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Review

Diversity of the Mountain Flora of Central Asia with Emphasis on Alkaloid-Producing Plants

Karimjan Tayjanov [1], Nilufar Z. Mamadalieva [1,*] and Michael Wink [2]

[1] Institute of the Chemistry of Plant Substances, Academy of Sciences, Mirzo Ulugbek str. 77, 100170 Tashkent, Uzbekistan; yolgonmas@mail.ru

[2] Institute of Pharmacy and Molecular Biotechnology, Heidelberg University, Im Neuenheimer Feld 364, 69120 Heidelberg, Germany; wink@uni-hd.de

* Correspondence: nmamadalieva@yahoo.com; Tel.: +9-987-126-25913

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Abstract: The mountains of Central Asia with 70 large and small mountain ranges represent species-rich plant biodiversity hotspots. Major mountains include Saur, Tarbagatai, Dzungarian Alatau, Tien Shan, Pamir-Alai and Kopet Dag. Because a range of altitudinal belts exists, the region is characterized by high biological diversity at ecosystem, species and population levels. In addition, the contact between Asian and Mediterranean flora in Central Asia has created unique plant communities. More than 8100 plant species have been recorded for the territory of Central Asia; about 5000–6000 of them grow in the mountains. The aim of this review is to summarize all the available data from 1930 to date on alkaloid-containing plants of the Central Asian mountains. In Saur 301 of a total of 661 species, in Tarbagatai 487 out of 1195, in Dzungarian Alatau 699 out of 1080, in Tien Shan 1177 out of 3251, in Pamir-Alai 1165 out of 3422 and in Kopet Dag 438 out of 1942 species produce alkaloids. The review also tabulates the individual alkaloids which were detected in the plants from the Central Asian mountains. Quite a large number of the mountain plants produce neurotoxic and cytotoxic alkaloids, indicating that a strong chemical defense is needed under the adverse environmental conditions of these mountains with presumably high pressure from herbivores.

Keywords: Central Asian Mountains; plant diversity; plant flora; alkaloid producing plants; plant defense mechanisms

1. Introduction

Since ancient times, humans have been using plants for treating various diseases and health disorders. In the last century, a large number of synthetic drugs with a wide range of actions were discovered, but medicinal plants still play an important role in folk and traditional medicines and in primary care in many developing countries. According to literature data, about 25% of the drugs prescribed worldwide are derived from plants [1,2].

Alkaloids are organic bases (alkali-like), nitrogen-containing natural products, often with a rather complicated chemical structure. They are produced by plants, fungi, bacteria and rarely by animals, and usually show substantial toxicological and pharmacological effects. The main function of alkaloids is that of chemical defense against herbivores (many of them are strong neurotoxins), and minor functions include defense against microbes and other plants (allelopathy) [3,4]. Alkaloids are widely distributed in the plant kingdom (especially within angiosperms) and usually occur as protonated molecules under physiological conditions. Alkaloids are often localized in specific organs: in some plants, in the roots, fruits (seeds) or latex, bark or leaves. Alkaloid distribution in the plant kingdom is uneven. About 10% to 25% of higher plants contain alkaloids [5]. Most alkaloid-containing plants

(ACPs) are found in the angiosperm families Berberidaceae, Boraginaceae, Colchicaceae, Fabaceae, Fumariaceae, Liliaceae, Papaveraceae, Ranunculaceae, and Rutaceae, etc.

Alkaloids and extracts of alkaloid-containing plants have been used throughout human history as remedies, poisons and psychoactive drugs. Many alkaloids have diverse and important physiological effects on humans, animals, and even insects. Some of them are therefore used in medicine, veterinary medicine, or agriculture. Alkaloids have a wide range of pharmacological activities including antitumor (berberine, homoharringtonine, sanguinarine, vinblastine, vincristine), stimulant (caffeine, cathinone, cocaine), hallucinogenic (dimethyltryptamine, ibogaine, mescaline, psilocybin), anticholinergic (atropine, hyoscyamine, scopolamine), analgesic (codeine, morphine), antiarrhythmic (allapinin, quinidine) and antimalarial activities (quinine) [3,6–9] (Figure 1). Therefore, some alkaloids are widely used in medicine to treat health disorders and infections.

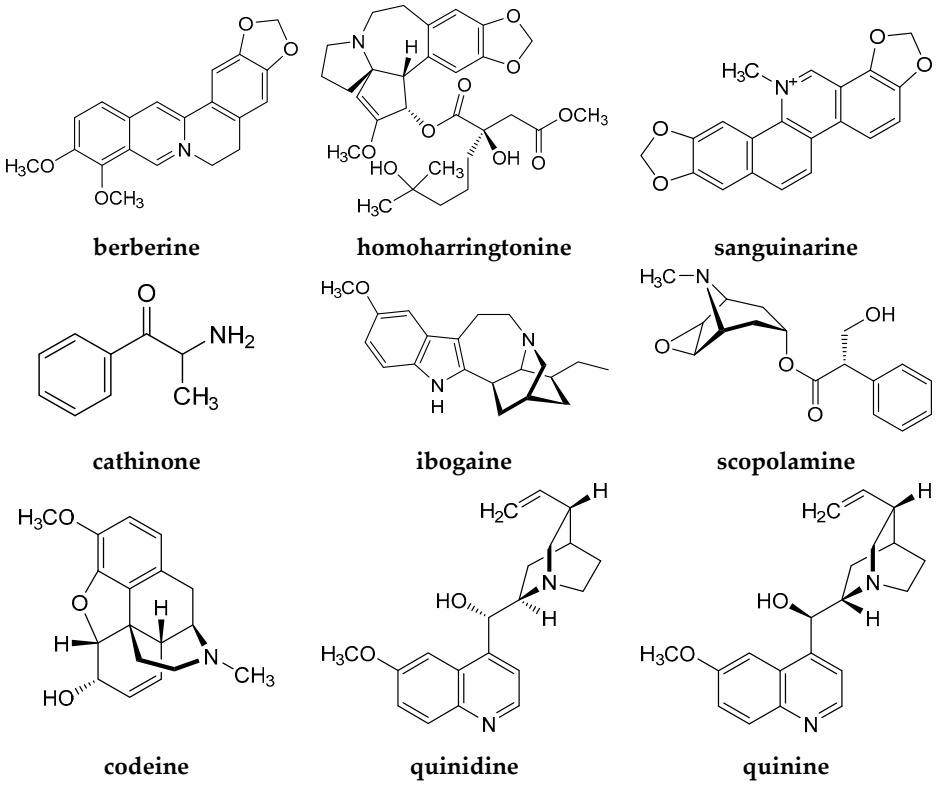

Figure 1. Structure of important alkaloids.

2. The Flora of Central Asian Countries (including Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan)

The biodiversity of the Central Asian mountains is favored by the uniqueness of relief and soil and climatic conditions. The Saur, Tarbagatai and Dzungarian Alatau mountain ranges are located in the territory of modern Kazakhstan. The Tien Shan covers an area of three republics, Kazakhstan, Kyrgyzstan and Uzbekistan. With regard to the Pamir-Alai, its northern part belongs to Uzbekistan and Kyrgyzstan, and the southern part to Tajikistan. The mountain Kopet Dag is located in Turkmenistan. Except Kopet Dag, all above-mentioned mountains all partially extend China. The flora of Central Asia is still not completely investigated and studies are still ongoing. The first comprehensive publication on the plants from Central Asia (it covers all of the Central Asian Republics of the former Soviet Union) is a compilation of many revised and updated local floras by Vvedenskiy and Kamelin; they listed 8097 plant species in their summary [10].

More than 5754 species of vascular plants have been found in Kazakhstan, along with 5000 species of fungi, 485 species of lichens and mosses, 2000 species of algae, and 500 species of bryophytes.

Among the vascular plants, 14% are endemic to Kazakhstan [11,12]. A total of 3786 higher plant species (875 genera and 150 families), and 3676 lower plants (fungi, lichens, algae, mosses) have been identified in Kyrgyzstan, including more than 200 endemic plant species and 200 species of medicinal plants [13]. In Tajikistan, 4550 species of higher vascular plants (30% of them endemic) and 3000 species of lower plants have been recorded [14]. The flora of Turkmenistan includes about 3140 higher plant species (2969 vascular plants and ferns, 12 gymnosperms, 140 mosses) and 3924 lower plant species (470 lichens, 827 algae, 2585 fungi), giving a total of 7064 plant species [15]. The flora of Uzbekistan contains more than 4500 vascular plants in 650 genera from 115 families. More than 4000 species of algae and more than 2000 species of fungi have been recorded in Uzbekistan [16].

A diversity of natural conditions in the mountains of Central Asia from the northern to the southern borders, as well as from the Alpine meadows to the foothills, favors plant biodiversity. The richness of Central Asian flora provides a great opportunity for a wide range of studies for the screening and identification of alkaloid-containing plants (ACPs). The first consolidated list of ACPs of the region was provided by Orekhov [17], Lazurevskiy and Sadykov [18,19], Massagetov [20,21], and Sokolov [22]. However, in these compilations results came from studies conducted both in the plains and in the mountains. Earlier pioneering studies on ACPs from certain areas of the mountains of Central Asia were provided by Gubanov [23–25], Ataev [26–30], Kholodkov [31,32], and Tayjanov [33–35]. It is still not yet possible to provide the exact number of the screened ACPs of the mountains of Central Asia, because many results by individual researchers have remained unpublished. Furthermore, the flora of some areas was studied repeatedly by different researchers in different years, which sometimes led to the publication of duplicated works (Table 1).

Table 1. Occurrence of alkaloid-containing plants in the mountains of Central Asia.

System of Mountains	Mountains and Ridges	Total Number of Species	Number of Species Analyzed for Alkaloids	Number of Alkaloid-Containing Species
Saur		661 *	436 *	301 *
Tarbagatai		1530–1540 [36], 1640 [37], 1195 *	676 *	130 *
	Saur and Tarbagatai		1265 [38]	
Dzungarian Alatau		1800 [35] *, 787 [39], 1250–1300 [36], 2168 [40], 1600 [41]	1021 [35] *	699 [35] *
	Dzungarian Alatau and Tien Shan		1732 [23–25,31,32,35]	
Western Tien Shan	Acha-Tash and Boor-Albas ridges			176 [42]
	Aksu-Zhabagly nature reserve	1312 [43]		
	Angren river (Chimgan and Birchmulla)		260 [18,19]	
	basins of Ugam and Pskem rivers	1200 [44]		
	Chodaksoy river	653 [45]		
	Ketmen-Tyubin Valley	900 [46]		
	Kungey Alatau, basin of the river of Chong-Kemin and the Issyk-Kul Lake	470 [31,47,48]		
	Mailuusuu river	377 [49]		
	Mogoltau ridge	950 [50]		
	Qurama ridge (Angren Valley)	914 [51]		
	Suusamyr Valley (northern slopes of Terskey Alatau)	1100 [32]	550 [33,34,52,53]	
	Talas Alatau	1491 [54]		
	Uzun-Akhmat ridge	900 [55]		
	Western Tien Shan	2000 [44]		
	Western Tien Shan and Turkmenistan			140 [56]
South western Tien Shan		2056 [57]		
	basin of Aksakata river	853 [58].		
	Chatkal ridge	981 [59], 1117 [60]		
	Kalba river (one of the inflow of Talas river)	752 [61]		
	Karatau	1350 [36]		
	Mashat mountains	1500 [62]		
	basin of Nauvalisay river (Ugam ridge)	921 [63]		
Central (Inner) Tien Shan		2000 [36]		
	Acha-Tash and Boor-Albas	800 [42]		
	Naryntau	1870 [64]		
	Talas Suusamyr region	465 [65]		
Northern Tien Shan	Chon-Aksu	584 [66]		
	Ili Alatau ridge	1282 [67]		
	Ketmentau ridge	1500–1600 [36], 800 [68]		

