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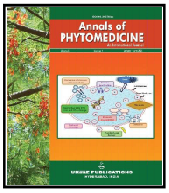

Review article: Open access

Phytochemical, pharmacological and biological properties of *Ajuga turkestanica* (Rgl.) Brig (Lamiaceae)

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Abstract

Ajuga turkestanica (Rgl.) Brig (Lamiaceae) is a medicinal, herbaceous flowering species which has been traditionally used in Uzbekistan for cure of various human diseases like, heart disease, muscle aches and stomach problems. This plant possesses diverse pharmacological activities, antibacterial activity, hypoglycemic activity, hypolipidemic action, anabolic activity: growth promotion, increase in protein synthesis in skeletal muscle cells, hepatoprotection activities. Several compounds have been isolated from *A. turkestanica*, which display a wide spectrum of biological and pharmacological activities. This review provides scientific information on the biologically active substances of the medicinal plant *A. turkestanica*, their structure, pharmacology, and applications in pharmaceuticals and medicine.

1. Introduction

There are more than 4,500 vascular plants in the flora of Uzbekistan, 9% of which are endemic, and the medicinal plant *Ajuga turkestanica* (Rgl.) Brig which is the object of our study, is also an endemic species. The medicinal plant, *A. turkestanica* is distributed as an endemic species in the Pamir Alay mountains of Boysun district. The mountainous areas of Boysun include the Hissar and Pamir Alay mountains. The Pamir-Alay is a mountain system in Tajikistan, Kyrgyzstan and Uzbekistan, encompassing various mountain ranges extending west from the Tian Shan Mountains, and located north of the main range of Pamir. It stretches between the valleys of the rivers Syr Darya (Fergana Valley) to its north and Vakhsh to its south. Part of these mountainous areas falls on the Surkhandarya region of Uzbekistan. According to the scientific literature, the flora of Surkhandarya is second only to the Transcaucasian republics in terms of species composition. This shows that Surkhandarya is rich in plants. There are more than 4,500 plant species in the country, of which 1646 species are found in the region. This fact shows that the flora of Surkhandarya region is rich and diverse. For this reason, there has long been a great interest in the study of the flora of this country. The flora of Surkhandarya region is part of the flora of Uzbekistan, of which 126 species are listed in the Red Book. These plant species belong to 105 families. *A. turkestanica* accumulates high levels of plant secondary compounds, known as phytoecdysteroids, which are the purported bioactive constituents and the focus of this research. The genus *Ajuga* is the part of the Lamiaceae family, comprisesed of 50 species, and about 300 taxa (including subspecies and varieties), distributed in Asia, Africa, Australia, North America, and Europe.

2. The use of *Ajuga* plants in traditional medicine

A. turkestanica is a widely used medicinal plant in the pharmaceutical industry, antimalarial and many species of medicinal plants, belonging to the *Ajuga* family (Njoroge and Bussmann, 2006), hypoglycemic (El-Hilaly *et al*., 2004), several scientific studies have shown its anti-inflammatory biological activity.

Studies of the phytochemical properties of *Ajuga* medicinal plants have shown that plants contain biologically active secondary metabolites, such as iridoids, diterpenes, phytoecsteroids, flavonoids, sterol glycosides and phenylethonoid glycosides. The pharmacology and therapeutic value of plants including *Ajuga reptans* have been described as early as 1948 (Newman, 1948). In

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East Africa, plants of the genus *Ajuga* have been used as a remedy for fever, toothache, dysentery, and high blood pressure (Baytop, 1984; Githinji and Kokwaro, 1993). Medicinal plants belonging to the *Ajuga* family for the treatment of diabetes in North Africa (Ziyyat *et al*., 1997; Jouad *et al*., 2001; Bnouham *et al*., 2002; Tahraoui *et al*., 2006; Eddouks *et al*., 2007), as well as various diseases associated with gastrointestinal diseases (Baytop, 1984; Bellakhdar *et al*., 1991) and finally high degree of effect. From the scientific literature, it is known that it is widely used in pharmaceuticals as an anthelmintic drug (Wessner *et al*., 1992; Rodriguez-Hahn *et al*., 1994; Yun *et al*., 1998).

The results of scientific research among medicinal plant species belonging to the *Ajuga* family show that plants belonging to this family, are antibacterial (Chen *et al*., 1996a; Chen *et al*., 1997; Bennaghmouch *et al*., 2001), antifungal (Kariba, 2001), in inflammatory diseases (Marc *et al*., 2008), as an antioxidant (Chenni *et al*., 2007), as an agent against insects and their larvae (Camps *et al*., 1981a; Camps and Coll, 1993; Bremner *et al*., 1998; Bondì *et al*., 2000; Fekete *et al*., 2004) are used in pharmaceuticals and agriculture.

