposed to a stressor, while responding with either decreased or no characteristic hormonal perturbations. Adaptation also implies being prepared to and capable of rapidly reassuming homeostasis after the stressor is withdrawn. As an example, a well-trained athlete can participate in an event that would induce a large HPA perturbation (stress response) in a sedentary person, and yet the athlete will be relatively unaffected. This is a result of adaptation that has occurred during the athlete’s training process. Additionally, if athletes are exposed to stressors they were not trained for, hormonal perturbations characteristic of a stress response would be expected; however, this response might not be as great as that found in less fit individuals. Furthermore, after the stress ended, their physiology

would be expected to re-establish homeostasis rapidly. This is a result of non-specific resistance to stress gained by virtue of a training-induced higher level of fitness.

The utility of plant adaptogens is analogous to the training an athlete undergoes in order to prepare for competition. Plant adaptogens cause our physiology to begin the adaptation process to stress. When a stressful situation occurs, consuming adaptogens generates a degree of generalized adaptation (or non-specific resistance) that allows our physiology to handle the stressful situation in a more resourceful manner.

As an example of this process, *Rhodiola rosea* administration promotes a moderate increase in the amount of serum immunoreactive beta-endorphin in rats under basal conditions. This moderate increase is similar to that found when rats are adapted to exercise. When *Rhodiola rosea*-treated rats were subjected to a 4-hour period of non-specific stress, the expected elevation in beta-endorphin was either not observed or substantially decreased. Consequently, the characteristic perturbations of the HPA were decreased or totally prevented.³ In these rats administration of *Rhodiola rosea* appears to have generated non-specific resistance and prepared the rats to respond more appropriately to the eventual stressful situation.

Chemical Composition

The chemical composition and physiological properties of *Rhodiola* species are to a degree species-dependent, although some overlap in constituents and physiological properties does exist in many *Rhodiola* species.

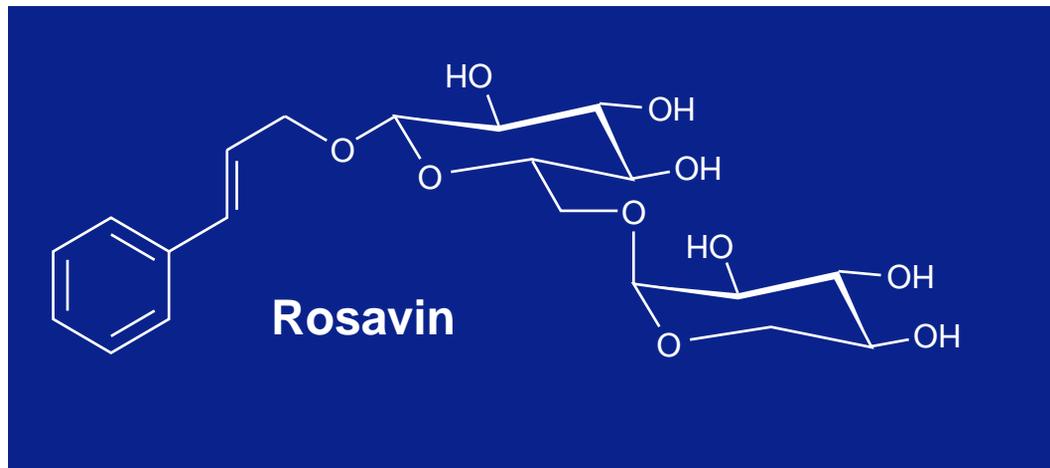
Twenty-eight compounds have been isolated from the roots and above-ground parts of *Rhodiola rosea*, including 12 novel compounds. The roots contain a range of biologically active substances including organic acids, flavonoids, tannins, and phenolic glycosides. The stimulating and adaptogenic properties of *Rhodiola rosea* were

originally attributed to two compounds isolated from its roots, identified as p-tyrosol and the phenolic glycoside rhodioloside. Rhodioloside was later determined to be structurally similar to the known glycoside salidroside found in several other plant species. Salidroside, rhodioloside, and occasionally rhodosin are used to describe this compound and are considered to be synonyms. Additional glycoside compounds isolated from the root include rhodioniside, rhodiolin, rosin, rosavin, rosarin, and rosiridin. These glycoside compounds are also thought to be critical for the plant's observed adaptogenic properties.^{1,4}