Table 1. *Cont.*

System of Mountains	Mountains and Ridges	Total Number of Species	Number of Species Analyzed for Alkaloids	Number of Alkaloid-Containing Species
	Ketmen—Temirlik ranges	520 [69]		
	Kungey Alatau	704 [70]		
	Mountains of Almaty	177 [71]		
	Northern slope of the Tien Shan (within Kyrgiyzstan)	1150 [36], 1544 [72]		
	Trans-Ili Alatau	1264 [67], 1800–2000 [36]		
	Syrdarya river valley and Karatau mountains	2000 [73], 350 [73], 1000– 2000 [74], 1666 [62,74]		
	Total in Tien Shan mountains	3251 *	1777 *	1117 *
Pamir-Alai	Alai Valley		550 [33,34,52,53]	
	Babatag, Aktau, Khodge Kazyan	726 [36]		
	Badakhshan	1567 [75], 308 [76]		
	Bartang, Gunt, Shakhdara, Vanj and Yazgulyam	1300–1500 [36]		
	basin of Aksu river	670 [36]		
	basin of Bartang river	1201 [77]		
	basin of Isfara river	1426 [78]		
	basin of Kyzyl-Eshme river	349 [79]		
	basin of Khodzha-Bakirgan river	1464 [80], 1500		
	basin of Tupalang river	1100–1500 [36]		
	Boysun area (foothills of the Hissars)	1481 [81]		
	Gissar Valley	805 [36,82]		
	Khujand and Mogoltau ridge			274 [26–30]
	Kugitang	580 [83], 588 [83], 675 [36], 743 [84]		
	Lake Kaindy (Pamir)	296 [85]		
	Nuratau reserve	626 [36], 786 [86]		
	Pamir	636 [87], 661 [79,85]		
	Pamir-Alai mountains	3422 [88–91] *	1794 [88–91] *	1165 [88–91] *
	Pamir-Alai-Nurata	526 [92,93]		
	Qashqadaryo (basin of the Qashqadaryo River and on the western slopes of the Pamir-Alai mountains)	1184 [36,94]		
	Shakhimardan-say river	1353 [95]		
	Turkestan ranges	839 [96]		
	Varsob	706 [36]		55 [97]
	Zarafshan mountains	1650 [36], 1600–2000 [98], 2588 [99]	550 [52]	
Kopet Dag	Central Kopet Dag and Karakalin Valley			190 [100]
	Central Kopet Dag	1387 [36], 1387 [101]		
	Eastern part of Central Kopet Dag	955 [102]		
	Feryuzinsk gorge, Sumbar Valley		120 [103]	
	Kopet Dag	1800 [36,104], 1942 [101]	650 [103]	438 [103]
	Northwest Kopet Dag	1140 [105]		
	Western Kopet Dag	926 [106], 1266 [107]		

* Data were obtained by us.

According to the data collected for this review, the areas in which ACPs were thoroughly analyzed come from Dzungarian Alatau and Tien Shan: here 1732 plant species were analyzed for the presence of alkaloids [23–25,31,32,35]. In certain areas of the Almaty region, 177 species were recorded [71], and more than 470 species on the northern and southern slopes of Kungey Alatau, the basin of the river of Chong-Kemin and Issyk-Kul Lake [31,47,48]. In the Suusamyr Valley, the northern slopes of Terskey Alatau, and the walnut forests of the Fergana range more than 1100 species were screened [32]; in the Alai Valley more than 550 species produce alkaloids [33,34,52,53]. In western Tien Shan about 260 species were investigated from the river of Angren, and the surrounding areas of the villages Chimgan and Brichmulla [18,19]. Some information is available about ACPs for some regions of the mountains of Pamir-Alai. For example, the basin of the Varsob river has 55 ACP species [97], the area of the city of Khujand and the Mogoltau ridge has 274 [26–30], western Tien Shan and Turkmenistan have 140 [56], the ridges of Acha-Tash and Boor-Albas have 176 [42], and central Kopet Dag and the Karakalin Valley have 190 [100]. Goryaev et al. [108,109] reported 139 ACPs for the mountainous part of Central Asia. Furthermore, individual alkaloids were isolated from 176 species cited in Orekhov [17], in 636 species analyzed by Massagetov [21], and from 131 species of plants from the mountains of Central Asia [22].

More than 8100 plant species have been recorded in the territory of Central Asia, 6000 species of which grow in the mountains of Central Asia [10]. It should also be mentioned that not all areas of mountainous Central Asia were investigated in relation to ACPs. Data are missing for the flora of Ferghana Valley, Pamir and Kopet Dag, the ridges of Syrdarya Karatau, the altitudes of Tien Shan, and the relict mountains and lowlands of the region of Central Asia. This indicates the need and great opportunities to search for new ACPs in the flora of this region, which can be sources for highly active medicinal products.

3. Alkaloid-Containing Plants (ACP) in the Flora of the Mountains of Central Asia

To our knowledge, no comprehensive source of information on the flora of the mountains of Central Asia exists. From the *Identification Guide of Plants of Central Asia* (Opredelitel rasteniy Sredney Azii) it is difficult to judge the number of plant species of the mountains of Central Asia, because many of the cited plants in this guide belong to all regions of this area [10].

The pioneering work by Fedchenko on the identification of the plants from the flora of Turkestan (it includes present-day Turkmenistan, Kazakhstan, Uzbekistan, Kyrgyzstan and Xinjiang (East Turkestan or Chinese Turkestan)) lists 5031 plant species [110]. The number of plants of the mountains Central Asia can be estimated by the lists of plant species of the individual regions. For example, there are 588 higher plant species in Kugitang [83], 1264 in Trans-Ili Alatau [67], 2000 in the Syrdarya Karatau mountains [73], 465 in the Talas Suusamyr region [65], 787 in Dzungarian Alatau [39], 900 in Uzun-Akhmat [55], 1200 in the basins of the Ugam and Pskem rivers [44], 636 in Pamir [87], and 1567 in Badakhshan [75].

Kamelin also described the flora for individual ranges and basins of Pamir Alai [36]. According to his data, there are 805 species in the flora of Gissar Valley, 706 in Varzob, 1100 in Tupalang, 675 in Kugitang, 1184 in Qashqadaryo, 726 in Babatag, Aktau, Khodge Kazyan, and 670 species in the basin of the Aksu river. For the western Pamirs (including the basins of the rivers Vanj, Yazgulyam, Bartang, Gunt and Shakhdara) Kamelin [36] described 1300–1500 species, for the mountain Zarafshan about 1650 species were described, and in Nurata 626 species were described. Later, the flora of the Syrdarya river and Karatau mountains was also analyzed, giving a total of 1666 species [74].

As mentioned earlier, it is difficult to estimate the total number of plants from the mountains of Central Asia. According to the publication *Identification Guide of Plants of Central Asia* [10], 8097 plant species are known from the mountains of Central Asia. From this list and according to our calculations, it can be assumed that 5350–5400 species grow in the mountains of Central Asia; this assumption is compatible with the tentative data of Korovin, who recorded 5500 species from this region [111].

Analyzing the mountain flora of Central Asia, it was deemed useful to start the survey with the northern mountains. In particular, the flora of the Saur and Tarbagatai with 1265 species had been analyzed for ACPs [38]. In his book, Bolshakov [112] provided a list of the trees of these ranges including 157 species. A total of 204 plant species have been recorded for the flora of the Tayjuzgen ravine which is a part of Saur [113]. After analyzing References [10,114], we determined 661 plant species in the Saur mountains, 301 of which produce alkaloids.

Stepanova identified 1640 species in the flora of Tarbagatai [37], but Kamelin [36] suggested that the total number of plant species would be rather 1530–1540 species. The flora of Tarbagatai, and as well as that of Saur, have not been investigated for ACPs, but Massagetov [21] provided a list of some ACPs for this area. There are also some publications of Kazakh botanists dedicated to plant resources [115,116]. We also compiled plant lists in order to identify ACPs. Our results indicated that the total number of plants of the Tarbagatai mountains is estimated to be around 1195 species and more than 130 produce alkaloids.

Dzungarian Alatau is a mountain system located at the junction of two floristic regions: the boreal and old Mediterranean regions [39–41]. Rubtsov [41] has identified about 1600 species in the Dzungarian Alatau ridge, whereas Kamelin [36] considered the number to be less than 300–350 species. After his critical reviews, Goloskokov [40] listed 2168 species in the flora of Dzungarian Alatau. On the basis of these references, we were able to define 1800 species in the mountainous part of this region. ACPs of the Dzungarian Alatau ridge have been studied by Gubanov [23–25] and us [35]. From 1080 plant species of this region, we investigated 1021 species for their alkaloid content, and among them 699 species contained alkaloids.

Among the mountain systems of Central Asia, the Tien Shan occupies a special place for its floral richness. The experts divided the Tien Shan into the western, central (inner) and northern [36,117,118]. Northern Tien Shan includes the Trans-Ili Alatau and Ketmen mountain ranges, the northern slope of the Kungey Alatau range and a number of low mountains. Among these ranges, the following can be considered to be sufficiently studied: the flora of the Kyrgyz Alatau range. For the northern slope of the Tien Shan ridge (within Kyrgyzstan) Nikitina [72] listed 1544 species of higher plants, but Kamelin [36] considered that the natural flora of the ridge should be around 1150, and together with the Kazakhstan part, the number does not exceed 1250 plant species. The Ili Alatau ridge is the richest and the central source of the flora according to Popov [67], consisting of 1282 species. About 1800–2000 species reported by Kamelin [36] for the flora of the Trans-Ili Alatau and for the neighboring Ketmentau ridge less than 300–400 species. According to Kukenov [68], the flora of Ketmentau contains more than 800 species. For the north slope of Kungey Alatau 704 species were recorded by Aristangaliev [70]. For the flora of the basin Chon-Aksu (Kungey Alatau), Kenjabaeva identified 584 species [66], and for the flora of the ranges Ketmen and Temirlik Sadirova [69], 520 species. Information on the exact number of the flora of central (inner) Tien Shan, including the intermountain and highland ridge of Issyk-Kul Lake, is missing, excluding data of Sobolev [119] and Golovkova [120]. By Arbaeva [42] about 800 species reported for the ranges of Acha-Tash and Boor-Albas, whereas for the central macro-slope of Naryntau, Andreenkov [64] listed 1870 species.

According to the preliminary data of Kamelin [36], approximately 2000 species grow in central Tien Shan. Western Tien Shan (mountain ranges of Syrdarya and Karatau, Kyrgyz Alatau, western Talas Alatau, Karjantau, Ugam, Pskem, Sandalash, Chatkal, Uzun Akhmat, Fergana, Qurama, Mogoltau) is the best-studied area for its vegetation and composition of flora. For all of western Tien Shan, Pavlov [44] reported about 2000 plant species. Floristically, the most-studied area is the Aksu-Zhabagly nature reserve, with 1312 species [43]. Taking into account the flora of the western spurs of the Talas Alatau, 1491 species are known (which make up 28% of whole vascular plant flora of Kazakhstan) [54]. Recently, for southwestern Tien Shan (Uzbekistan part), Tadjibaev [57] described 2056 species. For the eastern part of the Talas Alatau, a plant list for the basin of the Kalba river (one of the inflows of the Talas river) has been published which includes 752 species [61].