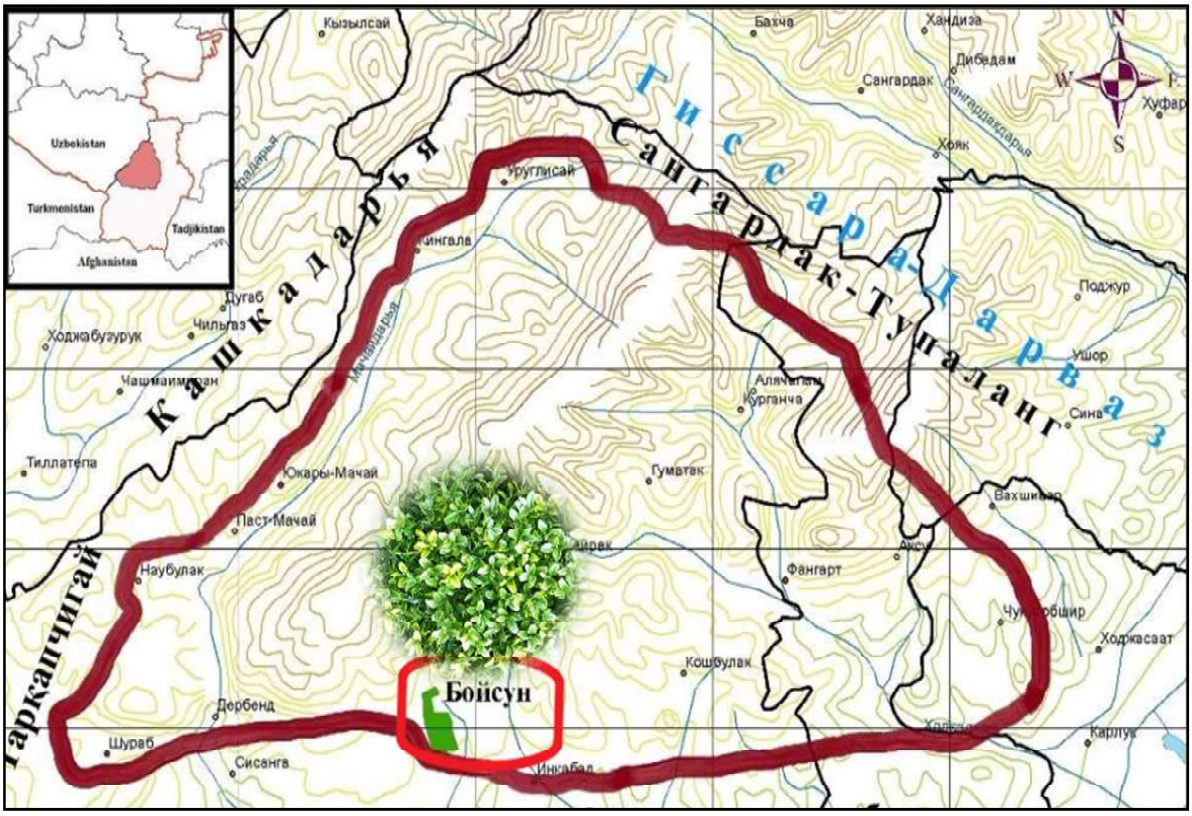

Figure 1: The area where the medicinal plant *A. turkestanica* is spread is Boysun district of Surkhandarya region (Botanical and Geographical map of Boysun).

3. Compounds isolated from plants of genus *Ajuga*

Like many medicinal plants belonging to the Lamiaceae family, biologically active secondary metabolites used in traditional medicine, pharmaceuticals, have been isolated from plants belonging to the genus *Ajuga*. For example, terpenoids (Camps *et al*., 1979; Camps *et al*., 1981b; Camps *et al*., 1982a; Camps *et al*., 1982b; Camps *et al*., 1984a; Camps *et al*., 1984b; Beauchamp *et al*., 1996; Chen *et al*., 1996a; Chen *et al*., 1997; Bremner *et al*., 1998; Cantrell *et al*., 1999; Ben Jannet *et al*., 1999; Ben Jannet *et al*., 2006; Castro *et al*., 2008), sterols (Cantrell *et al*., 1999; Akbay *et al*., 2003a), iridoids and glycosides (Kotenko *et al*., 1993; Takasaki *et al*., 1998; Akbay *et al*., 2003b), quinones (Khan *et al*., 1999a). Biologically active secondary metabolites have been isolated. There are many different types of medicinal plants on Earth. Among them are plant species of special interest. Such plants are plants of the genus *Ajuga*, which produce from their bodies biologically active secondary metabolites of phytoecteroid nature (Aliotta and Pollio, 1994; Baltaev, 2000; Báthori and Pongrâcz, 2005). Biologically active secondary metabolites, such as exteroids, diterpenes, phytoexteroids, flavonoids, glycosides, were isolated from the Uzbek. endemic plant *A. turkestanica*.

Table 1: Some biologically active substances isolated from plants of the genus *Ajuga*

