

Anti Stress Activity of Phytoecdysteroids Isolated from Aerial Part of *Silene claviformis*

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Authors' contributions

This work was carried out in collaboration among all authors. Authors UY and NR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors FE and VS managed the biological analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The aim of present study was to isolate the phytoecdysteroids from aerial part of *Silene claviformis* (Caryophyllaceae) and investigate their biological activity.

Place and Duration of Study: The investigation were carried out during 2019 and 2020 at laboratory of the chemistry of glycosides and department of the pharmacological and toxicology of Institute of the Chemistry of Plant Substances AS RUz, Tashkent, Uzbekistan.

Methodology: The phytoecdysteroids were isolated from aerial part of *Silene claviformis* using chromatographic methods. Thin-layer chromatography made on Silufol UV-254 and Merck plates, Fluka Analytical Germany, by spraying with alcohol solution of vanillin and heating for 1-2 minutes for 90-100^o, UV lamp light at 254 nm and 365 nm. Their structures were confirmed by NMR and IR spectroscopy. Sum of phytoecdysteroids was administered at a dose of 10 mg/kg orally. The data obtained during the experiments were processed and analyzed by the method of variation statistics using the Student t-criterion.

Results: *Silene claviformis* contains 2-deoxyecdysterone (1), polypodine B (2), 20-hydroxyecdysone (3), ecdysterone-20,22-acetalisovaleric aldehyde(4),integristeron A

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(5), cyasterone (6), ecdysterone-20,22-acetalisovalerian (7), 2-deoxy- α -ecdysone (8). The compounds 2 and 6 are reported for the first time from this genus. The biological activity (stress-protective effect) of the mentioned phytoecdysteroids studied for the first time. These compounds were tested on male mice for their biological activities and results showed that, the adrenal gland mass increased in relation to the adrenal gland mass of intact animals by 42.6%, they showed a significant decrease in the content of ascorbic acid and cholesterol by 56.5 and 49.1%, respectively. A significant decrease in glycogen content (by 30.1%) and a noticeable activation of lipid peroxidation processes were noted in the liver, as indicated by an increase of 69.2% in the content of malondialdehyde in the organ.

Conclusion: This is the first study reporting an orally biological investigation for *Silene claviformis*. The sum of phytoecdysteroids showed potent stress-protective activity. The stress-protective effect of phytoecdysteroids was more pronounced in compared the eleutherococcus extract.

Keywords: *Silene claviformis*; phytoecdysteroids; eleutherococcus extract; stress-protective effect.

1. INTRODUCTION

Nowadays the problem of increasing the general nonspecific resistance of the organism to stressful factors is relevant problem due to the frequent work of a human in extremely adverse climatic and industrial conditions, deteriorating environmental conditions, poor nutrition, and many other destabilizing factors. Therefore, the search for substances that can increase the adaptive potential and improve life quality is one of the priority tasks of modern pharmacology [1]. Earlier, it was reported that some phytoecdysteroids may be of noticeable interest in this regard [2,3].

An estimated 5%–6% of the terrestrial plant species accumulate detectable levels of ecdysteroids, among which *Ajuga*, *Serratula* and *Silene* spp., containing high amounts of these compounds are good sources of ecdysteroids [4]. From the point of view of the search for ecdysteroid-containing plants among the representatives of the domestic flora, plants of the genus *Silene* (Smolevka, family *Caryophyllaceae*) seem promising. This genus with about 400 representatives in the world flora, is represented by 153 species in the Commonwealth of Independent States and 84 species in Central Asia [5].

Caryophyllaceae species are known for their rich content in bioactive metabolites, such as flavonoids [6], triterpenesaponins [7], phytoecdysteroids and oligosaccharides [8]. The *Silene* genus (*Caryophyllaceae*) comprises more than 700 species widely distributed in temperate zones of the world [9].