No consensus exists among researchers about the total number of plants of Syrdarya Karatau. Starting with early estimates by Pavlov and Lipshits [73] of 350 species on the slopes, now the numbers range between 1000 and 2000 species [74]. Kamelin [36] determined about 1350 species for Karatau, 1500 species for the Mashat mountains, and overall 1666 species for the Syrdarya Karatau mountain region [62].

The Sary-Chelek Biosphere Reserve is located on the southern slopes of the Chatkal ridge (northwestern part of the Jalal-Abad region) in the Arkyt Valley. According to Borlakov [59], the flora of the reserve includes 981 species; 20 years later Krasovskaya and Levichev [60] described 1117 species for the Chatkal Reserve. The flora of the basin of the Aksakata river on the southwestern slope of the Chatkal range comprises 853 species according to Hudayberganov [58]. For the flora of the neighboring Nauvalisay river basin on the southeastern slope of the Ugam ridge (Ugam Chatkal National Park), Muzaffarova estimated 921 plant species [63]. Information about the flora of the Qurama ridge is missing, except for the flora of Angren Valley, with 914 species [51]. For the southern slope of the ridge (Chodaksoy river), Tadjibaev [45] identified 653 plant species.

Komarov [50] recorded 950 species in the flora of the Mogoltau ridge including the low mountains. In the eastern part of the Fergana Valley a number of ridges exist from the Tien Shan mountain systems. The flora and vegetation of these areas have been well studied and described. For example, for the Uzun-Akhmat ridge, Tkachenko [55] reported about 900 species, and for the Ketmen-Tyubin Valley, Botbaeva [46] listed at least 900 species. According to Nabiev [49], 377 species grow in the river sediments of the Mailuusuu river (the basin of the Naryn river). Based on mentioned research materials and results from different researchers and our own data, we estimate that more than 3251 plant species occur in the Tien Shan mountains.

Alkaloid-bearing plants have been rather well studied in the flora of Tien Shan, including the work of Kyrgyz researchers on the basin of Issyk-Kul Lake [48], Sussamyr [31] and the Chon-kemin Valleys [121], and the Acha-Tash and Boor-Albas hills [42]. Part of the region was investigated by Gubanov [23,24] and Goryaev [108,109], as well as by Plekhanova [47]. Some ACPs were identified by Ataev [26–30]. Summarizing the results of the above-mentioned researchers and our records, we identified a high number of 1117 ACPs of a total of 1777 analyzed plants.

The Pamir-Alai mountains represent a mountain system of three Central Asian republics (Tajikistan, Kyrgyzstan and Uzbekistan). Part of the Pamir mountains is located in the south part of the Fergana Valley. Botanists and geographers usually subdivided the mountains into three parts: Pamir-Alai, and the western (Badakhshan) and eastern Pamirs [36,111,118] (or even five mountain ranges: the Alai mountains, the Zarafshan range, the Turkestan range, the Köýtendag (Kugitangtau) range and the Gissar range). The scientific investigations of the flora of the Alai Valley began with the works of A.P. Fedchenko and B.A. Fedchenko more than 100 years ago, in the period of the great geographic expeditions of the Russian geographic association into Central Asia. The first investigator of the Alai Valley, geobotanist Fedchenko visited the area in 1871 and published his findings on the flora of the Alai Valley in 1905 [122]. However, the plant flora of the Alai Valley needs further studies. Some of researchers, for example Vyhodtsev [123], proposed 6525 species for the Tien Shan-Alai mountains, but it is difficult to judge the number of species for the Alai Valley, because it has very close botanical-geographic relationships to central Tien Shan. Therefore, we have only the limited information of Ikonnikov and Ladygina [85] on the flora of Lake Kaindy (Pamir), where they recorded 296 species. On the southern slope of the western spurs of the Alai range (the basin of the Kyzyl-Eshme river) the same investigators later determined 349 plant species [79].

As a result of our research in the Alai Valley [52], we have collected and analyzed more than 550 plant species for their alkaloid content. A report of Khalkuziev [95] exists for the northern slope of the Alai range's Shakhimardan-say river with 1353 species, and there is data from Khudayberdiev [124], who studied the environmental and plant resources features of 90 species of Lamiaceae. Konnov [96] studied the diversity of *Juniperus*, and defined 839 species for the Turkestan ranges. Gaffarov [80] collected 1464 species in the basin of the Khodzha-Bakirgan river and his data is matched with the reports of Kamelin, covering 1500 species. Later, Gazybaev [78] listed 1426 species of higher plants in the flora of the basin of the Isfara river.

The flora of the western outpost of Pamir-Alai-Nurata consists of 526 species according to Zakirov [92,93]. Beshko [86] investigated the Nuratau reserve and reported 786 species. Among the Kugitang mountains, the flora of Zarafshan mountain is the most studied, and includes 1600–2000 species [98]. Zakirov published in his summary [99] that 2588 plant species occur in the mountainous part and lower reaches of the Zarafshan river. Based on this report, Kamelin [36] identified 1750 species for the natural mountainous part of Central Asia. About 805 species have been listed for the flora of the Gissar ridge (also known as the Hissar or Hisor range) by Grigorev [82], who studied the surroundings of Dushanbe. Information about the flora of central Gissar is lacking, except a report by Djanguzarov [125] listing 120 species of trees and shrubs for Tupalang river. Kamelin [36] reported at least 1500 species in the flora of the basin of the Tupalang river.

In the Pamirs, enough data have been collected for an assessment of the flora. As we mentioned above, the first information about the Pamir mountains was given by Fedchenko [126]. According to Ikonnikov [79,85], the flora of the Pamir mountains includes 661 species. In the list of plant species for Badakhshan, Fedchenko [76] described 308 species, whereas Ikonnikov [75] tabulated 1567 species. Later, 1201 species were described for the basin of the Bartang river (Badakhshan mountain) by Navruzshoev [77]. In the flora of Kugitang (separated Pamir-Alai mountain), 580 species exist according to Nevskiy [83]. Mustafaev [94] reported 1184 species from the western border of Pamir-Alai or the basin of the Qashqadaryo river. For the Surkhan reserve (Kugitang ridge), Ibragimov [84] reported 743 species, whereas the flora of the botanical-geographical region of Boysun area has 1481 species according to Turginov [81]. Summarizing the available data presented above and considering the published works (first to 10th volume of the *Guide*), we assumed that the flora of the Pamir-Alai mountains comprises 3422 species. From the available data in the literature [56,97,127,128] and our own chemical research on 1794 species [88–91] from the Pamir-Alai mountains, we assume that almost 30% of them (1165) produce alkaloids.

The last area includes the Kopet Dag mountain range on the border between Turkmenistan and Iran. The flora of Kopet Dag reflects its biogeographic connection with the Mediterranean and Turanian elements; it contains several autochthonous endemics. The flora of Kopet Dag is especially rich and Linchevskiy [106] listed 926 plant species from the western part of Kopet Dag, whereas Gudkova et al. [107] published a list of 1266 species from the same area. Kamelin [36] estimated that the flora of Kopet Dag within Turkmenistan includes 1800 species, with 1387 species in central Kopet Dag. Nikitin [102] determined 955 species for the eastern part of central Kopet Dag and 1387 species for the center of central Kopet Dag [101]. According to German and Tyrlishkin [104], about 1800 plant species occur in the Kopet Dag reserve. Kurbanov [105] reported 1140 species in the flora of northwest Kopet Dag. Presently, the list for Kopet Dag includes 1942 species (332 of them are endemic), 680 genera and 104 families of vascular plants, comprising 372 species of monocotyledons and 1546 of dicotyledons [101]. According to Gubanov and Mesheryakov [100], information exists for ACPs of central Kopet Dag and Karakalin Valley [129], and also of the Ashgabat and Mari regions. We also analyzed more than 120 species for their alkaloid content coming from the Feryuzinsk gorge, the Sumbar Valley and the surrounding area of several villages. From a total 650 species of the flora of the Kopet Dag, we discovered alkaloids in 438 plants [103].

The total number of plants from the mountains Central Asia and the number of analyzed ACP species are listed in Table 1, alkaloid-containing taxa are listed in Table 2, and the taxonomic distribution of the identified alkaloids is listed in Table 3.

As we mentioned above, according to our calculations, at least 5350–5400 plant species grow in the mountains of Central Asia. Alkaloids are widely distributed in the plant kingdom, especially within flowering plants (angiosperms). According to Tachtadjan's (1987) system of classification, 12 subclasses of Magnoliopsida and three subclasses of Liliopsida consist of ACPs in the mountains of Central Asia (Table 2). A total 1067 plant species (belonging to 109 families and 632 genera) of Magnoliopsida and 91 plant species (belonging to 20 families and 120 genera) of Liliopsida were preliminarily screened for alkaloids. Most ACPs are found in the following superorders: Ranunculidae (families Ranunculaceae, Berberidaceae, Papaveraceae), Rosidae (Fabaceae, Rutacea, Nitrariaceae, Zygophyllaceae), Lamiidae (Apocynaceae, Boraginaceae, Convolvulaceae), while in the Liliopsida only members of the subclass Liliales produce alkaloids (Melianthiaceae, Colchicaceae, Liliaceae, Amarryllidaceae). Ranunculaceae is the family containing the highest number of ACPs here, from which 185 alkaloids were isolated from 36 plant species. A total of 78 alkaloids were identified from eight plant species of Berberidaceae. The Caryophyllaceae are poor in ACPs, followed by Polygonaceae, Rubiaceae, Crassulaceae and Rosaceae.

Table 2. Taxonomic distribution of alkaloid-containing plants from Central Asia (by Tachtadjan [130]).