Medicinal plant	Family	Compounds	Reference
Ajuga australis R. Br	Lamiaceae	Amarasterone A Cyasterone Ecdysone 20-Hydroxyecdysone Makisterone A	Darvas *et al*. (1998)
A. bracteosa Benth	Lamiaceae	Cyasterone 20-Hydroxyecdysone	Darvas *et al*. (1998)
A. chamaepitys	Lamiaceae	Cyasterone 20-Hydroxyecdysone Makisterone A	Camps *et al*. (1985)
A. chameacistus	Lamiaceae	Cyasterone 20-Hydroxyecdysone	Kubo *et al*. (1982)
A. chia Schreb	Lamiaceae	Cyasterone 20-Hydroxyecdysone	Ikan and Ravid (1971) Makhsudov and Saatov (1995) Usmanov *et al*. (1971)
A. ciliate	Lamiaceae	20-Hydroxyecdysone	Matsuoka *et al*. (1969)
A. decumbens Thunb	Lamiaceae	Ajugalactone Ajugasterone C Cyasterone Decumbesterone A 20-Hydroxyecdysone	Koreeda *et al*. (1971) Imai *et al*. (1969a) Takasaki *et al*. (1999)
A. incisa Maxim	Lamiaceae	Ajugasterone B Cyasterone 20-Hydroxyecdysone Polypodine B	Imai *et al*. (1969a)
A. iva Schreb	Lamiaceae	Ajugasterone B Cyasterone 24(28)-Dehydromakisterone A 24,25-Dehydroprecysterone 23-Hydroxycyasterone 24-Hydroxycyasterone 20-Hydroxyecdysone Makisterone A 22-Oxocyasterone (22-dehydrocyasterone)]	Coll *et al*. (2007) Knafagy *et al*. (1979) Wessner *et al*. (1992) Sabri *et al*. (1981) Ikan and Ravid (1971)
A. japonica Miq	Lamiaceae	Ajugasterone C Cyasterone 20-Hydroxyecdysone	Imai *et al*. (1969b)
A. laxmanni Benth	Lamiaceae	20-Hydroxyecdysone Makisterone A	Darvas *et al*. (1998) Bergamasco and Horn (1983)
A. linearifolia Pampan	Lamiaceae	Cyasterone 20-Hydroxyecdysone	Darvas *et al*. (1998) Bergamasco and Horn (1983)
Ajuga macrosperma var. *breviflora*	Lamiaceae	Ajugacetalsterone C Ajugacetalsterone D Breviflorasterone Cyasterone 20-Hydroxyecdysone 20-Hydroxyecdysone-2-acetate 20-Hydroxyecdysone-3-acetate Makisterone A	Castro *et al*. (2008)
A. multiflora	Lamiaceae	Cyasterone 20-Hydroxyecdysone Makisterone A	Darvas *et al*. (1998) Yul *et al*. (1998) Coll *et al*. (2007)

Medicinal plant	Family	Compounds	Reference
A. nipponensis Makino	Lamiaceae	Ajugacetalsterone A Ajugacetalsterone B Ajugasterone C Ajugasterone D Cyasterone Cyasterone-22-acetate 22-Dehydrocyasterone-2-glucoside 20-Hydroxyecdysone 22-Oxocyasterone (22-dehydrocyasterone) Polypodine B	Coll *et al*. (2000) Zeng *et al*. (2003) Chou and Lu (1980) Lafont (1989) Imai *et al*. (1969a)
A. reptans L.	Lamiaceae	Ajugalactone Ajugasterone B Cyasterone 20-Hydroxyecdysone 20-Hydroxyecdysone-22-acetate 29-Norcyasterone 29-Norcyasterone-2-acetate 29-Norsengosterone Polypodine B Reptansterone Sengosterone Viticosterone E	Camps *et al*. (1982a) Calcagno *et al*. (1996) Alexeeva *et al*. (1998) Hikino *et al*. (1968)
A. taiwanensis	Lamiaceae	Ajugalide E Cyasterone Cyasterone-22-acetate	Chan *et al*. (2005)
A. reptans var. atropurpurea	Lamiaceae	Ajugalactone Cyasterone Cyasterone-3-acetate 2-Dehydroajugalactone 3-Dehydroajugalactone 22-Dehydro-12-hydroxycyasterone 22-Dehydro-12-hydroxy-29-norcyasterone 22-Dehydro-12-hydroxy-29-norsengosterone 22-Dehydro-12-hydroxysengosterone 5,29-Dihydroxycapitasterone	Calcagno *et al*. (1996) Alexeeva *et al*. (1998)

4. Morphobiological characteristics of the medicinal plant *A. turkestanica*

A. turkestanica in the family Lamiaceae, was found in the Boysun mountainous region of Central Asia, Uzbekistan. This is a perennial herb that blooms in spring and forms pale purple inflorescences. The locals *A. turkestanica*, which means **"sanabor"**, *i.e.*, charmer, traditionally use it as a tonic and liver protection agent (Syrov *et al.*, 2003). The genus *Ajuga* is traditionally used for medicinal properties in many regions of the world (Hilaly *et al*., 2004).

5. Description

The body length of the plant reaches 40-60 cm. The stems are ascending, sometimes lying, hairy, hollow, thematically unknown 4-sided. The leaves are simple, elliptical or oblong, with a pointed tip, with straight edges. The lower part of the stem is located opposite the leaf strip. The flowers are small, light pink, located in the axils of two leaves. The fruit consists of four nuts, which are characteristic of the whole family of Lamiaceae.

Figure 2: *Ajuga turkestanica* (Rgl.) Brig.

6. Distribution

Pamir Alay, South-western Gissar (Kokhitang and Boysun), low mountains in southern Tajikistan. Grows on clay, petrous and rubbly slopes, rocks, taluses. Reaches elevation of up to 2500 m.