A range of antioxidant compounds have been identified in *Rhodiola rosea* and related species, including p-tyrosol, organic acids (gallic acid, caffeic acid, and chlorogenic acid), and flavonoids (catechins and proanthocyanidins).^{5,6} Significant free-radical scavenging activity has been demonstrated for alcohol and water extracts of *Rhodiola* sp. and is attributed to the variety of antioxidant compounds.^{5,6} p-Tyrosol has been shown to be readily and dose-dependently absorbed after an oral dose,^{7,8} and appears to produce a significant antioxidant⁸ and modest 5-lipoxygenase inhibitory activity⁹ *in vivo*.

Salidroside (rhodioloside), the additional salidroside-like glycoside compounds (rhodiolin, rosin, rosavin, rosarin, and rosiridin), and p-tyrosol are thought to be the most critical plant constituents needed for therapeutic activity.^{1,2} The contents of salidroside and p-tyrosol in root samples gathered from various areas in China have been shown to range from 1.3-11.1 mg/g and 0.3-2.2 mg/g, respectively.⁴ These two compounds have been found in all studied species of *Rhodiola*; however, the other active glycosides, including rosavin, rosin, and rosarin, have not been found in all examined *Rhodiola* species.^{5,6} Because of this variation within the *Rhodiola* genus, verification of *Rhodiola rosea* by high performance liquid chromatography (HPLC) is dependent on the content of the additional

Figure 1. Structure of Rosavin



glycosides (rather than salidroside and p-tyrosol); rosavin (Figure 1) is the constituent currently selected for standardization of extracts.¹⁰

Proposed Mechanisms of Action

The adaptogenic properties, cardiopulmonary protective effects, and central nervous system activities of *Rhodiola rosea* have been attributed primarily to its ability to influence levels and activity of monoamines and opioid peptides such as beta-endorphins.

Oral administration of a water extract of *Rhodiola rosea* to rats for 10 days modulated biogenic monoamines in the cerebral cortex, brain stem, and hypothalamus. In the cerebral cortex and brain stem, levels of norepinephrine and dopamine decreased, while the amount of serotonin increased substantially. In the hypothalamus, the results were reversed with a 3-fold increase in the amount of norepinephrine and dopamine, and a trend toward reduced serotonin levels. It is believed these changes in monoamine levels are a result of *Rhodiola rosea* inhibiting the activity of the enzymes responsible for monoamine degradation, monoamine oxidase and catechol-O-methyltransferase. It is also believed *Rhodiola rosea* facilitates the transport of neurotransmitters within the brain.¹¹ In addition

to these central effects on monoamines, *Rhodiola rosea* has been reported to prevent both catecholamine release and subsequent cAMP elevation in the myocardium, and the depletion of adrenal catecholamines induced by acute stress.¹²

Abstracts of untranslated Russian research indicate that a great deal of the activity of *Rhodiola rosea* might be secondary to an ability to induce opioid peptide biosynthesis and through the activation of both central and peripheral opioid receptors.^{3,13-15} Lack of current availability of the complete text of these articles make verification of these effects impossible.

Experimental Studies

Adaptogenic Activity

Rhodiola rosea appears to offer generalized resistance against physical, chemical, and biological stressors in rats and other animals studied. Evidence also suggests cardioprotective and anticancer benefits in animals.