Ecdysteroids represent a large family of steroid hormones that play a crucial role in arthropods'

physiology. The most abundant representative of these compounds, 20-hydroxyecdysone (20E), regulates the reproduction, embryogenesis, diapauses and molting of arthropods [10]. Their role in plants is still to be fully understood, but it had been suggested that they have high importance in several plants as defensive agents against non-adapted herbivores [11]. Ecdysteroids secreted from plants (phytoecdysteroids) being in most cases hormones for arthropods, they are not for warm-blooded ones [12]. However, they were able to regulate many physiological processes in their bodies [13,14]. In this case, phytoecdysteroids do not have toxic or any side effects [15]. It was found that the beneficial shifts occurring under the influence of phytoecdysteroids in the mammalian organism are accompanied by a noticeable improvement in their functional status, which is manifested by activation of the central nervous system, increased efficiency, and increased adaptive capabilities of the body to environmental stressors [16]. Under the influence of phytoecdysteroids, the production of conditioned defense reflexes accelerated, the endurance of animals in relation to various physical activities increased [17,18]. Their sexual behavior intensified [19]. An increase in the resistance of animals after the introduction of phytoecdysteroids to stressful environmental factors was noted [20,21]. Some attention should be paid to the data on the ability to resist various helminthes infections using ecdysteroids [22].

Plants of the genus *Silene* (*Caryophyllaceae*) are known as sources of ecdysteroids, a class of compounds with adaptogen and anabolic activity [23].

Silene claviformis is a perennial grassy plant (size 15-25cm) growing on the slopes of the lower belt of Tashkent and Samarkand districts mountains. It is widespread in Central Asia.

The present deals with the isolation and structure elucidation of eight known phytoecdysteroids (Fig. 1) from the buthanol extract of aerial parts of *Silene claviformis*. Since several isolated compounds were described as possessing an interesting stress-protector activity, we found it pertinent to evaluate the stress-protector activity of the sum of ecdysteroids.

2. MATERIALS AND METHODS

2.1 Plant Material

Plants of *Silene claviformis* was collected in June, 2018 from Tashkent region of mountains and the plant materials were identified by Dr. Nigmatullayev A.M. at the Institute of the Chemistry of Plant Substances (ICPS), Uzbekistan. A voucher specimen (No. 2518) has been deposited in the herbarium of Department of Herbal Plants in the ICPS, Tashkent, Uzbekistan.

2.2 General Remarks

The isolated individual ecdysteroids have been identified on the basis of the IR spectroscopy, and ^1H NMR spectroscopy, R_f and melting point on the A.Kruss Optronic Germany, M 5000; 90-264 VIAC, as well as by comparison with reference compounds. Silicagel KSK 100/160 μm have been used for column chromatography. Thin-layer chromatography made on Silufol UV-254 and Merck plates, Fluka Analytical Germany, by spraying with alcohol solution of vanillin and heating for 1-2 minutes for 90-100 $^\circ$, UV lamp light at 254 nm and 365 nm. The NMR ^1H and ^{13}C spectra were recorded by VN MRS-400 Plus (Varian) NMR spectrometer with an operating frequency of 400 MHz.

2.3 Experimental Animals

This study was performed using male mice with body weight varies from 19-20 g. Mice were kept in one polyacrylic cage and all mice were quarantined for 1 week before the experiments. All animals were housed under standard controlled conditions with temperature of $24 \pm 2^\circ\text{C}$, humidity of $50\% \pm 5\%$ and 12-h light/dark cycle. Mice were given free access to food

(standard commercial mice chow) and water as well as received care according to European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes (Strasbourg, 1986).

3 EXPERIMENTAL CHEMICAL PART

3.1 Extraction

The freshly collected whole plant material (1kg) was air dried at 23°C for 1 week after collection and then grounded into powder with a Waring blender. After grinding, plant material was triturated with MeOH (3x5L) (each for 3days) at room temperature (23°). The extracts were combined and evaporated (in a rotary vacuum evaporator at 40°) and 52g of dried extract was obtained. The crude extract was suspended in water and hydrophobic compounds were removed upon partition with chloroform (CHCl_3), after with ethyl acetate (EtOAc) and then n-butanol BuOH. The combined butanol extracts were evaporated to dryness under reduced pressure (at 46°C).