Class	Subclass	Order	Family	Number				
				Genera	Species	Preliminary Investigated Species for Alkaloids	Alkaloid-Containing Species	Number of Identified Alkaloids
Magnoliopsida	Magnoliidae	Ceratophyllales	Ceratophyllaceae	1	1	1	-	-
	Ranunculidae	Ranunculales	Ranunculaceae	17	160	76	36	185
			Berberidaceae	3	12	9	8	78
		Paeoniales	Paeoniaceae	1	2	2	-	-
		Papaverales	Papaveraceae	4	25	18	11	59
			Hypecoaceae	1	5	4	4	11
			Fumariaceae	5	34	17	13	74
	Caryophyllidae	Caryophyllales	Caryophyllaceae	25	215	66	-	-
			Chenopodiaceae	29	97	44	8	11
		Polygonales	Polygonaceae	7	73	12	-	-
		Plumbaginales	Plumbaginaceae	11	9	6	-	-
	Hamamelidae	Hamamelidales	Plantanaceae	1	1	1	-	-
		Betulales	Betulaceae	1	2	2	-	-
	Dilleniidae	Elatinales	Elatinaceae	1	1	1	-	-
		Hupericales	Clusiaceae	1	5	2	-	-
		Primulales	Primulaceae	7	50	7	-	-
		Violales	Violaceae	1	25	9	-	-
		Tamaricales	Tamaricaceae	4	13	3	-	-
		Salicales	Salicaeae	2	26	2	-	-
		Cucurbitales	Cucurbitaceae	1	4	2	-	-
		Begoniales	Datiscaceae	1	1	1	-	-
		Buxales	Cistaceae	1	1	1	-	-
		Malvales	Malvaceae	5	18	2	-	-
		Capparales	Capparaceae	2	4	4	1	1
			Brassicaceae	86	280	69	1	13
			Resedaceae	1	2	2	2	8
		Urticales	Urticaceae	2	4	4	-	-
			Ulmaceae	2	5	4	-	-
			Moraceae	2	4	4	-	-
			Cannabaceae	2	2	2	-	-
		Euphorbiales	Euphorbiaceae	3	29	7	1	1
		Thymelaeales	Thymelaeaceae	5	9	2	-	-
	Rosidae	Saxifragales	Saxifragaceae	5	21	2	-	-
			Grossulariaceae	2	10	2	-	-
			Grassulaceae	6	38	11	-	-
		Droserales	Parnassiaceae	1	3	2	-	-
		Rosales	Rosaceae	32	221	21	-	-

Table 2. *Cont.*

Class	Subclass	Order	Family	Number				
				Genera	Species	Preliminary Investigated Species for Alkaloids	Alkaloid-Containing Species	Number of Identified Alkaloids
		Myrtales	Lythraceae	1	1	1	1	10
			Onagraceae	3	19	4	-	-
		Fabales	Fabaceae	24	673	174	6	37
		Sapindales	Sapindaceae	1	1	1	-	-
		Rutales	Rutaceae	2	8	8	6	48
			Tetradiclidaceae	1	1	1	-	-
			Nitrariaceae	1	2	2	2	35
			Peganaceae	1	1	1	1	18
			Anacardiaceae	2	2	2	-	-
		Linales	Linaceae	1	8	5	-	-
		Geraniales	Biebersteiniaceae	1	2	1	1	1
			Geraniaceae	3	22	8	-	-
		Polygalales	Polygalaceae	1	1	1	-	-
		Celastrales	Celastraceae	1	3	2	-	-
		Santalales	Santalaceae	1	2	2	1	3
		Rhamnales	Rhamnaceae	5	8	6	-	-
		Elaeagnales	Elaeagnaceae	2	5	3	2	9
		Vitales	Vitaceae	2	2	1	-	-
	Cornidae	Apiales	Apiaceae	67	240	67	2	6
		Dipsacales	Dipsacaceae	4	15	6	1	2
			Valerianaceae	3	33	3	-	-
			Caprifoliaceae	3	23	3	-	-
		Adoxales	Adoxaceae	1	1	1	-	-
			Sambucaceae	1	1	1	-	-
	Lamiidae	Gentianales	Gentianaceae	7	46	26	15	9
			Rubiaceae	7	65	17	-	-
			Apocynaceae	2	2	2	1	66
			Asclepiadaceae	2	5	3	-	-
		Oleales	Oleaceae	2	6	2	-	-
		Solanales	Solanaceae	5	10	8	3	13
		Convolvulales	Convolvulaceae	2	15	12	5	18
			Cuscutaceae	1	11	2	-	-
		Polemoniales	Polemoniaceae	1	1	1	-	-
		Boraginales	Boraginaceae	30	134	40	22	25
		Scrophulariales	Scorphulariaceae	20	167	60	11	23
			Bignoniaceae	1	1	1	1	2

Table 2. *Cont.*

Class	Subclass	Order	Family	Number				
				Genera	Species	Preliminary Investigated Species for Alkaloids	Alkaloid-Containing Species	Number of Identified Alkaloids
			Plantaginaceae	1	8	2	-	-
		Hippuridales	Hippuridaceae	1	1	1	-	-
		Lamiales	Verbenaceae	2	2	2	-	-
			Lamiaceae	45	339	91	3	1
	Asteridae	Campanulales	Campanulaceae	9	21	4	1	2
		Asterales	Asteraceae	81	1167	66	12	12
Liliopsida	Lilidae	Liliales	Iridaceae	5	33	13	-	-
			Melanthiaceae	1	2	2	2	37
			Colchicaceae	1	5	5	5	55
			Liliaceae	10	82	15	8	79
		Amaryllidales	Alliaceae	1	139	9	2	1
			Amaryllidaceae	2	7	7	7	17
			Asphodelaceae	1	27	10	6	2
			Ixioliriaceae	1	2	1	-	-
			Hemerocallidaceae	1	1	1	-	-
		Asparagales	Convollariaceae	1	1	1	-	-
			Asparagaceae	1	6	4	-	-
		Orchidales	Orchidaceae	9	17	3	-	-
		Juncales	Juncaceae	2	23	1	-	-
		Cyperales	Cyperaceae	17	96	4	-	-
		Poales	Poaceae	60	290	10	1	10
	Arecidae	Arales	Araceae	2	4	3	-	-
		Thyphales	Thyphaceae	1	6	1	-	-
	Alismatidae	Butomales	Butomaceae	1	1	1	-	-
		Alismatales	Alismataceae	2	2	2	-	-
		Juncaginales	Juncaginaceae	1	2	1	-	-
Lycopodiopsida	Lycopodiidae	Lycopodiales	Lycopodiaceae	2	2	2	-	-
Equisetopsida	Equisetidae	Equisetales	Equisetaceae	5	5	4	1	4
Polypodiopsida/ Pteridopsida	Polypodiidae	Polypodiales	Polypodiales	12	15	1	-	-
Gnetopsida	Gnetidae	Ephedrales	Ephedraceae	1	12	7	6	2
Pinopsida	Pinidae	Pinales	Pinaceae	3	5	2	-	-
		Cupressales	Cupressaceae	1	6	4	-	-

Table 2. *Cont.*

Class	Subclass	Order	Family	Number				
				Genera	Species	Preliminary Investigated Species for Alkaloids	Alkaloid-Containing Species	Number of Identified Alkaloids
In total								
Magnoliopsida	Magnoliidae	1	1	1	1	1	-	-
	Ranunculidae	3	36	31	238	125	73	407
	Caryophyllidae	3	4	72	394	128	8	11
	Hamamelidae	2	2	2	3	3	-	-
	Dilleniidae	14	19	129	483	128	5	23
	Rosidae	15	23	99	1054	261	20	161
	Cornidae	3	6	79	313	81	3	8
	Lamiidae	9	16	129	813	270	61	157
	Asteridae	2	2	90	1188	70	13	14
Liliopsida	Lilidae	7	15	113	731	83	31	201
	Arecidae	2	2	3	10	4	-	-
	Alismatidae	3	3	4	5	4	-	-
Lycopodiopsida	Lycopodiidae	1	1	2	2	2	-	-
Equisetopsida	Equisetidae	1	1	5	5	4	1	4
Polypodiopsida/ Pteridopsida	Polypodiidae	1	1	12	15	1	-	-
Gnetopsida	Gnetidae	1	1	1	12	7	6	2
Pinopsida	Pinidae	2	2	4	11	6	-	-

Table 3. Occurrence of isolated alkaloids in alkaloid-producing Central Asian plants.

Subclass	Order	Family	Genus	Species	Isolated Alkaloids	Reference
Ranunculidae	Ranunculales	Ranunculaceae	*Aconitum* L.	*A. anthoroideum* DC.	Condelphine, tadzhaconine	[131]
				A. chasmanthum Stapf	Aconitine, isotalatizidine	[131]
				A. karakolicum Rapaics	12-Acetylnapelline, 12-acetylnapelline *N*-oxide, acofine, aconifine, aconitine, 1-benzoylkarasamine, delsoline, dihydrosongorine, 12-epinapelline, isoboldine, karakolidine, karakoline, karakanine, karasamine, monticamine, napelline, napelline *N*-oxide, neoline, phenyl-β-naphtylamine, secokaraconitine, songorine	[131]
				A. leucostomum Worosch.	*N*-Acetylsepaconitine, acsinatine, corydine, *N*-deacetyllappaconitine, *N*-demethylcolletine, excelsine, glaunidine, lappaconidine, lappaconitine, leuconine, *O*-methylarmepavine, sepaconitine	[131]
				A. monticola Steinb.	Delsoline, deoxydelsoline, dihydromonticamine, monticamine, monticoline, norsongorine, songoramine, songorine, songorine *N*-oxide	[131]
				A. nemorum M.Pop.	14-Acetyltalatizamine, 14-benzoyltalatizamine, talatizamine	[131]
				A. rotundifolium Kar. et Kir.	Atisine chloride, isoatisine	[131]
				A. saposhnikovii B.Fedtsch. (*A. nemorum* M. Pop.)	14-Acetyltalatizamine, 14-dehydrotalatizamine, isoboldine, talatizamine	[131]
				A. soongaricum Stapf	12-Acetyl-12-epinapelline, 15-acetylsongoramine, 15-acetylsongorine, aconifine, aconine, aconitine, isoboldine, napelline, napelline *N*-oxide, neoline, norsongorine, phenyl-β-naphthylamine, songoramine, songorine	[131]
				A. talassicum M. Pop.	14-Acetyltalatizamine, actaline, condelphine, 11-dehydrokobusine, isotalatizidine, kobusine, lappaconitine, pseudokobusine, talasamine, talasimidine, talasimine, talatizamine, talatizidine, talatizine	[131]
				A. transchelii Steinb. (*A. nemorum* M. Pop.)	Isotalatizidine, talatizamine	[131]
				A. seravschanicum Steinb.	Atidine, atisine-azomethine, atisine chloride, heteratisine, hetisine, hetisine, isoatisine, nominine, reticuline, tadzhaconine, zeraconine, zeraconine *N*-oxide, zeravschanizine	[131]
			Aquilegia L.	*A. karelinii* (Baker) O. et B.Fedtsch.	Magnoflorine	[131]
			Atragene L.	*A. sibirica* L.	Aconitine, delphinine	[131]
			Consolida S.F. Gray	*C. ajacis* (L.) Schur	Delcosine	[131]
				C. orientalis (J.Gay) Schroeding.	Delcosine, delsoline, lycoctonine	[131]
			Delphinium L.	*D. biternatum* Huth	Anthranoyllyc octonine, 14-benzoylbrowniine, 14-benzoyldelcosine, browniine, 14-dehydrobrowniine, 14-dehydrodelcosine, delbiterine, delcosine, delphatine, delsoline, methyllycaconitine	[131]