In the test of swimming "to the limit," *Rhodiola rosea* administration increased the swimming time of rats 135-159 percent. Working capacity of the rats consistently improved throughout the supplementation period.¹⁶

Eggs from the freshwater snail *Lymnaea stagnalis* were incubated in water extracts of *Rhodiola rosea* and subsequently exposed to a variety of environmental stressors, including heat shock (43°C for four minutes), oxidative stress (600 µM menadione for two hours), and heavy metal-induced stress (one-hour exposure to 150 µM copper sulphate or 20 µM cadmium chloride). Exposure to these environmental stressors kills 80-90 percent of larvae within four days post-exposure. Pre-incubation with *Rhodiola rosea* extract afforded a significant degree of non-specific resistance against each of these environmental stressors as measured by rate of survival. While only nine percent of the control population survived exposure to heat shock, approximately 90 percent of snail larvae pre-incubated with *Rhodiola rosea* (40.5 µg/ml) survived. Pre-incubation with *Rhodiola* resulted in non-specific resistance to oxidative stress (survival of approximately 68 percent) and heavy metal stress (approximately 28-35 percent of larvae survived depending on the metal exposure).¹⁰

Two experiments have suggested possible benefit on various aspects of learning and memory in rats under certain experimental conditions. *Rhodiola rosea* extract administered orally at a dose of 0.1 mL/day for 10 days resulted in a non-significant trend toward protection against impairments in memory, as assessed by step-down passive avoidance, induced by electroshock in rats.¹⁷ *Rhodiola rosea* extract was administered in a single dose of 0.10 mL. Improvements in both learning and memory retention, as determined by using a maze test with negative reinforcement, were observed. Repeated dosing with the same quantity of the extract over a 10-day period generated significant improvement in long-term memory as assessed by the maze test with negative enforcement and the “staircase” method with positive enforcement. However, in this experiment two other doses were tested (0.02 and 1.0 mL) and were found to have no substantial effect on learning and memory.¹

This suggests the possibility of an efficacious dose of *Rhodiola rosea* administration, above and below which beneficial physiological effects might be less likely. In the other experimental conditions investigated (active avoidance with negative reinforcement using a “shuttle box” and passive avoidance using “step down” and “step through”) no beneficial effects on either learning or memory were observed with any of the administered doses of *Rhodiola rosea*.¹

Cardioprotective Activity

Rhodiola rosea has been shown to moderate against stress-induced damage and dysfunction in cardiovascular tissue. Treatment with *Rhodiola rosea* extract prevents the decrease in cardiac contractile force secondary to environmental stress in the form of acute cooling and contributes to stable contractility. In animals, acute cooling leads to a decrease in myocardial contractile activity that partially recovers during the first 18 hours after the cold-stress is removed. This recovery is viewed as only partial, since the heart tissue is incapable of stable contractility during perfusion. Pretreatment with *Rhodiola rosea* extracts appears to create a beneficial adaptive response in this type of stress. When *Rhodiola* pretreated rats were exposed to acute cooling, the decrease in contractility was prevented and stable contractility of heart tissue occurred during perfusion.¹⁸

Other reports suggest administration of *Rhodiola rosea* protects cardiovascular tissue from stress-induced catecholamine release¹² and mitigates against adrenaline-induced arrhythmias in rats.^{13,14,19} The antiarrhythmic effect of *Rhodiola rosea* is suggested to be secondary to an ability to induce opioid peptide biosynthesis¹³ and related to the stimulation of peripheral kappa-opioid receptors.¹⁴

Table 2. Conditions Suggested to Benefit from *Rhodiola rosea* Supplementation²³

Amenorrhea	Depression	Insomnia
Asthenia	Fatigue	Periodontal Disease (topical)
Cancer	Headaches	Schizophrenia
Colds and Flu	Hypertension	Sexual Dysfunction (males)