3.1.1 Isolation of phytoecdysteroids using column chromatography

The BuOH extract (20g) was chromatographed over a silica gel column (silica particle size: 63-100 μm ; Chemapol, Prague, Czech Republic). The column packed using a simple dry-pack method. The butanol extract was applied in dried form mixed with silica gel and carefully added to the top of the column. The column (750g silica size 10x60cm) was eluted with CHCl_3 -MeOH in the ratio of 100:1, 90:1, 80:1, 73:1, 65:1, 60:1, 50:1, 40:1, 30:1, 20:1, 12:1, 9:1, 4:1, 2:1, 1:1 to yield four fractions. Fraction 1 (2.5g) was obtained containing a mixture of less polar ecdysteroids and was further subjected to column chromatography and eluted with MeOH-EtOAc (50:1) to yield compounds as 2-deoxyecdysterone(1) (0.11g), 20-hydroxyecdysone (3) (0.31g), ecdysterone-20,22-acetalisovaleric aldehyde(4) (0.006g). Repeated chromatography of fraction. 2 (3.5g) over a silica gel column (MeOH-EtOAc in the ratio of (30:1), (12:1); MeOH- CHCl_3 in the ratio of (9:1), (6:1) and (4:1)) yielded pure integristerone A (5) (0.07g). Fraction 3 (3.1g) was subjected to column chromatography, eluted with MeOH-EtOAc in the ratio of (20:1) and MeOH- CHCl_3 in the ratio of (15:1), (12:1) to obtain ecdysterone-20, 22-acetalisovalerian (7) (0.0062g). 2-deoxy- α -ecdysone (0.22g), compounds (8) was

obtained from fraction 4 (4.3g), which was separated through repeated column chromatography (MeOH-EtOAc in the ratio of 6:1, 4:1).

The fraction 5 (2.9g) and fraction 6 (2.7g) were subjected to column chromatography on silica gel, eluting with CHCl₃-MeOH increasing order of polarity. (100:1, 80:1, 60:1, 50:1, 30:1, 20:1, 15:1, 12:1, 9:1, 4:1, 1:1) and obtained pure compounds from this fractions such as polygodine B (2) (0.028g) and cyasterone (6) (0.075 g).

3.2 Experimental Biological Part

The experiments were performed on male mice weighing 19–20 g. The general stress response was caused by hanging them by the back cervical fold for 18 hours [24]. Sum of phytoecdysteroids was administered at a dose of 10 mg/kg orally (in the form of an aqueous emulsion with Arabian gum) immediately before the experiment. The reference preparation was eleutherococcus liquid extract manufactured by Dalkhimprom OJSC, administered orally at a dose of 0.2 ml/20 g body weight (previously dealcoholized), which, under appropriate conditions was able to increase the organism's adaptive capacity for stressful effects [25]. Control animals received an adequate amount of an aqueous emulsion of Arabian gum. The effectiveness of phytoecdysteroids was assessed by the degree to which it prevented changes in the mass of the adrenal glands (the content of ascorbic acid and cholesterol in them), thymus, spleen and liver, observed under acute stress

[24,25]. Additionally, glycogen content and malondialdehyde (MDA) were determined in the liver and the number of ulcers formed in the stomach was also calculated [26]. The sum of phytoecdysteroids and eleutherococcus extract were introduced after the first swim (water temperature 27-28°C). The antitoxic and antihypoxic effect of the sum of phytoecdysteroids also attributed to adaptogenic agents [1], was evaluated first by the survival of mice with intraperitoneal administration of a 25% ethanol solution at a dose of 9.8 g/kg, and then on the model of tissue hypoxia caused by intraperitoneal administration of sodium nitroprusside at a dose of 25 mg/kg [27,28]. The data obtained during the experiments were processed by the method of variation statistics using the Student t-criterion.

4. RESULTS AND DISCUSSION

4.1 Phyto-chemical Analysis

A preliminary investigation of *Silene claviformis* plant has confirmed the presence of phytoecdysteroids in its composition and allowed to isolate and identify its main eight ecdysteroids (e.g. see Fig. 1), such as (1) 2-deoxyecdysterone (0.011%), (2) polygodine B (0.0028%), (3) 20-hydroxyecdysone (0.031%) of dry plant's weight [29], (4) ecdysterone-20,22-acetalisovaleric aldehyde (0.0006%) [30], (5) integristeron A (0.007%) (6) cyasterone (0.0075%) [31], (7) ecdysterone-20,22-acetalisovalerian (0.00062%) [30], (8) 2-deoxy- α -ecdysone (0.02%) [32].