Table 3. *Cont.*

Subclass	Order	Family	Genus	Species	Isolated Alkaloids	Reference
				D. confusum M. Pop.	14-Acetylbrowniine, 14-acetylkarakoline, 14-acetylnudicaulidine, 14-acetylviriescenine, anthranoyllycoctonine, condelphine, delcosine, delsoline, 18-deoxylycoctonine, isoboldine, isotalatizidine, 14-methylisotalatizidine, methyllycaconitine, nevadenzine, virescenine	[131]
				D. dictyocarpum DC.	14-Acetyldelectine, *N*-acetyldelectine, anthranoylylcoctonine, 14-benzoyldictyocarpine, dehydrodictysine, delectine, delectinine, delporphine, demethyleneeldelidine, dictyocarpine, dictysine, eldelidine, eldeline, isoboldine, lycoctonine, *N*-methyllaurotetanine, methyllycaconitine	[131]
				D. elatum L.	14-Deacetylnudicauline, delectinine, elatine, eldeline, nudicauline	[131]
				D. iliense Huth	Browniine, 6-dehydrodelcorine, delcoridine, delcorine, dictyocarpinine, eldeline, ilidine, lycoctonine	[131]
				D. oreophilum Huth	14-Acetylbrowniine, anthranoyllycoctonine, lycoctonine, methyllycaconitine	[131]
				D. poltoratskii Rupr. (*D. speciosum* M. Bieb.)	Ajacine, antranoyllycoctonine, delpoline, karakoline, lycoctonine, methyllycaconitine	[131]
				D. rotundifolium Afan	Browniine, methyllycaconitine	[131]
				D. semibarbatum Bien. ex Boiss.	Anthranoyllycoctonine, lycoctonine, methyllycaconitine	[131]
				D. ternatum Huth	6-Dehydroeldelidine , delcorine, delpheline, delterine, dictyocarpine, glaucine, lycoctonine, methyllycaconitine, terdeline, ternatine	[131]
				D. turkestanium auct. (*D. corymbosum* Regel)	Browniine, cordizine, corumdephine, corumdizine, corumdizinine, dehydrodelcorine, delcoridine, delcorine, delcorinine, delphatine, delpheline, demethylenedelpheline, deoxydelcorine, dictysine, *N*-ethyl-des-*N*-methyldictizine, lycoctonine, methyllycaconitine	[131]
			Thalictrum L.	*Th.alpinum* L.	Hernandezine (thalicsimine)	[131]
				Th. flavum L.	Berberine, cryptopine, magnoflorine, thalflavidine, thalflavine, thalicarpine, thalicminine, thaliglucinone (thalicsine)	[131]
				Th. foetidum L.	Berberine, corunnine, fetidine, glaucine, harmine, isoboldine, magnoflorine, 7-oxoglaucine (*O*-methylateroline), thalfine, thalfinine, thalflavine, thalicmidine	[131]
				Th. isopyroides C.A. Mey.	Cabudine, cryptopine (thalisopirine), dehydrothalicmine, isoboldine, magnoflorine, 1-oxo-6,7-dimethoxy-2-methy1-1,2-dihydroisoquinoline, thalicmine, thalicminine, thalisopidine, thalisopyne, thalisopynine	[131]
				Th. longipedunculatum E. Nikit.	Berberine, columbamine, glaucine, magnoflorine, *O*-methylthalicberine, thalicberine, thalicminine, thalicsimidine, thalidasine, thaliglucinone (thalicsine), thalphetidine (thalictrinine)	[131]

Table 3. *Cont.*

Subclass	Order	Family	Genus	Species	Isolated Alkaloids	Reference
				Th. minus L.	α-Allocryptopine, β-allocryptopine (thalictrimine), argemonine, aromoline, berberine, corunnine, dehydrothalicmine, glaucine, jatrorrhizine, magnoflorine, *N*-methylargemonine, β-*N*-methylcanadine, *N*-methyltetrahydropseudoberberine, *O*-methylthalicberine (thalmidine), palmatine, preocoteine *N*-oxide, thalbadensine, thalicberine, thalicmidine, thalicmidine N-oxide, thalicmine, thalicminine, thalicsimidine, thalmethine, thalmine, thalphenine	[131]
				Th. simplex L.	β-Allocryptopine, berberine (thalsine), hernandesine (thalicsimine), magnoflorine, thalicmine, thalicminine, thalicsimidine, thalictrisine, thaliclucinone (thalicsine), thalphetidine (thalictrinine), thalsimidine, thalsimine	[131]
				Th. strictum Ledeb. (*Th. flavum* L.)	Argemonine, berberine, magnoflorine, *O*-methylcassyfiline, preocoteine, thalicmine, thalicminine, thalicsimidine, thalictuberine, 2,3,7-trimethoxy-8,9-methylendioxy-*N*-methylpavinane	[131]
				Th. sultanabadense Stapf	Hernandezine, hernandezine 2′-*N*-oxide, O-methylthalmine, thalbadensine, thalictine, thalidezine	[131]
		Berberidaceae	*Berberis* L.	*B. heteropoda* Schrenk (B. sphaerocarpa)	Aromoline, berbamine, berbamunine, berberine, berpodine, columbamine, glaucine, 8-hydroxydihydropalmatine, isoboldine, isocorydine, isotetrandrine, jatrorrhizine, laudanidine, laudanosine, magnoflorine, *N*-methylcoclaurine, *N*-methyldihydroberberine, noroxohydrastinine, oblongine, 8-oxoberberrubine, oxyacanthine, palmatine, pseudopalmatine, reticuline, (–)-tetrahydroberberine, thalicmidine	[131]
				B. iliensis M.Pop.	Berbamine, berbamunine, berberine, berberrubine, columbamine, jatrorrhizine, magnoflorine, *N*-methylcoclaurine, (+)-β-*N*-methylcorypalmine, obaberine, oxyacanthine, palmatine	[131]
				B. integerrima Bunge	Armepavine, berbamine, berbamunine, berberine, columbamine, glaucine, heliamine, intebrimine, intebrine, intebrinine, isoboldine, isocorydine, isocorydine *N*-oxide, isotetrandrine, jatrorrhizine, magnoflorine, oxyacanthine, palmatine, reticuline, thalicmidine, thalicmidine *N*-oxide	[131]
				B. nummularia Bunge	Aromoline, berbamine, berbamunine, berberine, bernumicine, bernumidine, bernumine, columbamine, corypalline, glaucine, isoboldine, isocorydine, isotetrandrine, jatrorrhizine, laudanosine, magnoflorine, *N*-methylcoclaurine, noroxohydrastinine, numularine, obaberine, oxyacanthine, palmatine, reticuline, (–)-tetrahydroberberrubine, thalicmidine, (+)-thalictricavine	[131]
				B. oblonga (Bunge) Schneid.	Berbamine, berbamunine, berberine, columbamine, corypallinium or 3,4-dihydrocorypallinium, glaucine, isocorydine, jatrorrhizine, magnoflorine, 2-*N*-methylberbamine, 2′-*N*-methylisotetrandrine, oblongamine, oblongine, oxyacanthine, palmatine, thalicmidine	[131]

Table 3. *Cont.*

Subclass	Order	Family	Genus	Species	Isolated Alkaloids	Reference
				B. turcomanica Kar.	Armepavine, aromoline, berbamine, berberine, columbamine, corydine, corypalline, epiberberine, glaucine, isoboldine, isocorydine, jatrorrhizine, magnoflorine, *O*-methylisothalicberine, *N*-methylcorydaldine, oxyacanthine, palmatine, papaverine, thalicmidine, turcamine, turcberine, turcomanine, turcomanidine, turconidine	[131]
				B. vulgaris L.	Bargustanine, berbamine, berbamunine, berberine, berberrubine, berlambin, columbamine, dihydroberberine (lambertin), isocorydine, isotetrandrine, jatrorrhizine, magnoflorine, 8-oxoberberine, oxyacanthine, palmatine, yuzifine	[131]
			Gymnospermium Spach	*G. albertii* Regel (*Leontice alberti* Regel)	Albertamine, albertidine, albertine, anabasine, darvasamine, darvasine, leontalbamine, leontalbine, leontalbinine, leontidine, leontine, matrine, *N*-methylcytisine, (+)-sophoridine, taspine	[131]
				G. darvasicum Regel (*Leontice darwasica* Regel)	Anabasine, darvasamine, darvasine, darvasoline, leontalbinine, leontidine, leontine, (–)-lupanine, *N*-methylcytisine, (+)-sophoridine, taspine	[131]
	Papaverales	Papaveraceae	*Chelidonium* L.	*Ch. majus* L.	Chelerythrine, chelidonine, protopine, sanguinarine, (–)-stylopine (chelidamine)	[131]
			Glaucium Adans.	*G. corniculatum* (L.) J.Rudolph.	a-Allocryptopine, corydine, dehydrocorydine, glaucine, glaufidine, isocorydine, *N*-methylstylopine, norbracteoline, predicentrine, protopine, reticuline, sanguinarine, thalicmidine	[131]
				G. elegans Fisch. et Mey.	a-Allocryptopine, chelerythrine, chelidonine, chelirubine, corydine, corunine(glauvine), dihydrochelerythrine, glaucine, isoboldine, isocorydine, 7-oxoglaucine (*O*-methylateroline), protopine, sanguinarine, thalicmidine	[131]
				G. fimbrilligerum (Trautv.) Boiss.	α-Allocryptopine, chelerythrine, chelidonine, columbamine, corydine, corydine *N*-oxide, corytuberine, dehydrocorydine, dihydrosanguinarine, epiglaufidine, glaufidine, glaufine, glaufinine, glaunidine, glaunine, isoboldine, isocorydine, isocorypalmine, isocorytuberine, magnoflorine, *N*-methylcoclaurine, *N*-methyllindcarpine, α-*N*-methylstylopine, norcorydine, norisocoridine, protopine, reticuline, sanguinarine, scoulerine	[131]
				G. squamigerum Kar. et Kir.	α-Allocryptopine, chelerythrine, chelidonine, corydine, cryptopine, glaufine, isoboldine, isocorytuberine, magnoflorine, (–)-β-*N*-methylcanadine, protopine, reticuline, sanguinarine, scoulerine	[131]
			Papaver L.	*P. angrenicum* Pazij	Pangrenine	[131]
				P. croceum Ledeb.	Amurine, corydine, nudaurine, oxosanguinarine, protopine	[131]
				P. gybridum L.	Protopine, reticuline, scoulerine	[131]
				P. pavonium Schrenk	α-Allocryptopine, cheilantifoline, protopine, scoulerine	[131]
			Roemeria Medik.	*R. hybrida* (L.) DC.	Protopine, roemeridine	[131]
				R. refracta DC.	Anonaine, (–)-ephedrine, liriodenine, (–)-mecambroline, (+)-pseudoephedrine, reframine, roemerine, roemrefidine, roemrefine	[131]