Anticancer Activity

Administration of *Rhodiola rosea* appears to have potential as an anticancer agent, and might be useful in conjunction with some pharmaceutical antitumor agents. In rats with transplanted solid Ehrlich adenocarcinoma and metastasizing rat Pliss lymphosarcoma, supplementation with *Rhodiola rosea* extract inhibited the growth of both tumor types, decreased metastasis to the liver, and extended survival times.²⁰ Administration of *Rhodiola rosea* extract also directly suppressed the growth of and the extent of metastasis from transplanted Lewis lung carcinomas.²¹ When *Rhodiola rosea* extract was combined with the antitumor agent cyclophosphamide in these same tumor models, the antitumor and antimetastatic efficacy of drug treatment was enhanced. The authors also commented that, “complete abrogation of the haematotoxicity of cyclophosphamide” was observed.²¹ The chemotherapeutic drug Adriamycin is known to induce pronounced liver dysfunction, generally reflected by an increase in transaminase levels. In animal experiments, adding *Rhodiola rosea* extract to a protocol with Adriamycin resulted in an improved inhibition of tumor dissemination (as compared to that found with Adriamycin alone), and the combined protocol prevented liver toxicity.²²

Clinical Studies

Although *Rhodiola rosea* has been studied in the former Soviet Union for more than 35 years, this research is presently unavailable for review. This makes it impossible to verify the Russian claims of its antidepressant, anticancer, cardioprotective, and central nervous system enhancing properties.²³ Available animal evidence seems supportive of a possible role for this plant adaptogen in many of these conditions. Table 2 outlines the conditions suggested to benefit from *Rhodiola* supplementation.

There have also been claims that this plant has great utility as a therapy in asthenic conditions (decline in work performance, sleep disturbances, poor appetite, irritability, hypertension, headaches, and fatigue) developing subsequent to intense physical or intellectual strain, influenza and other viral exposures, and other illness.²³ Two randomized, double-blind, placebo-controlled trials of the standardized extract of *Rhodiola rosea* root (SHR-5) provide a degree of support for these claimed adaptogenic properties and indicate possible utility in asthenic conditions induced by overwork or over study. SHR-5 is standardized to contain rosavin (3.6%), salidroside (1.6%), and p-tyrosol (<0.1%).¹⁰

Darbinyan et al evaluated the effect of chronic administration of 170 mg of SHR-5 for 14 days on aspects of mental performance and fatigue on 56 healthy male and female physicians (age 24-35) on night duty. Mental performance was evaluated using tests to determine speed of visual and auditory perception, attention capacity, and short-term memory. Based on the results of the battery of tests used, a Fatigue Index was calculated. The trial was divided into three periods: (1) a two-week test period of one SHR-5 or placebo tablet daily; (2) a two-week washout period; and (3) a third two-week cross-over period of one placebo or SHR-5 tablet daily. A statistically significant improvement in Fatigue Index was observed during the first two-week period in the SHR-5 group, and the improved mental performance reverted toward baseline values during the washout period. Administration of SHR-5 for the final two weeks of the six-week night duty period was unable to significantly offset declines in mental performance.²⁴

Spasov et al investigated the effects of SHR-5 on male medical students during an exam period. Forty students were randomized to receive either 50 mg SHR-5 or placebo twice daily for a period of 20 days. The students receiving the standardized extract of *Rhodiola rosea* demonstrated significant improvements in physical fitness, psychomotor function, mental performance, and general wellbeing. Subjects receiving the *Rhodiola rosea* extract also reported statistically significant reductions in mental fatigue, improved sleep patterns, a reduced need for sleep, greater mood stability, and a greater motivation to study. The average exam scores between students receiving the *Rhodiola rosea* extract and placebo were 3.47 and 3.20, respectively.²⁵