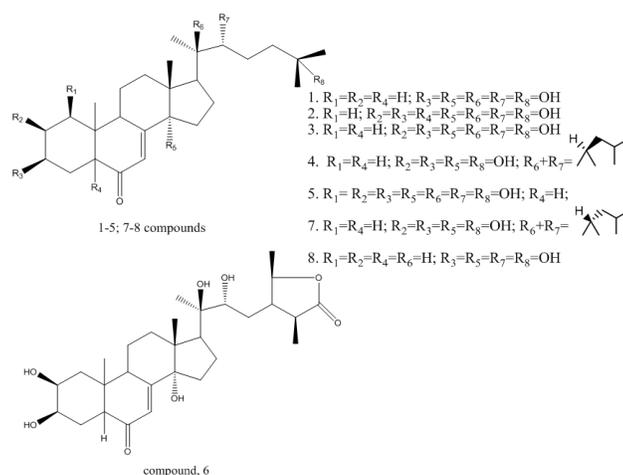


Fig. 1. Structure of compounds 1-8 from *Silene claviformis*

Table 1. Physico-chemical properties of phytoecdysteroids isolated from *Silene claviformis*

Compound no.	Compound name	Composition	Temperature (°C)	Yield,% of plant mass
1	2-Deoxy-20-hydroxyecdysone	C ₂₇ H ₄₄ O ₆	254-255	0.011%
2	Polypodine B	C ₂₇ H ₄₄ O ₈	253-254	0.028%
3	20-Hydroxyecdysone	C ₂₇ H ₄₄ O ₇	242-243	0.031%
4	Hydroxyecdysone-20,22-acetylisovaleraldehyde	C ₃₂ H ₅₂ O ₇	-	0.0006%
5	Integristerone A	C ₂₇ H ₄₄ O ₈	247-248	0,007%
6	Cyasterone	C ₂₉ H ₄₄ O ₈	163-164	0.0075%
7	Hydroxyecdysone-20,22-acetylisovaleraldehyde	C ₃₂ H ₅₂ O ₇	-	0.00062%
8	2-Deoxy-α-ecdysone	C ₂₇ H ₄₄ O ₅	233-234	0.023%

4.1.1 2-deoxyecdysterone (1)

White powder, mp 240–241°C, $[\alpha]_D^{23} + 81.2 \pm 2^\circ$ (c 0.50; metanol). ¹³C NMR spectrum (100 MHz, C₅D₅N-d₆, δ, ppm): 30.01 (C-1), 28.05 (C-2), 65.28 (C-3), 34.03 (C-4), 55.70 (C-5), 202.16 (C-6), 120.12 (C-7), 165.94 (C-8), 34.98 (C-9), 38.54 (C-10), 21.47 (C-11), 31.67 (C-12), 47.51 (C-13), 83.87 (C-14), 31.76 (C-15), 21.77 (C-16), 49.88 (C-17), 17.69 (C-18), 23.29 (C-19), 76.87 (C-20), 21.65 (C-21), 76.86 (C-22), 28.77 (C-23), 42.58 (C-24), 68.89 (C-25), 30.21 (C-26), 30.44 (C-27).

4.1.2 Polypodine B (2)

White powder, mp 250–251°C, $[\alpha]_D^{23} + 94.2 \pm 2^\circ$ (c 0.50, MeOH). ¹³C NMR spectrum (100 MHz, DMSO-d₆, δ, ppm): 33.359 (C-1), 68.405 (C-2), 68.757 (C-3), 34.904 (C-4), 78.500 (C-5), 199.768 (C-6), 119.354 (C-7), 165.037 (C-8), 36.965 (C-9), 43.832 (C-10), 21.100 (C-11), 30.949 (C-12), 46.866 (C-13), 82.873 (C-14), 30.312 (C-15), 20.249 (C-16), 48.619 (C-17), 17.210 (C-18), 16.512 (C-19), 76.232 (C-20), 21.034 (C-21), 75.709 (C-22), 26.123 (C-23), 41.445 (C-24), 66.423 (C-25), 29.028 (C-26), 30.090 (C-27).