Feature: Medicinal

Used part: Root and body parts

Ingredients: Phytoecdizon contains: turkesterone, ecdisterone, ciasterone, ayugstan, (on the leaf): ecdisterone, ayugalactone, ayugasterone and other substances.

Use in traditional medicine: In folk medicine, this plant is used to prevent obesity, hair loss and gastrointestinal diseases. In medicine, substances derived from this plant are used in the treatment of cardiovascular diseases (myocardial infarction) (Chandel and Bagai, 2010; Sher and Al-Yemeni, 2011; Kaithwas *et al.*, 2012; Ahmad *et al.*, 2012; Ahmad *et al.*, 2014; Jan *et al.*, 2014).

Table 2: Ethnobotany and traditional use of plants of *A. turkestanica*

Name	Flowers	Phenology	Population status	Pharmacological properties and treatments	Traditional use
A. turkestanica (Rgl.) Brig.	solitary, axillary(bright pink-purple)	Flowers in May-June, fruits by the end of May.	Usually found in populations of 10-300 individuals, and in greater numbers in herbaceous Artemisiagrass complexes.	Anabolic activity and cholagogic action	Heart disease, muscle aches, stomach problems (Mamatkhanov *et al.*, 1998; Abdukadirov *et al.*, 2004)

Table 3: Compounds isolated from some plants of *A. turkestanica*

Name	Compounds	Reference
A. turkestanica (Rgl.) Brig.	20-Hydroxyecdysone-2,3-Acetonide, 20-hydroxyecdysone (20E), ecdysterone, turkesterone, cyasterone, ajugasterone, ajugalactone, cyasterone-22 acetate and phytoecdysteroids	Usmanov *et al.* (1971); Usmanov *et al.* (1973); Usmanov *et al.* (1974) Usmanov *et al.* (1975); Usmanov *et al.* (1977); Usmanov *et al.* (1978) Shimomura *et al.* (1989a); Shimomura *et al.* (1989b); Kotenko *et al.* (1993) Syrov *et al.* (1997); Tajasaki *et al.* (1998); Wu *et al.* (1998); Tsuji *et al.* (1999) Wu *et al.* (2000); Abdukadirov *et al.* (2004); Abdukadirov *et al.*, (2005); Ramazanov and Syrov *et al.* (2006); Grace *et al.* (2008)

7. Phytochemical profile of the medicinal plant *A. turkestanica*

The biological activity of secondary biologically active meobolites isolated from the underground and upper parts of the *A. turkestanica,* medicinal plant is related to the presence of phytocidsteroid compounds in the plant. These biologically active substances do not have androgenic properties. Experiments in animals have shown that these compounds have a tonic effect and enhance resistance to various stress factors (Syrov *et al.*, 1986; Mamatkhanov *et al.*, 1998). In laboratory experiments in rats, it was found that these bioactive substances reduce the area of necrosis that occurs after myocardial infarction (Kurmukov, 1991). Drugs based on biologically active compounds of the medicinal plant *A. turkestanica* are approved for use in Uzbekistan in the treatment of myocardial infarction, post-infarction recovery and treatment of hypoxic malnutrition in the fetus (Kurmukov and Ermishina, 1992; Kurmukov *et al.*, 1991). Ecsteroids cause a decrease in the amount of cholesterol and glucose in the blood, resulting in a positive effect on the liver and intestines due to increased protein synthesis and increase the permeability of the protective effect of nerve tissue. The bioactive substance turkesterone isolated from the plant *A. turkestanica* is also widely used in the field of pharmacology as a biologically active agent with various pharmacological effects on the human body. Turkesterone has tonic properties. It stimulates mental and physical work, protects against the negative effects of various stressors. Under the influence of turkesterone, protein biosynthesis in the body is improved, especially in muscle tissue, erythropoiesis and immunogenesis are accelerated. Its use normalizes creatine synthesis, causes positive changes in carbohydrate, lipid and electrolysis metabolism, thereby improving metabolism and increasing the body's functional capacity. Turkesterone corrects impaired metabolism in organs and tissues in various pathological conditions (myocardial dystrophy, toxic damage to the liver and kidneys, anemia, destructive changes in the gastric mucosa and outer subcutaneous layer, bone fractures and other injuries) and helps restore their functions. It is a powerful antioxidant and delays premature aging of the body.

Phytoecdysteroids are plant steroids belonging to the family *A. turkestanica* and other *Ajuga*, mainly containing 19-29 carbon molecules. Most of them possess a cholest-7-en-6-one carbon skeleton (C27), synthesized from phytosterols in the cytosol through the mevalonic acid pathway. They display a wide array of benefits in agriculture and in folk medicine and are readily available in large amounts. In fact, their concentrations in plants are generally

higher than those found in arthropods. They can be found in the leaves, roots, fruit, flowers, bark, rhizomes, and seeds, with their contents varying among organs, developmental stages, seasons, and habitats. The phytoexsteroids of the *A. turkestanica* plant exhibit physiological activity in insects and they affect a wide range of insects at very low concentrations and are not harmful to human or animal cells.

8. Pharmacological and biological properties of the medicinal plant *A. turkestanica*

Various extracts or purified compounds from *A. turkestanica* exhibit diverse biological characteristics, which are hypoglycemic, antitumor, antibacterial, antivirus, cytotoxic, as well as increase in insulin sensitivity in experimental diabetes. Herein, we describe the biological activities as well as its active extracts or compounds.