Dosage and Toxicity

In the two double-blind clinical trials, the dose of a standardized *Rhodiola rosea* extract ranged from 100-170 mg per day. The content of rosavin consumed in these daily

doses is approximately 3.6-6.14 mg. The therapeutic dose of available *Rhodiola rosea* preparations will vary depending on degree of standardization; however, for chronic administration rosavin content within the above range seems prudent. This would suggest a dose of approximately 360-600 mg *Rhodiola rosea* daily of an extract standardized for one-percent rosavin, 180-300 mg of an extract standardized for two-percent rosavin, or the dose of between 100-170 mg for an extract standardized for 3.6-percent rosavin. As an adaptogen, chronic administration is normally begun several weeks prior to a period of expected increased physiological, chemical, or biological strain, and continued throughout the duration of the challenging event or activity. When using *Rhodiola rosea* as a single dose for acute purposes (e.g., for an exam or athletic competition), the suggested dose is three times the dose used for chronic supplementation.

The Russian approach to long-term supplementation with adaptogens generally calls for repeating cycles characterized by short periods of adaptogen administration, followed by an interval with no supplementation.²⁶ *Rhodiola rosea* has been administered for periods ranging from as little as one day (acute administration) up to four months. Until more specific information is available, a dosing regime following the established patterns used with other plant adaptogens, with periodic intervals of abstinence, seems warranted when *Rhodiola rosea* is being used chronically.

At the doses administered in the clinical trials, a complete absence of all side effects has been reported. However, preliminary clinical feedback indicates that at doses of 1.5-2.0 grams and above of *Rhodiola rosea* extract standardized for two-percent rosavin, some individuals might experience an increase in irritability and insomnia within several days. It is possible that other physiological parameters that benefit from a lower dose of *Rhodiola*

rosea extract might be exacerbated by a dose that is inappropriately high and/or sustained for prolonged periods of time.

Evidence on the safety and appropriateness of *Rhodiola rosea* supplementation during pregnancy and lactation is currently unavailable.

Conclusion

Consistent with benefits found with other adaptogenic substances, *Rhodiola rosea* appears to offer generalized resistance to physical, chemical, and biological stressors. Available evidence suggests it can be a suitable substitute in conditions where other adaptogens might be considered. However, *Rhodiola rosea* also appears to be unique among the currently available adaptogenic herbs and might offer an advantage in some clinical conditions and stressful circumstances. Unlike Korean and Siberian ginseng, which are thought to exert their adaptogenic activity primarily at the level of HPA function,²⁷⁻²⁹ *Rhodiola rosea* appears to exert its adaptogenic effects by working centrally and peripherally on monoamine and opioid synthesis, transport, and receptor activity. If this is in fact the case in humans, it suggests the potential for therapeutic utility of *Rhodiola rosea* in conditions not particularly responsive to administration of ginseng products. It also suggests the possibility of potential synergistic interactions among *Rhodiola rosea* and other plant adaptogens.

Based on the proposed mechanism of action and available experimental data, *Rhodiola rosea* appears to offer an advantage over other adaptogens in circumstances of acute stress. A single dose of *Rhodiola rosea* prior to acute stress produces favorable results and prevents stress-induced disruptions in function and performance. Acute stress tends to initially impact monoamine levels and endorphins, while chronic stress places greater demands on the HPA axis. While this is a generalization and there is obvious overlap in the

stress response, *Rhodiola* does seem to exert a pronounced effect on aspects of the acute stress response. Since many stressful situations are acute in nature, and sometimes unexpected, an adaptogen that can be taken acutely in these circumstances, rather than requiring chronic advance supplementation, could be very useful.

Rhodiola rosea also offers some cardioprotective benefits not associated with other adaptogens. Its proposed ability to moderate stress-induced damage and dysfunction in cardiovascular tissue might make *Rhodiola rosea* the adaptogen of choice among patients at higher risk for cardiovascular disease.

Since *Rhodiola rosea* administration appears to impact central monoamine levels, it might also provide benefits and be the adaptogen of choice in clinical conditions characterized by an imbalance of central nervous system monoamines. This is consistent with Russian claims for improvements in depression and schizophrenia. It also suggests that research in areas such as seasonal affective disorder, fibromyalgia, and chronic fatigue syndrome, to name a few clinical conditions, is warranted.