Table 3. *Cont.*

Subclass	Order	Family	Genus	Species	Isolated Alkaloids	Reference
		Hypecoaceae	*Hypecoum* L.	*H. erectum* L.	α-Allocryptopine, coptisine, corydamine, hypecorine, hypecorinine, hyperectine, isohyperectine, (–)-β-*N*-methylcanadine, protopine	[131]
				H. lactiflorum Kar. et Kir.	α-Allocryptopine, hypecorine, hypecorinine, protopine	[131]
				H. pendulum L.	Protopine	[131]
				H. trilobum Trautv.	Chelerythrine, protopine, sanguinarine	[131]
		Fumariaceae	*Corydalis* Venth.	*C. fimrillifera* Korsh.	Protopine	[131]
				C. glaucescens Regel	Bulbocapnine, corydaline, protopine	[131]
				C. gortschakovii Schrenk	(–)-Adlumidine, (–)-adlumine, (+)-bicuculline, bracteoline, cheilantifoline, corgoine, corunnine, corydine, corytuberine, cryptopine, domesticine, gortschakoine, isoboldine, isocorydine, *N*-methylcoclaurine, protopine, reticuline, scoulerine, sendaverine, sendaverine *N*-oxide, (+)-stylopine, thalicmidine, yuzifine, yuzifine *N*-oxide	[131]
				C. ledebouriana Kar. et Kir.	(–)-Adlumidine, (–)-adlumine, α-allocryptopine, berberine, (–)-bicuculline, bulbocapnine, (–)-cavidine, chelerythrine, corledine, corydaline, corypalline, cryptopine, dihydrochelerythrine, dihydrosanguinarine, hunnemanine, isocorydine, ledeboridine, ledeborine, ledecorine, lederine, *N*-methylcoclaurine, oxosanguinarine, palmatine, protopine, (±)-raddeanine, raddeanone, sanguinarine, scoulerine, severtzine, sibiricine, (+)-tetrahydrocorysamine, tetrahydropalmatine	[131]
				C. paniculigera Regel et Schmalh.	(–)-Adlumidine, (–)-adlumine, (+)-bicuculline, coclaurine, corunnine, dihydrosanguinarine, oxosanguinarine, pancoridine, pancorine, pancorinine, protopine, sanguinarine, sibiricine, (+)-stylopine, thalicmidine, wilsonirine	[131]
				C. popovii Newski ex M. Pop.	Bulbocapnine, corydaline	[131]
				C. pseudoadunca M. Pop.	(–)-Adlumidine, (+)-bicuculline, (+)-bicuculline, coclaurine, coreximine, corftaline, (+)-p-hydrastine, protopine, reticuline, reticuline N-oxide, sanguinarine, (–)-scoulerine, sibiricine, (+)-stylopine, wilsonirine, yuzifine	[131]
				C. sewertzowii Regel	Adlumidiceine, α-allocryptopine, (–)-bicuculline, chelerythrine, coclaurine, coreximine, corlumine, cryptopine, dihydrosanguinarine, isoboldine, protopine, sanguinarine, scoulerine, severtzine, severtzinine, sibiricine	[131]
				C. stricta Steph. ex Fisch.	(–)-Adlumidine, (–)-adlumine, (+)-bicuculline, cheilantifoline, coreximine, corypalline, dihydrosanguinarine, (+)-d-β-hydrastine, isoboldine, isocorypalmine, *N*-methylcoclaurine, *N*-methylcorypalline, N-methylstylopine, pancoridine, pancorinine, picnorrine, protopine, reticuline, sanguinarine, (–)-scoulerine, (+)-stylopine, wilsonirin, yuzifine	[131]

Table 3. *Cont.*

Subclass	Order	Family	Genus	Species	Isolated Alkaloids	Reference
			Cysticorydalis Fedde ex Jconn.	*C. fedtschenkoana* (*Corydalis fedtschenkoana* Regel)	Bulbocapnine, protopine, sanguinarine	[131]
			Fumaria L.	*F. micrantha* Lag.	Protopine, fumaramine	[131]
				F. schleicheri Soy- Willem.	Adlumidiceine, adlumidine, (–)-bicuculline, (±)-bicuculline, fumaritine, (+)-α-hydrastine, isoboldine, oxohydrastinine, protopine, (+)-stylopine, (±)-stylopine	[131]
				F. vaillantii Loisel.	Adlumidiceine, (–)-adlumidine, (–)-adlumine, (+)-bicuculline, cheilantifoline, coclaurine, fumariline, (+)-α-hydrastine, isoboldine, ledecorine, N-methyladlumine, *N*-methylstylopine, noryuzifine, parfumine, protopine, reticuline, scoulerine, (+)-stylopine, vaillantine	[131]
Caryophyllidae	Caryophyllales	Chenopodiaceae	*Anabasis* L.	*A. aphylla* L.	Anabasamine, anabasine, aphyllidine, aphylline, hydroxyaphylline, lupinine, methyl ester of aphyllinic acid, oxoaphyllidine	[131]
				A. salsa (C.A. Mey.) Benth. ex Volkens	(–)-2,6-Dimethylpiperidine	[131]
			Chenopodium L.	*Ch. botrys* L. (*Dysphania botrys* (L.) Mosyakin & Clemants)	Betaine	[132]
			Hammada Iljin	*H. leptoclada* (M. Pop. ex Iljin) Iljin	Dipterine, eleagnine, leptocladine (*N*-methyltetrahydroharman), *N*-methyl-β-phenethylamine, *N*-methyltetrahydro-β-carboline	[131]
				H. wakhanica (Pauls.) Iljin	Leptocladine, *N*-methyl-β-phenethylamine	[131]
			Nanophyton Less.	*N. erinaceum* (Pall.) Bunge	(–)-2,6-Dimethylpiperidine, (–)-1,2,6-trimethylpiperidine	[131]
			Salsola L.	*S. pestifer* Nels. (*S. iberica* Sennen & Pau)	(–)-Salsolidine, (+)-salsoline	[131]
				S. subaphylla C.A. Mey (*Aellenia subaphylla*, *Halothamnus subaphyllus*)	Subaphylline	[131]
Dilleniidae	Capparales	Capparidaceae	*Capparis* L.	*C. spinosa* L. (*C. herbacea*)	(+)-Stachydrine	[131]
		Brassicaceae	*Diptychocarpus* Trautv.	*D. strictus* (Fisch. ex Bieb.) Trautv.	Deoxydipthocarpaine, deoxydipthocarpamine, deoxydipthocarpidine, *N*,*N*′-diisopropylurea, dipthaline, dipthamine, dipthocarpaine, dipthocarpamine, dipthocarpidine, dipthocarpilidine, dipthocarpiline, diptocarpinine, *N*-isopropylurea	[131]
		Resedaceae	*Reseda* L.	*R. lutea* L.	Luteanine, phenyl-β-naphthylamine	[131]
				R. luteola L.	Lutine, lutinine, β-hydroxyphenylethylamine, phenyl-β-naphthylamine, resedine, resedinine (barbarine)	[131]
	Euphorbiales	Euphorbiaceae	*Andrachne* L.	*A. rotundifolia* C.A. Mey.	Andrachnine	[133]

Table 3. *Cont.*

Subclass	Order	Family	Genus	Species	Isolated Alkaloids	Reference
Rosidae	Myrtales	Lythraceae	*Punica* L.	*P. granatum* L.	Pseudopelletierine, pelletierine, isopelletierine, methylpelletierine, 1-pelletierine, dl-pelletierine, methylisopelletierine, 2-(2-propenyl)-piperidine, *N*-(2′,5′-dihydroxyphenyl)-pyridinium chloride, punigratane	[134–136]
	Fabales	Fabaceae	*Ammopiptanthus* Cheng. f.	*Piptanthus nanus* M. Pop. [*Ammopiptanthus nanus* (M.Pop.) Cheng fil.]	(+)-Lupanine, piptamine, piptanthine, sparteine	[131]
			Thermopsis R.Br.	*Th. alpina* (Pall.) Ledeb.	Alpine, argentine, cytosine, *N*-methylcytisine, pachycarpine, thermopsine	[131]
				Th. alterniflora Regel et Schma1h.	Alteramine, anagyrine, argentamine, argentine, cytosine, dimethamine, *N*-methylcytisine, pachycarpine, thermopsine	[131]
				Th. dolichocarpa V. Nikit.	Cytisine, pachycarpine, thermopsine	[131]
				Th. turkestanica Gand. (*Th. lanceolata* R. Br.)	Anagyrine, argentine, cytosine, dithermamine, *N*-methylcytisine, pachycarpine, rhombifoline, thermopsamine, thermopsine, cytosine, thermopsine	[131]
			Vexibia Rafin.	*V. alopecuroides* L. (*Sophora alopecuroides* L.)	Allylaloperine, aloperine, baptifoline, cytosine, 13,14-dehydrosophoridine, 13,14-dehydrosophoridine *N*-oxide, 3-α-hydroxysophoridine, isosophoridine, matrine, matrine *N*-oxide, *N*-methylaloperine, neosophoramine, 5,6,11,12,13,14,15,16-octadehydroaloperane, sophocarpine, sophocarpine *N*-oxide, sophoramine, (–)-sophoridine, sophoridine *N*-oxide, sophorine (base 8), tricrotonyltetramine	[131]
	Rutales	Rutaceae	*Dictamnus* L.	*D. angustifolius* G.Don. fil. ex Sweet	Dictamnine, dubamine, dubinidine, evoxine, γ-fagarine, isodictamnine, isopteleine, preskimmianine, skimmianine	[131]
			Haplophyllum A. Juss.	*H. acutifolium* (DC.) G.Don. fil.	Acetamide, acutine, evoxine, haplamine, perfamine, skimmianine	[131]
				H. dubium Korov.	Dubamine, dubinidine, dubinine, evoxine, γ-fagarine, folifidine, foliosidine, graveoline, haplopine, norgraveolline, robustine, skimmianine	[131]
				H. latifolium Kar. et Kir.	Dubamine, evoxine, glycoperine, haplamide, haplamidine, haplatine, haplopine, 7-isopentenyloxy-γ-fagarine, skimmianine	[131]
				H. perforatum Kar. et Kir.	Acetylhaplophyllidine, anhydroevoxine, anhydroperforine, dictamnine, dihydrohaplamine, dubinidine, evodine, evoxine, evoxoidine, flindersine, folimine, foliosidine, glucohaplopine, glycoperine, graveoline, haplafine, haplamine, haplophidine, haplophyllidine, haplopine, haplosamine, haplosidine, haplosine, haplosinine, 7-isopentenyloxy-γ-fagarine, methylevoxine, *N*-methyl-2-phenylquinolin-4-one, monoacetylglycoperine, perfamine, perforine, platydesmine, robustine, skimmianine, triacetylglycoperine	[131]
				H. popovii Korov.	Evoxine, hapovine, skimmianine	[131]

Table 3. *Cont.*

Subclass	Order	Family	Genus	Species	Isolated Alkaloids	Reference
		Nitrariceae	*Nitraria* L.	*N. schoberi* L.	Acetylkomavine, *N*-allylisonitrarine, dehydroschoberine, deoxypeganine, deoxyvasicinone, dihydronitraraine, evoxine, isonitrarine, isoschoberidine, komavine, *N*-methylnitrarine, nitramidine, nitramine, nitraraine, nitraramine, nitraramine *N*-oxide, nitrarine, nitraroxine, schoberidine, schoberine, sibiridine, tetramethylenedihydro-β-carboline, tetramethylenetetrahydro-β-carboline, tetramethylentetrahydro-β-carboline *N*-oxide, tryptamine, (±)-vasicinone	[131]
				N. sibirica Pall.	Dehydroschoberine, deoxyvasicinone, dihydroschoberine, isonitramine, nitrabirine, nitrabirine *N*-oxide, nitramine, (+)-nitramine, nitraraidine, nitraramidine, nitraramine, nitraramine *N*-oxide, nitraroxine, phenylnitrabirine, schoberine, sibiridine, sibirine, sibirinine, (–)-vasicinone	[131]
		Peganaceae	*Peganum* L.	*P. harmala* L.	Deoxypeganidine, deoxypeganine, deoxyvasicinone, dipegine, dipeginole, harmaline, harmine, isopeganidine, pegamine, peganidine, (–)-peganine, (±)-peganine, peganol, quinaldine, quinoline, (–)-vasicinone, (±)-vasicinone, vasicol	[131]
	Geraniales	Biebersteiniaceae	*Biebersteinia* Steph.	*B. multifida* DC.	(-)-Vasicinone	[131]
	Santalaes	Santalaceae	*Thesium* L.	*Th. minkwitzianum* B.Fedtsch.	(+)-Isoretronecanol, thesine, thesinine	[131]
	Elaeagnales	Elaeagnaceae	*Elaeagnus* L.	*E. angustifolia* L.	Dihydroharman, eleagnine (tetrahydroharman), harman, *N*-methyltetrahydro-β-carboline, *N*-methyltetrahydroharmol, tetrahydroharmol	[137]
			Hippophae L.	*H. rhamnoides* L.	4-[(E)-p-Coumaroylamino]butan-1-ol, 4-[(Z)-p-coumaroylamino]butan-1-ol, hippophamide, dihydroharman, eleagnine (tetrahydroharman), harman, *N*-methyltetrahydro-β-carboline, tetrahydroharmol, serotonine	[137,138]
Cornidae	Apiales	Apiaceae	*Conium* L.	*C. maculatum* L.	Coniine, γ-coniceine, *N*-methylconiine, conhydrine, pseudoconhydrine	[139,140]
			Prangos Lindl.	*P. pabularia* Lindl.	Prangosine	[131]
	Dipsacales	Dipsacaceae	*Dipsacus* L.	*D. azureus* Schrenk (*D. dipsacoides* (Kar. et Kir.) Botsch.)	Cantleyine, gentianine	[131]
Lamiidae	Gentianales	Gentianaceae	*Centaurium* Gilib.	*C. turcicum* Ronn. (*Erythraea centaurium* Rafin.)	Gentianine	[131]
			Gentiana L.	*G. barbata* Froel.	Gentianine	[131]
				G. decumbens L. fil.	Gentianine	[131]