Table 4: Medicinal/pharmacological/biochemical properties of plant extract and compounds isolated from *A. turkestanica*

Medicinal plant	Medicinal/pharmacological/ biological property	Plant extract/chemicals isolated from the plant	Reference
A. turkestanica (Rgl.) Brig.	Antibacterial activity	Phytoecdysteroids (*in vitro*)	Ulukanli *et al*. (2005)
	Hypoglycemic activity	Ecdysteroids	Kutepova *et al*. (2001) El-Hilaly and Lyoussi (2004)
	Hypolipidemic action	Ecdysteroids	Syrov *et al*. (1983)
	Stimulation of aquaporins – human skin hydration	Aq.- and EtOH- extract; phytoecdysteroids (*in vitro*)	Dumas *et al*. (2002) Dumas *et al*. (2007)
	Stimulation of erythropoesis (experimental anemia)	Silenoside A, turkesterone	Syrov *et al*. (1997)
	Renoprotection (in experimental uremia)	Phytoecdysterone (ecdysterone and turkesterone)	Syrov and Khushbaktova (2001)
	Anabolic activity: Growth promotion	Turkesterone; 2-deoxy-alphaecdysone	Syrov (2001)
	Stimulation of protein synthesis in the liver Increase in protein synthesis in skeletal muscle cells Increase in protein synthesis in liver	Phytoecdysteroids (cyasterone, ecdysterone, turkesterone) Phytosteroids (*in vitro* and *in vivo* in rats) Turkesterone (mouse)	Syrov *et al*. (1978) Gorelick-Feldman *et al*. (2008) Syrov *et al*. (1978)
	Hepatoprotection (against liver toxins)	Ecdysterone, turkesterone, cyasterone, iridoid glycosides (rats)	Syrov *et al*. (1986) Syrov *et al*. (1992a) Syrov *et al*. (1998) Syrov and Khushbaktova (2001)
	Increase in blood flow	Ecdysteroids	Tsuji *et al*. (1999)
	Normalization of cell energetics and lipid metabolism in the liver in experimental diabetes	Phytoecdysteroides, ecdysterone and turkesterone	Tashmukhamedova *et al*., (1985) Syrov *et al*., (1992b)
	Reversal of mitochondrial dysfunction in experimental hepatitis and diabetes	Phytoecdysteroids (ecdysterone, turkesterone and cyasterone)	Tashmukhamedova *et al*. (1986)
	Increase in insulin sensitivity in experimental diabetes	Ecdysterone, ecdysteroid	Kosovskii *et al*. (1989)
	Biliary secretagogue	Phytoecdysteroids (ecdysterone, turkesterone and cyasterone)	Syrov *et al*. (1986)

9. Accumulation and biosynthesis of phytoecdysteroids in plant *A. turkestanica*

A. turkestanica, a medicinal perennial plant from the family Lamiaceae (mint) and indigenous to Uzbekistan, provides a rich source of phytoecdysteroids (Abdukadirov *et al*., 2004). The phytoecdysteroid content of *A. turkestanica* includes 20E, turkesterone, cyasterone, cyasterone 22-acetate, ajugalactone, ajugasterone B, -ecdysone and ecdysone 2,3-monoacetonide along with iridoids and neo-clerodane diterpenes (Usmanov *et al*., 1971, 1973, 1975, 1978; Baltaev, 2000; Ramazanov, 2005; Grace *et al*., 2008). Air-dried leaves from *A. turkestanica* have been reported to contain 0.02% 20E and roots have been reported to contain 0.045 % 20E and 0.052 % turkesterone. Plant tissue culture strategies for phytoecdysteroid production in *A. turkestanica* have been investigated, including the development of callus cultures initiated from ovaries by and cell suspension and hairy root cultures initiated

from leaves by Cheng *et al.* (2008). With the onset of germination, phytoecdysteroid levels stored in seeds initially decrease per fresh weight basis. As the plant develops, phytoecdysteroids are transported from the seeds to the cotyledons and then from the cotyledons to the first true leaves, and from each leaf set to the newly developing leaves, dynamically cycling and accumulating in the most apical leaves as the plant matures (Grebenok and Adler, 1991).

Let us now consider the synthesis of phytoecteroids in plants. Phytoecdysteroids belong to the terpene class of secondary metabolites and are biosynthesized through the mevalonic acid pathway in which mevalonic acid, cholesterol and acetyl-CoA are direct precursors (Bàthori and Pongrácz, 2005). The chemical structure of an ecdysteroid is characterized by a cyclopentano-perhydro-phenanthrene skeleton with an alkyl side chain at C17, containing a 7-en-6-one chromophore and several hydroxyl groups. The variations in number and location of hydroxyl groups on the steroid backbone account for the diversity of ecdysteroids in nature. 20-Hydroxyecdysone (20E, also commonly reported as ecdysterone, -ecdysterone and -ecdysone) is the most prevalent and abundant phytoecdysteroid produced by plants, and a major component in phytoecdysteroid containing herbal extracts (Baltaev, 2000; Báthori *et al*., 2008). The diagram below shows a schematic representation of the mechanism of 20-Hydroxyecdysone synthesis in a plant (Figure 3). Additionally, levels of phytoecdysteroid accumulation in certain plant tissues, such as young developing leaves and floral structures, are high enough to cause premature molting and death in non-adapted insects and nematodes after ingestion (Dinan, 1992; Adler and Grebenok, 1995).