4.1.3 20-Hydroxyecdysone (3)

White crystals, mp 240–241°C (Me₂CO), $[\alpha]_D^{23} + 63.2 \pm 2^\circ$ (c 6.30, MeOH). UV spectrum (C₂H₅OH, λ_{max}, nm) (log ε): 245 (4.01). IR spectrum (KBr, ν, cm⁻¹): 3435 (OH), 1665 (7-en-6-keto group).

Compound **3** was identified by direct comparison of its thin layer chromatography with that of an authentic sample of 20-hydroxyecdysone [29].

4.1.4 Ecdysterone-20,22-acetalisovaleric aldehyde(4)

UV spectrum (C₂H₅OH, λ_{max}, nm) (log ε): 242 (4.01). IR spectrum (KBr, ν, cm⁻¹): 3440 (OH), 1670 (7-en-6-keto group).

Compound **4** was identified by direct comparison of its thin layer chromatography with that of an authentic sample of 20-hydroxyecdysone [30].

4.1.5 Integristeron A (5)

White powder, mp 246–248°C, $[\alpha]_D^{23} + 36.1 \pm 2^\circ$ (c 0.43; metanol). UV spectrum 245nm (lgε 4.00). in IR spectrum 3400 and 1660cm⁻¹.

4.1.6 Cyasterone(6)

White powder, mp 157–158°C, $[\alpha]_D^{23} + 60.0 \pm 2^\circ$ (c 1.0, Py). ¹³C NMR spectrum (100 MHz, C₅D₅N, δ, ppm): 32.959 (C-1), 68.556 (C-2), 68.622 (C-3), 34.987 (C-4), 51.903 (C-5), 203.961 (C-6), 122.359 (C-7), 166.343 (C-8), 38.480 (C-9), 42.962 (C-10), 21.868 (C-11), 32.568 (C-12), 48.704 (C-13), 84.669 (C-14), 32.417 (C-15), 21.498 (C-16), 49.210 (C-17), 18.427 (C-18), 16.432 (C-19), 77.305 (C-20), 21.620 (C-21), 74.513 (C-22), 50.533 (C-23), 39.223 (C-24), 40.423 (C-25), 179.716 (C-26), 24.962 (C-27), 80.359 (C-28), 19.860 (C-29)

4.1.7 Ecdysterone-20, 22-acetalisovalerian (7)

UV spectrum (C₂H₅OH, λ_{max}, nm) (log ε): 242 (4.01). IR spectrum (KBr, ν, cm⁻¹): 3440 (OH), 1670 (7-en-6-keto group).

Compound **7** was identified by direct comparison of its thin layer chromatography with that of an authentic sample of 20-hydroxyecdysone [30].

Compound **7** had the same molecular mass as **4** and presented the same NMR features except a triplet at (δ 5.05; t: 5.3; 1H) in place of the triplet signal a-H (δ 5.28; t: 5.2; 1H) for **4**. This triplet could be assigned to the signal observed for an epimer of **4** at the asymmetric carbon of the acetal function.

4.1.8 2-Deoxy- α -ecdysone(**8**)

White powder, mp 240–241°C, $[\alpha]_D^{23} + 92.1 \pm 2^\circ$ (c 0.55; metanol). ^{13}C NMR spectrum (100 MHz, $\text{C}_5\text{D}_5\text{N}$ -d6, δ , ppm): 29.49 (C-1), 28.07 (C-2), 59.86 (C-3), 33.12 (C-4), 51.65 (C-5), 202.42 (C-6), 121.40 (C-7), 166.33 (C-8), 34.48 (C-9), 37.01 (C-10), 21.01 (C-11), 31.72 (C-12), 48.01 (C-13), 84.04 (C-14), 31.73 (C-15), 24.87 (C-16), 48.22 (C-17), 16.00 (C-18), 24.44 (C-19), 43.00 (C-20), 14.72 (C-21), 74.10 (C-22), 26.80 (C-23), 42.48 (C-24), 70.02 (C-25), 29.92 (C-26), 30.45 (C-27).