Administration of *Rhodiola rosea* appears to have potential as an anticancer agent, and might be useful in conjunction with some pharmaceutical antitumor agents. While available evidence is limited to animal models, results appear promising. This is an area that would benefit from additional research.

The clearest indication for *Rhodiola rosea* administration is for the asthenic condition resulting from acute or chronic overwork, which may manifest as decline in work performance, sleep disturbances, poor appetite, irritability, hypertension, headaches, and fatigue.

Some animal and preliminary clinical evidence suggests the need for a narrow range of therapeutic dosage of *Rhodiola rosea*, above and below which beneficial physiological effects might be less likely. Because of this, it

seems prudent to keep doses at a moderate level both in terms of the quantity and duration of supplementation. While *Rhodiola rosea* appears to be a promising plant medicine, and has been investigated intensively in Russia, additional research is required before any conclusions with respect to its therapeutic utility can be made.

References

- Petkov VD, Yonkov D, Mosharoff A, et al. Effects of alcohol aqueous extract from *Rhodiola rosea* L. roots on learning and memory. *Acta Physiol Pharmacol Bulg* 1986;12:3-16.
- Brekhman II, Dardymov IV. New substances of plant origin which increase nonspecific resistance. *Ann Rev Pharmacol* 1969;9:419-430.
- Lishmanov IB, Trifonova ZV, Tsibin AN, et al. Plasma beta-endorphin and stress hormones in stress and adaptation. *Biull Eksp Biol Med* 1987;103:422-424. [Article in Russian]
- Linh PT, Kim YH, Hong SP, et al. Quantitative determination of salidroside and tyrosol from the underground part of *Rhodiola rosea* by high performance liquid chromatography. *Arch Pharm Res* 2000;23:349-352.
- Lee MW, Lee YA, Park HM, et al. Antioxidative phenolic compounds from the roots of *Rhodiola sachalinensis* A. Bor. *Arch Pharm Res* 2000;23:455-458.
- Ohsugi M, Fan W, Hase K, et al. Active-oxygen scavenging activity of traditional nourishing- tonic herbal medicines and active constituents of *Rhodiola sacra*. *J Ethnopharmacol* 1999;67:111-119.
- Visioli F, Galli C, Bornet F, et al. Olive oil phenolics are dose-dependently absorbed in humans. *FEBS Lett* 2000;468:159-160.
- Bonanome A, Pagnan A, Caruso D, et al. Evidence of postprandial absorption of olive oil phenols in humans. *Nutr Metab Cardiovasc Dis* 2000;10:111-120.
- de la Puerta R, Ruiz Gutierrez V, Hoult JR. Inhibition of leukocyte 5-lipoxygenase by phenolics from virgin olive oil. *Biochem Pharmacol* 1999;57:445-449.
- Boon-Niermeijer EK, van den Berg A, Wikman G, Wiegant FA. Phyto-adaptogens protect against environmental stress-induced death of embryos from the freshwater snail *Lymnaea stagnalis*. *Phytomedicine* 2000;7:389-399.
- Stancheva SL, Mosharoff A. Effect of the extract of *Rhodiola rosea* L. on the content of the brain biogenic monamines. *Med Physiol* 1987;40:85-87.
- Maslova LV, Kondrat'ev BI, Maslov LN, Lishmanov IB. The cardioprotective and antiadrenergic activity of an extract of *Rhodiola rosea* in stress. *Eksp Klin Farmakol* 1994;57:61-63. [Article in Russian]
- Lishmanov IB, Maslova LV, Maslov LN, Dan'shina EN. The anti-arrhythmia effect of *Rhodiola rosea* and its possible mechanism. *Biull Eksp Biol Med* 1993;116:175-176. [Article in Russian]
- Maimeskulova LA, Maslov LN, Lishmanov IB, Krasnov EA. The participation of the mu-, delta- and kappa-opioid receptors in the realization of the anti-arrhythmia effect of *Rhodiola rosea*. *Eksp Klin Farmakol* 1997;60:38-39. [Article in Russian]
- Lishmanov IB, Naumova AV, Afanas'ev SA, Maslov LN. Contribution of the opioid system to realization of inotropic effects of *Rhodiola rosea* extracts in ischemic and reperfusion heart damage in vitro. *Eksp Klin Farmakol* 1997;60:34-36. [Article in Russian]
- Azizov AP, Seifulla RD. The effect of elton, leveton, fitoton and adapton on the work capacity of experimental animals. *Eksp Klin Farmakol* 1998;61:61-63. [Article in Russian]
- Lazarova MB, Petkov VD, Markovska VL, et al. Effects of meclufenoxate and Extr. *Rhodiolae roseae* L. on electroconvulsive shock-impaired learning and memory in rats. *Methods Find Exp Clin Pharmacol* 1986;8:547-552.
- Afanas'ev SA, Alekseeva ED, Bardamova IB, et al. Cardiac contractile function following acute cooling of the body and the adaptogenic correction of its disorders. *Biull Eksp Biol Med* 1993;116:480-483. [Article in Russian]
- Maimeskulova LA, Maslov LN. The anti-arrhythmia action of an extract of *Rhodiola rosea* and of n-tyrosol in models of experimental arrhythmias. *Eksp Klin Farmakol* 1998;61:37-40. [Article in Russian]