10. The role of secondary metabolites derived from the *A. turkestanica* in human health

The use of plants that have the property of synthesizing extrinsic compounds was also known to humans in ancient times. At present, modern methods of using these biologically active compounds in pharmaceuticals and medicine have been developed. *Asteraceae,* Lamiaceae plant families, which are now known in the world flora, are used in the production of ecdisterone and drugs based on them. In the flora of Uzbekistan, the plant *A. turkestanica*, which belongs to the family Lamiaceae, is also considered as a raw material rich in exdesteroid compounds. However, recent large-scale use of the plant has led to the species being listed as an endemic species. Compounds of ecsteroid nature isolated from the plant are widely used in medicine.

The physiological effects of ecdysteroids on the human body and warm-blooded animals are very diverse. They regulate mineral, carbohydrate, lipid and protein metabolism (Catalan *et al*., 1985; Kosovski *et al*., 1989; Kholodova *et al*., 1997). Their ability to normalize blood sugar can be useful in the treatment of diabetes (Takahashi and Nishimoto, 1992). Ecdysteroids also normalize cholesterol levels relieve liver inflammation caused by toxic hepatitis

Table 5: Identified compounds in chloroform extracted volatiles of the roots of *A. turkestanica* (Mamadalieva *et al.*, 2013)

Plant part	Name of compounds
Root	1,2,7,8,8a,9,10,10a-Octahydro-2,2,7,7-tetramethylphenanthrene
	4²-18-Norkaur-16-ene
	Abieta-9(11),8(14),12-trien-12-ol (Ferruginol)
	Abieta-6,8,11,13-tetraen-12-yl acetate
	Totarol
	Stigmast-5-en-3-ol (²-Sitosterol)
	16±,17-Epoxypregn-4-ene-3,20-dione
	3,17-Dihydroxypregn-5-en-20-one
	20-Methyl-pregna-5,17-dien-3²-ol
	16-Dehydropregnenolone
	Pregnane-3,11,20-trione
	5-Pregnen-3²-ol-7,20-dione
	3,7-Dioxocholan-24-oic acid
	Pregna-4,9 (11)-dien-20-ol-3-on-19-oic acid
	Ajuforrestine A
	4,18-Epoxy-6,19-dihydroxy-13-cleroden-15,16-olide-19-acetate
	Stigmast-4-en-3-one
	4,4-Dimethylcholesta-7,9(11)-dien-3-ol
	Olean-12-en-3-one
	Betulin
	Barrigenol

(Syrov *et al*., 1986); have the ability to duplicate the effect of vitamin D_3, showing an antirachitic effect. They are known to exhibit antioxidant, antimicrobial (Volodin *et al*., 1999; Osipova *et al*., 2002), anti-inflammatory and wound healing properties. In addition, they have an immunomodulatory, adaptive, stress-protective and nootropic effects, as well as the anticonvulsant effect in spontaneous epilepsy (Hanaya *et al*., 1997). Stimulation of hematopoietic function (erythropoiesis), increased regeneration, and an increase in the concentration of red blood cells and hemoglobin in the blood have been established using 20-hydroxyecdysone (Syrov *et al*., 1997). There is an increase in the activity of elements of the blood protective system - lymphocytes and neutrophils (Trenin and Volodin, 1999), and an increase in the functions of phagocytosis. Acetates and 20-hydroxyecdysone derivatives also stimulated DNA biosynthesis in human and animal lymphocytes activated by polyclonal mitogens. The preventive and therapeutic effect of phytoecdysteroids in inducing anemia and leukopenia , in the treatment of threatening abortion, disorders in the activity of sexual function (Mirzaev *et al*., 2000), as well as menopausal syndrome caused by age-related changes in the regulation of the reproductive cycle. Ecdysteroids cause anabolic effects by stimulating protein biosynthesis in the liver, kidneys, and muscle muscles (Syrov *et al*., 1975). This property is widely used to correct body weight during the training process and to achieve high performance in professional sports.