4.2 Biological Part

In control mice hanging by the neck fold for a long time, a rather characteristic picture of the stress reaction developed [24,25]. Their adrenal gland mass increased in relation to the adrenal gland mass of intact animals by 42.6%, they showed a significant decrease in the content of ascorbic acid and cholesterol by 56.5 and 49.1%, respectively. The mass of thymus gland decreased by 39.5, the spleen - by 48, and the liver by 24.4%. A significant decrease in glycogen content (by 30.1%) and a noticeable activation of lipid peroxidation processes were noted in the liver, as indicated by an increase of 69.2% in the content of *malondialdehyde* in the organ. Although a few, but distinct ulcerations were observed in the stomach (see Table 2).

The introduction (before starting of the stressful effect) sum of phytoecdysteroid to mice in many respects impeded the development of the noted negative changes in the animal organism. First of all, the phytoecdysteroid sum substantially inhibited the adrenal hypertrophy and the decrease of ascorbic acid and cholesterol in their content. As a result, the adrenal mass was only 9.8% higher in this group of animals than in intact animals at $p > 0.05$. The content of ascorbic acid and cholesterol at the same time had a clear tendency to normalize (only 8.4 and 15.4% lower than intact values).

The phytoecdysteroid sum also protected the thymus and spleen from involution. Their mass in this case was only 8.9 and 11.6 lower than that of intact animals. The phytoecdysteroid sum significantly prevented trophic disturbances in the gastric mucosa, and significantly reduced the number of bleeding ulcerations in it. Table 2 shows that the sum of phytoecdysteroids was not inferior to the known *Eleutherococcus* extract with the same action in their ability to increase the adaptive potential of the body to a stressful effect [25], and in some cases had an even more pronounced effect.

A high ability of phytoecdysteroids sum to increase the general non-specific resistance of the body to complex or adverse environmental conditions was also revealed in a series of other experiments. The mice after swimming to complete fatigue (rather severe stress associated with the fact that water is not their characteristic habitat) were removed from the bath with water and at the same time, injected the amount of phytoecdysteroids (similarly to the reference drug), then had one hour rest, and again forced to swim.

The obtained results presented in Table 3. In intact (in this version of the experiment — control animals), the duration of repeated swimming in relation to the first was 45.2%. Under the influence of phytoecdysteroid sum and *eleutherococcus* extract, the recovery process was faster. In the first case, the duration of the repeated swimming in relation to the previous was 89.1%, and in the second - 80.0%, respectively. Table 4 shows that the sum of phytoecdysteroids, like the extract of *eleutherococcus*, exhibits a very distinct antitoxic effect to alcohol (attributed to adaptogenic remedies [28]). So, the introduction of 25% ethanol solution at a dose of 9.8 g/kg, all control animals died. The death rate of individuals in the group of mice receiving the sum of phytoecdysteroids was 45%, and in the group of mice receiving *eleutherococcus*, the antitoxic effect to alcohol is very pronounced (65%).

A similar pattern observed in the tissue hypoxia model. Preliminary single administration of the phytoecdysteroid sum increased the life expectancy of mice with intraperitoneal administration of sodium nitroprusside by 74%. *Eleutherococcus* extract in this case was less effective (effect only 31%) (see Table 5).

Table 2. The effect the sum of phytoecdysteroid on some manifestations of the stress response in mice under conditions of stress hanging in comparison with the extract of eleutherococcus (M ± m, n=6)

Experiment conditions	Intact animals	Stress		
		Control	Sum of phytoecdysteroids	Extract of eleutherococcus
Mass of organs, mg				
Adrenal glands	6.1 ± 0.27	8.7 ± 0.67 ¹	6.7 ± 0.33 ²	7.0 ± 0.36 ²
Thymus	48,3 ± 2,1	29.2 ± 1,9 ¹	44.0 ± 1,9 ^{2,3}	34,2 ± 0.94 ^{1,2}
Spleen	177,6 ± 7.6	92.0 ± 7,2 ¹	157,0 ± 6.2 ^{2,3}	122,4 ± 4.8 ^{1,2}
Liver	3106 ± 192	2349 ± 170 ¹	2957 ± 163 ²	2678 ± 159
Content, mg %				
Ascorbic acid in adrenal glands	299 ± 10,6	130 ± 7.5 ¹	274 ± 9.9 ^{2,3}	169 ± 7.0 ^{1,2}
Cholesterol in adrenal glands	2153 ± 113	1097 ± 52.7 ¹	1871 ± 108 ^{2,3}	1407 ± 32.6 ^{1,2}
Glycogen in liver	1861 ± 67.4	1301 ± 86.6 ¹	1748 ± 42.2 ²	1590 ± 57.4 ^{1,2}
malondialdehyde in liver, nmol/mg of protein	0.500 ± 0.04	0,846 ± 0.03 ¹	0,516 ± 0.03 ^{2,3}	0,619 ± 0.02 ^{1,2}
Stomach ulcers				
Total	-	1.51 ± 0.43	0.3 ± 0.21 ²	1.0 ± 0.36 ³