Table 3. *Cont.*

Subclass	Order	Family	Genus	Species	Isolated Alkaloids	Reference
				G. kaufmanniana Regel et Schmalh.	Gentianaine, gentiananine, gentianine	[131]
				G. kirilowii Turcz.	Gentianine	[131]
				G. macrophylla Pall. (*G. fetissovii* Regel et Winkl.)	Gentianine	[131]
				G. olgae Regel et Schmalh.	Gentianadine, gentianaine, gentiananine, gentioflavine	[131]
				G. olivieri Griseb.	Gentianadine, gentianaine, gentiananine, gentianine, gentioflavine, gentiotibetine, oliveramine, oliveridine	[131]
				G. tianschanica Rupr.	Gentiananine, gentianine, gentioflavine	[131]
				G. turkestanorum Gand. (*Gentianella turkestanorum* (Gand.) Holub.)	Gentianadine, gentianaine, gentianamine, gentiananine, gentianine	[131]
				G. vvedenskyi Grossh.	Gentiananine, gentianine	[131]
			Lomatogonium A. Br	*L. rotatum* (L.) Fries ex Fern.	Gentianine	[131]
			Swertia L.	*S. connata* Schrenk	Gentiananine, gentianine, gentioflavine	[131]
				S. graciliflora Gontsch.	Gentiananine, gentianine, gentioflavine	[131]
				S. marginata Schrenk	Gentiananine, gentianine, gentioflavine	[131]
		Apocynaceae	*Vinca* L.	*V. erecta* Regel et Schmalh.	*N*-Acetylvinerine, akuammicine, akuammidine, akuammine, (+)-apovincamine, O-benzoyltombosine, (–)-1,2-dehydroaspidospermidine, 14,15-dehydro-3-oxokopsinine, 14,15-dehydro-3-oxokopsinine *N*-oxide, 5,22-dioxokopsane, (±)-eburnamine, (–)-eburnamonine, epoxykopsinine, ercinamine, ercinaminine, ervincidine, ervincinine, ervine, ervinidine, ervinidinine, 10-hydroxystrictamine, 11-hydroxystrictamine, isoreserpiline, kopsinilam, kopsinilamine, kopsinine (erectine), kopsinine *N*-oxide, majdine, majoridine (majdinine), 1-methoxytabersonine (ervamicine), 10-methoxyvellosimine, 11-methoxyvincadifformine (ervinceine), 11-methoxyvincadifformine *N*-oxide, 10-methoxyvinorine, O-methylakuammine, minovincinine, picrinine (vincaridine), pseudokopsinine, pseudokopsinine chloromethylate, pseudokopsinine *N*-oxide, (+)-quebrachamine, quebrachidine (vincarine), reserpinine, skimmianine, tombozine, venalstonine, (–)-vincadifformine (ervamine), vincaerectine, vincamajine, vincamidine, (+)-vincamine (minorine), vincanicine, vincanidin, (–)-vincanine (norfluorocurarine), (±)-vincanine (vinervidine), vincanine *N*-oxide, vincaricine, vincarinine, vincine, vineridine, vineridine *N*-oxide, vinerine, vinerine *N*-oxide, vinerinine, vinervine, vinervinine	[131]

Table 3. *Cont.*

Subclass	Order	Family	Genus	Species	Isolated Alkaloids	Reference
	Solanales	Solanaceae	*Hyoscyamus* L.	*H. niger* L.	Apoatropine, apohyoscine, α-belladonnine, β-belladonnine, hyoscine, hyoscyamine, tropine	[131]
				H. pusillus L.	Apoatropine, apohyoscine, hyoscine or {(–)-scopolamine}, hyoscyamine, tropine	[131]
			Physochlaina G. Don.	*Ph. alaica* Korotk. (*Ph. dubia* Pasch.)	Apoatropine, apohyoscine, atropine, α-belladonnine, β-belladonnine, (–)-3α,6β-dihydroxytropane {(–)-3α,6β-tropandiole}, 6-hydroxyatropine {(–)-6-hydroxyhyoscyamine}, 6-hydroxyhyoscyamine, 6-hydroxyhyoscyamine *N*-oxide, hyoscine {(–)-scopolamine}, hyoscyamine, physochlaine, tropine	[131]
	Convolvulales	Convolvulaceae	*Convolvulus* L.	*C. krauseanus* Regel et Schmalh.	Convolamine, convolamine *N*-oxide, convolicine, convolidine, convoline, convolvidine, convolvine, phyllalbine	[131]
				C. lineatus L.	Cuscohygrine	[131]
				C. olgae Rgl. et Schmalh.	Cuscohygrine	[131]
				C. pseudocantabrica Schrenk	Convolamine, convolicine, convolidine, convoline, convolvidine, convolvine, phyllalbine	[131]
				C. subhirsutus Regel et Schmalh.	Confolidine, confoline, conpropine, convolacine, convolamine, convolicine, convolidine, convoline, convolvidine, convolvine, convosine, nortropine, phyllalbine, phyllalbine *N*-oxide, subhirsine	[131]
	Boraginales	Boraginaceae	*Caccinia* Savi	*C. macranthera* (Banks & Sol.) Brand (*Caccinia crassifolia* (Vent.) K. Koch)	Supinine, heliotridine or retronecine trachelanthate	[141]
			Cynoglossum L.	*C. pictum* Soland.	Echinatine, echinatine *N*-oxide, heliosupine, heliosupine *N*-oxide	[131]
			Echium L.	*E. vulgare* L.	Asperumine, asperumine *N*-oxide, heliosupine	[131]
			Lindelofia Lehm.	*Lindelofia anchusoides* Lindl. (*Lappula macrostyla* (Bunge) M.Pop.)	Echinatine, lindelofamine, lindelofine, lindelofine *N*-oxide, viridiflorine	[131]
				L. olgae (Regel et Smirn.) Brand	Viridiflorine, viridiflorine *N*-oxide	[131]
				L. pterocarpa (Rupr.) M. Pop.	Viridiflorine, viridiflorine *N*-oxide	[131]
				L. stylosa (Kar. et.Kir.) Brand	Echinatine, echinatine *N*-oxide, lindelofine, lindelofine *N*-oxide, viridiflorine, viridiflorine *N*-oxide	[131]
				L. tschimganica (Lipsky) M.Pop. ex Pazij	Echinatine, karategine, viridiflorine	[131]

Table 3. *Cont.*

Subclass	Order	Family	Genus	Species	Isolated Alkaloids	Reference
			Paracaryum Boiss.	*P. hymalaense* (Klotzsch) Clarke (*Mattiastrum himalayense* (Klotzsch) Brand)	Viridiflorine, viridiflorine *N*-oxide	[131]
			Rindera Pall.	*R. baldshuanica* Kusn. (*Rindera tetraspis* Pallas)	Echinatine, rinderine, trachelanthamine	[131]
				R. cyclodonta Bunge (*Rindera tetraspis* Pallas)	Echinatine, lindelofine, lindelofine *N*-oxide	[131]
				R. echinata Regel	Echinatine, trachelanthamine, trachelanthamine *N*-oxide	[131]
				R. oblongifolia M. Pop.	Echinatine, karategine, turkestanine	[131]
			Solenanthus Ledeb.	*S. circinnatus* Ledeb.	Echinatine, karategine	[131]
				S. coronatus Regel	Echinatine	[131]
				S. hirsutus Regel	Echinatine, karategine, turkestanine	[131]
				S. karateginus Lipsky	Echinatine	[131]
				S. turkestanicus (Regel et Smirn.) Kusn.	Rinderine, turkestanine	[131]
			Trachelanthus Kuntze	*T. hissaricus* Lipsky	Trachelanthamine, trachelanthamine *N*-oxide, viridiflorine, viridiflorine *N*-oxide	[131]
				T. korolkovii Lipsky	Trachelanthamidine, trachelanthamine, trachelanthamine *N*-oxide	[131]
			Trichodesma R.Br.	*T. incanum* (Bunge) A.D.C.	Incanine, incanine *N*-oxide, trichodesmine, trichodesmine *N*-oxide	[131]
			Ulugbekia Zak.	*U. tchimganica* (B.Fedtsch.) Zak.	Uluganine	[131]
	Scrophulariales	Scrophulariaceae	*Leptorhabdos* Schrenk	*L. parviflora* (Benth.) Benth.	Aloperine, leptorhabine, (+)-leptorhabine, pachycarpine, sophoramine, sophorcarpine, (–)-sophoridine	[131]
			Linaria Mill.	*L. popovii* Kuprian.	(±)-Peganine	[131]
				L. transiliensis Kuprian.	Deoxyvasicinone, (±)-peganine, (–)-vasicinone	[131]
				L. vulgaris Mill.	(±)-Peganine	[131]
			Pedicularis L.	*P. dolichorrhiza* Schrenk	*N*-Methylcytisine, plantagonine	[131]
				P. ludwigii Regel	Indicaine, platagonine	[131]
				P. macrochila Vved.	Gentiananine, noractinidine, plantagonine	[131]
				P. olgae Regel	Indicaine, indicainine, *N*-methylcytisine, pedicularidine, pedicularine, pediculidine, pediculine, pediculinine, plantagonine	[131]
				P. rhinanthoides Schrenk	Plantagonine, tecostidine	[131]
				P. violascens Schrenk	Indicaine, plantagonine	[131]
			Verbascum L.	*V. soongoricum* Schrenk	Anabasine, plantagonine	[131]
		Bignoniaceae	*Incarvillea* Juss.	*I. olgae* Regel	Indicaine, (–)-plantagonine	[131]