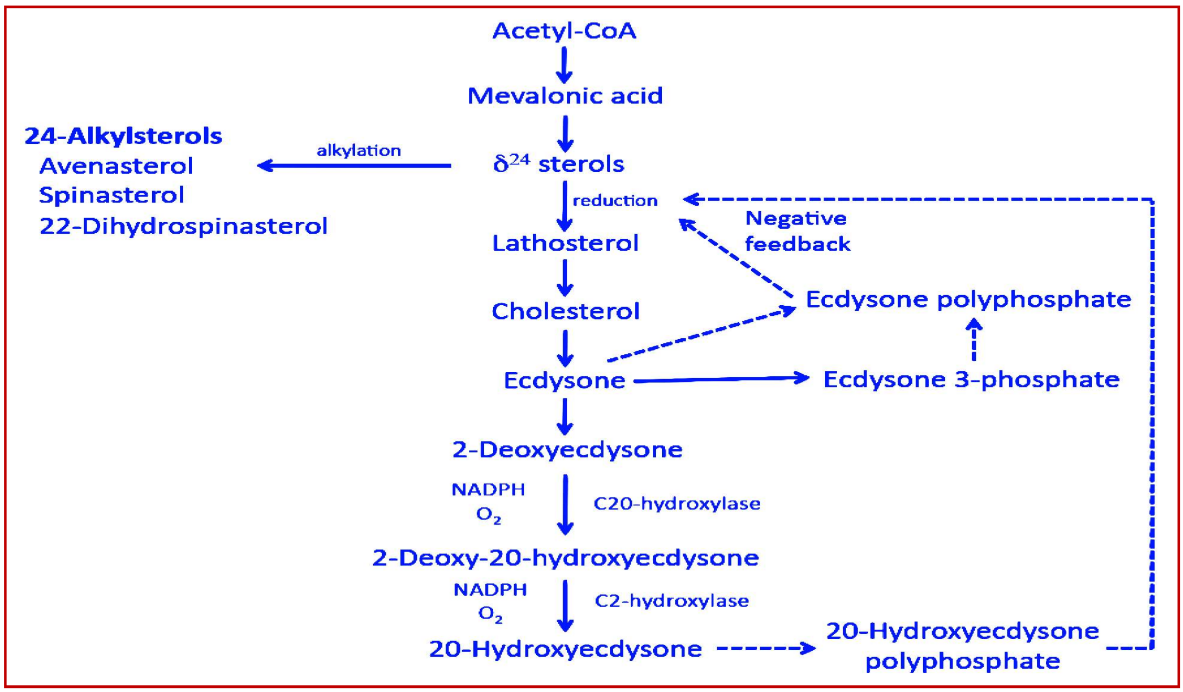

Figure 3: Mechanism of phytoecdysteroid biosynthetic formation compiled by Adler and Grebenok, (1999) and Bakrim *et al.* (2008).

The phytoecdysteroids and iridoids isolated from the *A. turkestanica* plant are listed below (Figure 4).

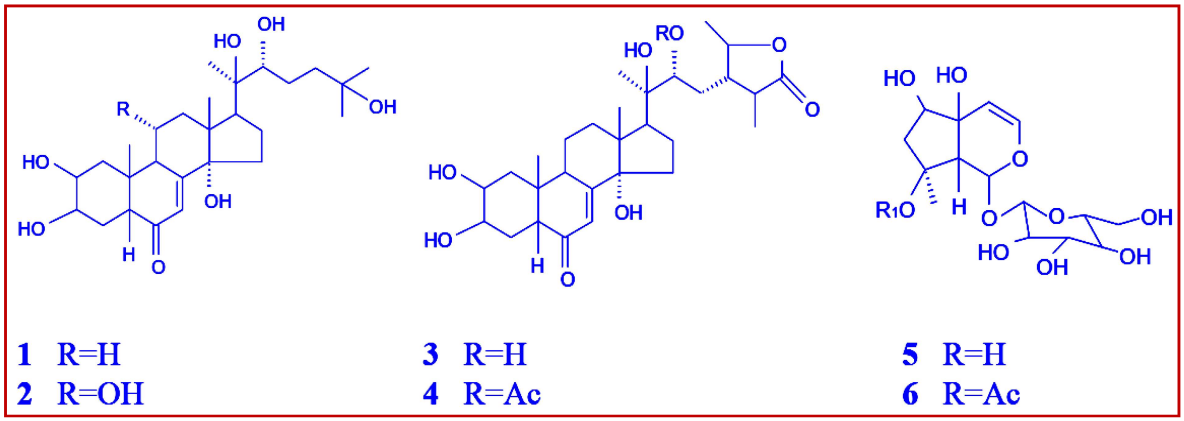

Figure 4: Chemical structure of phytoecdisteroids isolated from the medicinal plant, *A. turkestanica* (Mamadalieva *et al.*, 2013).

In official scientific medicine, ecdysteroids containing natural compounds are used for disorders of the cardiovascular, central nervous and reproductive systems, as tonic and stimulating agents for mental and physical fatigue, decreased working capacity, impotence, and weakening of the functions of various organs can be used to heal wounds and ulcers, treat burns, improving sexual function, stimulating libido and eliminating discomfort in sexual life (Jakovljevic, *et al.*, 2015; Atay *et al.*, 2016; Yousaf *et al.*, 2018). In sports and military medicine, preparations based on them serve to adapt and improve the health of a healthy person under conditions of limiting factors, including overcoming extreme physical and mental stress. Outside of official medicine, prophylactic use as adaptogenic, anabolic, antidepressant, hemorheological, nootropic and antitumor agents are most widespread (Ahmad *et al.*, 2012; Ahmad and Habib, 2015; Chandel and Bagai, 2010). The pharmacodynamics of the adaptogenic effect of ecdysteroid-containing plants are based on the effects of stimulation of specific and nonspecific immunity, increased resistance and increased boundaries of the body's adaptation to various infections, physical exertion, intoxication; improved tolerance of heat, cold, oxygen, lack of vet (Rani *et al.*, 2017; Ali *et al.*, 2019). The general tonic effect develops gradually and is expressed in increased stress resistance of the body, activation of metabolism, endocrine and autonomic regulation and is accompanied by increased appetite and secretion of the glands of the gastrointestinal tract, increased tone of the hollow organs (Jan *et al.*, 2014; Kaithwas *et al.*, 2012; Sher and Al-Yemeni, 2011). In addition to these effects, there is a restoration of reduced vascular tone, a slight increase in blood pressure and an improvement in the rhythm of the heart, not a pronounced psychostimulating effect.