Note: * - Reliably in relation to the corresponding indicators of intact animals, 2 - to the control, 3 - reliably between groups of animals receiving the sum of phytoecdysteroids and eleutherococcus extract (p < 0.05)

Table 3. The effect of phytoecdysteroid sum on the recovery process after "physical work" to complete fatigue in comparison with the extract of eleutherococcus (M ± m, n=6)

Experiment conditions	First swimming duration	Repeat swimming duration	Duration of repeated swimming in relation to the first one, %
Intact animals	33.3 ± 1.3	15.3 ± 0.76 ¹	45.9
Phytoecdysteroid sum	34.0 ± 1,5	30.3 ± 1.3 ²	89.1
Extract of eleutherococcus	33.5 ± 1.2	26.8 ± 1.2 ^{1,2}	80.0

Note: 1 - Reliably in respect to the duration of the first swimming control, 2 - reliably between the duration of repeated swimming of intact animals and those receiving the sum of phytoecdysteroids and eleutherococcus extract (p < 0.05)

Table 4. The effect of the phytoecdysteroids sum on the survival of mice after intraperitoneal administration of lethal dose of ethanol in comparison with the extract of eleutherococcus

Experiment conditions	Number of animals in the group	Number of dead animals			
		In 1 hour		In 24 hours	
		Unit	%	Unit	%
Control	20	5	25	15	100
Phytoecdysteroids sum	20	3	15	9	45
Extract of eleutherococcus	20	4	13	13	65

Table 5. The effect of the phytoecdysteroids sum on the life expectancy of mice with tissue hypoxia in comparison with the eleutherococcus extract (M ± m, n=6)

Experiment conditions	Number of animals in the group	Life expectancy	Life expectancy increase (%)
Control	10	9.3 ± 0.52	
Phytoecdysteroids sum	10	16.2 ± 1.5 ^{1,***}	74
Extract of eleutherococcus	10	12.2 ± 0.66 ¹	31

Note: 1 - Reliably in respect to the control, 2 - reliably between the duration of intact animals and those receiving the sum of phytoecdysteroids and eleutherococcus extract (p < 0.05)

The ability of the sum of phytoecdysteroids to prevent negative changes in the animal organism under acute stress accompanied by disturbances in individual metabolic processes indicated the possibility of its use to prevent the development of the pathological changes symptom complex in response to various destabilizing factors affecting both individual organs and systems, and the organism as a whole.

5. CONCLUSION

Our studies conclude that *Silene claviformis* contains 2-deoxyecdysterone (1), polypodine B (2), 20-hydroxyecdysone (3), ecdysterone-20,22-acetalisovaleric aldehyde(4), integristeron A (5), cyasterone(6), ecdysterone-20,22-acetalisovalerian (7), 2-deoxy- α -ecdysone(8). The compounds 2 and 6 are reported for the first time from this genus.

The biological activity (stress-protective effect) of the mentioned phytoecdysteroids studied for the first time. The sum of phytoecdysteroids reduces negative changes in mice after immobilization stress. It prevents the involution of the thymus and spleen and increases adrenal glands mass (i.e., normalizes the content of ascorbic acid and cholesterol in the adrenal glands). In the liver of animals after stress, the sum of phytoecdysteroids prevents a sharp decrease of glycogen, eliminates the imbalance of lactic and pyruvic acids, supports homeostasis of macroergic phosphoric compounds, increases the activity of antioxidant enzymes, and inhibits lipid peroxidation. The stress-protective effect of phytoecdysteroids was more pronounced in compare to the eleutherococcus extract.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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