20. Udintsev SN, Shakhov VP. The role of humoral factors of regenerating liver in the development of experimental tumors and the effect of *Rhodiola rosea* extract on this process. *Neoplasma* 1991;38:323-331.
21. Udintsev SN, Schakhov VP. Decrease of cyclophosphamide haematotoxicity by *Rhodiola rosea* root extract in mice with Ehrlich and Lewis transplantable tumors. *Eur J Cancer* 1991;27:1182.
22. Udintsev SN, Krylova SG, Fomina TI. The enhancement of the efficacy of adriamycin by using hepatoprotectors of plant origin in metastases of Ehrlich's adenocarcinoma to the liver in mice. *Vopr Onkol* 1992;38:1217-1222. [Article in Russian]
23. Germano C, Ramazanov Z, Bernal Suarez M. *Arctic Root (Rhodiola Rosea): The Powerful New Ginseng Alternative*. New York, NY: Kensington Publishing Corp; 1999.
24. Darbinyan V, Kteyan A, Panossian A, et al. *Rhodiola rosea* in stress induced fatigue – a double blind cross-over study of a standardized extract SHR-5 with a repeated low-dose regimen on the mental performance of healthy physicians during night duty. *Phytomedicine* 2000;7:365-371.
25. Spasov AA, Wikman GK, Mandrikov VB, et al. A double-blind, placebo-controlled pilot study of the stimulating and adaptogenic effect of *Rhodiola rosea* SHR-5 extract on the fatigue of students caused by stress during an examination period with a repeated low-dose regimen. *Phytomedicine* 2000;7:85-89.
26. Baranov AI. Medicinal uses of ginseng and related plants in the Soviet Union: recent trends in the Soviet literature. *J Ethnopharmacol* 1982;6:339-353.
27. Hiai S, Yokoyama H, Oura H, Yano S. Stimulation of pituitary-adrenocortical system by ginseng saponin. *Endocrinol Jpn* 1979;26:661-665.
28. Fulder SJ. Ginseng and the hypothalamic-pituitary control of stress. *Am J Chin Med* 1981;9:112-118.
29. Golotin VG, Gonenko VA, Zimina VV, et al. Effect of ionol and eleutherococcus on changes of the hypophyseo-adrenal system in rats under extreme conditions. *Vopr Med Khim* 1989;35:35-37. [Article in Russian]