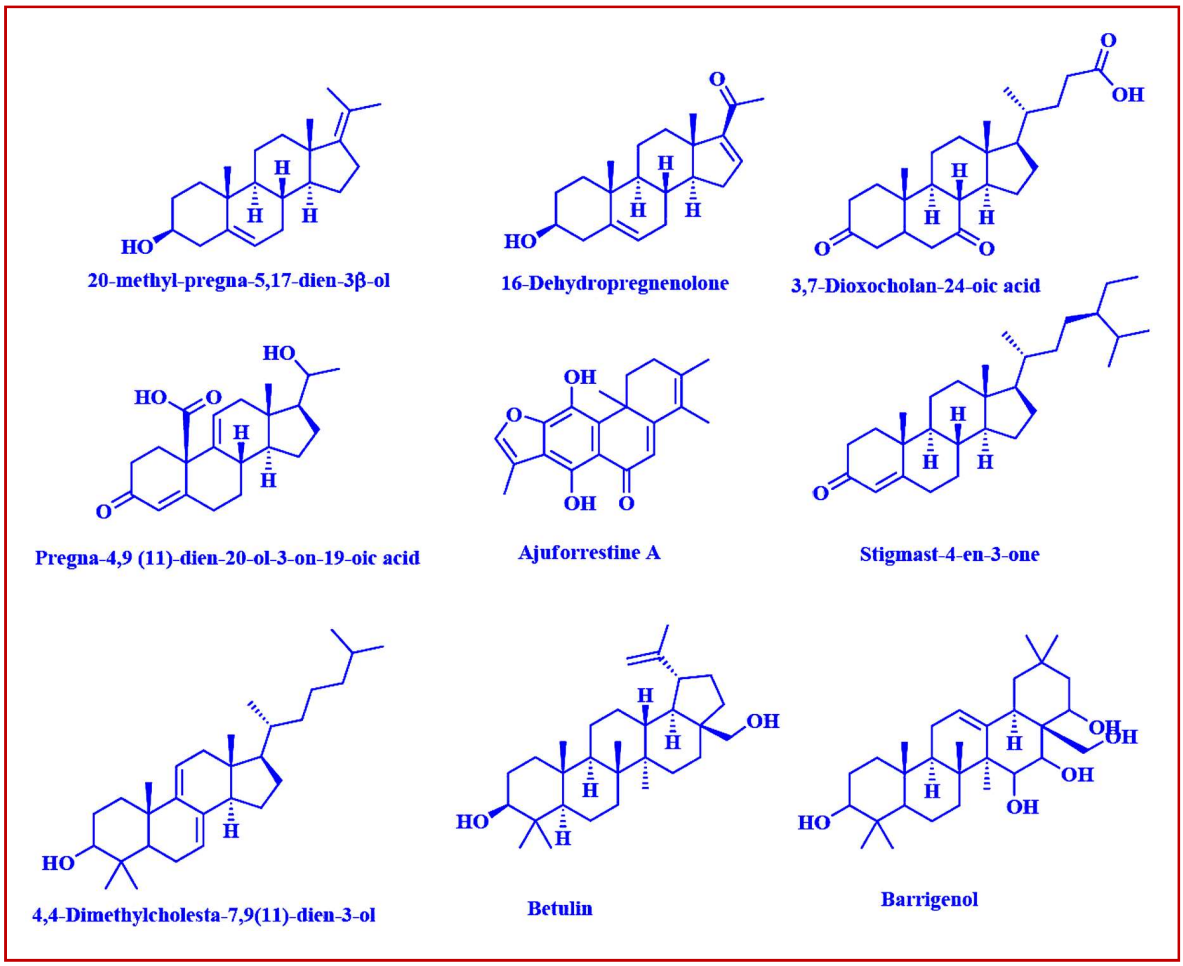

Figure 5: Structure of compounds identified from the root extract of the medicinal plant, *A. turkestanica* (Mamadalieva *et al.*, 2013).

11. Conclusion

The medicinal plant *A. turkestanica*, an endemic species of the Boysun Pamir-Alay Mountains, contains exdesteroid compounds. These biologically active exdisteroid compounds are used in traditional medicine and pharmaceuticals. In the flora of Uzbekistan, *A. turkestanica* is a medicinal plant, rich in phytoecdisteroid raw materials. Due to the biological, pharmacological, medicinal properties of the plant *A. turkestanica*, its widespread use in pharmaceuticals, the plant is on the verge of extinction, which leads to limited access to biologically active substances from the plant. Therefore, it is necessary to propagate the plant *A. turkestanica*, to create its natural plantations. It is necessary to improve the methods of obtaining biologically active substances from plants by biotechnological methods, *i.e.*, by endophytic micro-organisms.

Conflict of interest

The authors declare that there are no conflicts of interest in the course of conducting the research. All the authors had final decision regarding the manuscript and decision to submit the findings for publication.

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