Table 3. *Cont.*

Subclass	Order	Family	Genus	Species	Isolated Alkaloids	Reference
	Lamiales	Lamiaceae	*Lagochilus* Bunge	*L. plantycalyx* Schrenk ex Fisch. et Mey.	(+)-Stachydrine	[131]
			Phlomoides Moench	*P. speciosa* Rupr. (*Eremostachys speciosa* Rupr.)	(+)-Stachydrine	[131]
			Stachys L.	*S. betonicaeflora* Rupr.	(+)-Stachydrine	[131]
Asteridae	Campanulales	Campanulaceae	*Codonopsis* Wall.	*C. clematidea* (Schrenk) Clarke	Codonopsine, codonopsinine	[131]
	Asterales	Asteraceae	*Echinops* L.	*E. chantavicus* Trautv.	*N*-Methyl-4-aminoquinolinium	[131]
				E. karatavicus Regel et Schmalh.	*N*-Methyl-4-aminoquinolinium	[131]
				E. maracandicus Bunge	*N*-Methyl-4-aminoquinolinium	[131]
				E. ritro L.	*N*-Methyl-4-aminoquinolinium	[131]
			Jurinea Cass.	*J. suffruticosa* Regel	Yurimine, yurinine	[142]
			Saussurea DC.	*S. elegans* Ledeb.	Elegantine	[131]
			Senecio L.	*S. franchetii* C. Winkl.	Sarracine *N*-oxide	[131]
				S. jacobaea L.	Jacobine, (–)-othosenine, renardine	[131]
				S. renardii C. Winkl.	(+)-Othosenine, renardine, seneciphylline	[131]
				S. subdentatus Ledeb.	Renardine, seneciphylline	[131]
				S. vernalis Waldst. et Kit.	Platyphylline, seneciphylline	[131]
				S. vulgaris L.	Senecionine	[131]
Lilidae	Liliales	Liliaceae	*Fritillaria* L.	*F. eduardii* (Regel) Vved. (*Petillium eduardii* (Regel) Vved.)	Edpetilidine, edpetilidinine, edpetiline, edpetilinine, edpetine, edpetinosine, edpetisidine, edpetisidinine, edpetisine, edpetisinine, eduardine, eduardinine, imperialine (sipaimaine, raddeanine), imperialine *N*-oxide, imperialone, imperiasine, peimisine, petine, petine *N*-oxide	[131]
				F. raddeana (Regel) Vved. ex Pazij (*Petillium raddeanum* Vved. ex Pazij)	Edpetiline, edpetine, imperialine, imperialine *N*-oxide, imperialone, isodihydroimperialine, peimisine, petilidine, petiline, petilinine, petisidine, petisidinine, petisidinone, petisine, petisinine, radpetine	[131]
				F. walujewii Regel (*F. ferganensis* Losinsk.)	Rinolidine, rinoline, rinolinine, solanidine, valivine	[131]

Table 3. *Cont.*

Subclass	Order	Family	Genus	Species	Isolated Alkaloids	Reference
			Korolkowia Regel	*K. sewertzowii* Regel (*Fritillaria sewertzowii* Regel)	Acetylsevedine, diacetylsevedine, kordiline, korselidine, korselimine, korsemine, korseveramine, korseveridine, korseveridinine, korseveriline, korseverilinone, korseverine, korseverinine, korsevine, korsevinine, korsidine, korsiline, korsinamine, korsine, korsine *N*-oxide, korsinine, petisidine, sevcoridinine, sevcorine, sevedamine, sevedine, sevedinine, sevedine *N*-oxide, seveline, severidine, severidinine, severine, severine *N*-oxide, severzine, severtcidine, solanidine	[131]
			Rhinopetalum Fisch.	*Rh. bucharicum* (Regel) Losinsk.	Imperialine, rinoline, rinolinine, solanidine	[131]
				Rh. karelinii Fisch. ex Alexand.	Rinoline, rinolinine, solanidine	[131]
				Rh. stenantherum Regel	β-Chaconine, solanidine, stenantidine, stenantine, stenanzamine, stenanzidine, stenanzidinine, stenanzine	[131]
			Lilium L.	*L. martagon* L.	Lilidine	[131]
		Melanthiaceae	*Veratrum* L.	*V. lobelianum* Bernh.	Deacetylprotoveratrine A, deacetylveralosine, dideacetylprotoberatrine A, germbudine, germerine, germidine, germinaline, germinalinine, germine, germinine, germitetrine, isorubijervine, isorubijervosine, jervine, 15-(–)-2-methylbutyrylgermine, 3,15-(2′-methylbuturyl) germine, neogermitrine, protoveratrine A, pseudojervine, rubijervine, solanidine, γ-solanine, veralcamine, veralodine, veralodinine, veralodisine, veralomine, veralosidine, veralosidinine, veralosine, veralosinine, veramarine, veramine, veratroylzygadenine, verazine, verdine, verdinine	[131]
				V. nigrum L.	Deacetylprotoveratrine A, dideacetylprotoveratrine A, germerine, germidine, isorubijervine, jervine, protoveratrine A, rubijervine, veramarine, veramine, veratroylzygadenine, verazine	[131]
		Colchicaceae	*Colchicum* L.	*C. kesselringii* Regel	Allocolchicine, colchamine (demecolcine), colchiceine, colchicines, 3-demethylallocolchicine, 2-demethylcolchicine, 3-demethylcolchicine, 2-demethyl-β-lumicolchicine, 2-demethyl-γ-lumicolchicine, 3-demethyl-β-lumicolchicine, 3-demethyl-γ-lumicolchicine, 3,10-didemethylcolchicine (3-demethylcolchiceine), *N*-formyldeacetylcolchicine, isoregecoline, isoregelinone, kesselridine, kesselringine, krokiflorinine, krokiflorinine *N*-oxide (krokiflorine), krokiflorinone, β-lumicolchicine, γ-lumicolchicine, luteine, regecoline, regelamine, regeline, regelinine, regelinone, yolantamine, yolantimine	[131]

Table 3. *Cont.*

Subclass	Order	Family	Genus	Species	Isolated Alkaloids	Reference
				C. luteum Baker	Colchameine (demecolceine), colchamine (demecolcine), colchiceine, colchicines, colchilutine, collutine, collutine *N*-oxide, 2-demethylcolchamine (2-demethyldemecolcine), 2-demethylcolchicine, 3-demethylcolchicine, 2-demethyl-β-lumicolchicine, 2-demethyl-γ-lumicolchicine, 3-demethyl-β-lumicolchicine, 2,10-didemethylcolchicine, 3,10-didemethylcolchicine (3-demethylcolchiceine), *N*-formyldeacetylcolchicine, kesselringine, β-lumicolchicine, luteicine, luteidine, luteidine cis-*N*-oxide, luteidine trans-*N*-oxide, luteine, luteinine, luteinone	[131]
			Merendera Ramond	*M. jolanthae* Czerniak.	Colchameine (demecolceine), colchamine (demecolcine), colchiceine, colchicines, 2-demethylcolchamine (2-demethyldemecolcine), 3-demethyl-γ-lumicolchicine, 3,10-didemethylcolchicine (3-demethylcolchiceine), β-lumicolchicine, luteidine, trigamine *N*-oxide, yolantamine, yolantidine, yolantimine, yolantine, yolantinine	[131]
				M. robusta Bunge	Bechuanine (merenderine, S-floramultine), colchameine, colchamine (demecolcine), colchiceine, colchicines, deacetylcolchiceine, deacetylcolchicine, 3-demethylcolchamine (2-demethyldemecolcine), 2-demethylcolchicine, 3-demethylcolchicine, 2-demethyl-β-lumicolchicine, 2-demethyl-γ-lumicolchicine, 3-demethyl-β-lumicolchicine, 2,10-didemethylcolchicine, 3,10-didemethylcolchicine (3-demethylcolchiceine), *N*-formyldeacetylcolchicine, β-lumicolchicine, γ-lumicolchicine, merobustine, merobustinine, *N*-methylcolchamine (*N*-methyldemecolcine), robustamine, robustamine cis-*N*-oxide	[131]
				M. sobolifera Fisch. et Mey.	Colchameine, colchamine, colchicines, 2-demethylcolchamine (2-demethyldemecolcine), 2-demethylcolchicine, 2-demethyl-β-lumicolchicine, β-lumicolchicine	[131]
	Amaryllidales	Alliaceae	*Allium* L.	*A. altaicum* Pall.	Alline	[131]
				A. senescens L.	Alline	[131]
		Amaryllidaceae	*Sternbergia* Waldst. et Kit.	*St. lutea* (L.) Spreng.	Hemanthamine, lycorine, pancratine, tazettine	[131]
			Ungernia Bunge	*U. ferganica* Vved. ex Artjushenko	Galanthamine, hippeastrine, hordenine, lycorine, pancratine, tazettine, (–)-ungiminorine	[131]
				U. oligostroma Vved. (*U. minor* Vved.)	Lycorine, tazettine, ungeremine, ungiminoridine, (–)-ungiminorine	[131]
				U. sewertzovii (Regel) B.Fedtsch.	Galanthamine, hippeastrine, lycorine, (+)-narwedine, (±)-narwedine, (–)-narwedine, pancratine, tazettine, ungerine, (–)-ungiminorine, unsevine	[131]
				U. tadshikorum Vved. ex Artjushenko	Galanthamine, hippeastrine, hordenine, lycorine, pancratine, tazettine, ungerine	[131]
				U. victoris Vved. ex Artjushenko	Galanthamine, hippeastrine, hordenine, lycorine, (±)-narwedine, pancratine, tazettine	[131]

Table 3. *Cont.*

Subclass	Order	Family	Genus	Species	Isolated Alkaloids	Reference
				U. vvedenskyi S.Khamid.	Galanthamine, hippeastrine, hordenine, lycorine, (±)-narwedine, pancratine, tazettine, ungiminoridine, (–)-ungiminorine, (±)-ungiminorine, ungvedine	[131]
		Asphodelaceae	*Eremurus* M. Bieb.	*E. fuscus* (O.Fedtsch.) Vved.	Hordenine, *O*-methylhordenine	[131]
				E. hilariae M.Pop. et Vved.	Hordenine	[131]
				E. olgae Regel	Hordenine (eremursine)	[131]
				E. regelii Vved.	Hordenine	[131]
				E. sogdianus (Regel) Franch.	Hordenine	[131]
				E. tianschanicus Pazij et Vved. ex Golosk.	Hordenine, *O*-methylhordenine	[131]
	Poales	Poaceae	*Lolium* L.	*L. cuneatum* Nevski	*N*-Acetylnorloline, *N*-formylloline, *N*-formylnorloline, lolidine, loline, lolinine, lolinine *N*-oxide, *N*-methylloline, *N*-methyl-*N*-formylloline, norloline	[131]
Equisetidae	Equisetales	Equisetaceae	*Equisetum* L.	*E. arvense* L.	Equisetin, nicotine, palustrine, palustrinine	[143]
Gnetidae	Ephedrales	Ephedraceae	*Ephedra* L.	*E. ciliata* Fisch. & C.A.Mey. (*E. kokanica* Regel)	(–)-Ephedrine, (+)-pseudoephedrine	[131]
				E. equisetina Bunge	(–)-Ephedrine, (+)-pseudoephedrine	[131]
				E. fedtschenkoae Pauls.	(–)-Ephedrine, (+)-pseudoephedrine	[131]
				E. intermedia Schrenk et C.A.Mey.	(–)-Ephedrine, (+)-pseudoephedrine	[131]
				E. lomatolepis Schrenk	(–)-Ephedrine, (+)-pseudoephedrine	[131]
				E. procera Fisch. et C.A.Mey.	(–)-Ephedrine, (+)-pseudoephedrine	[131]

In conclusion, many plants of Central Asia produce alkaloids. The percentage of alkaloid-producing plants within angiosperms has been estimated to be 10%–25%. In the flora of Central Asia, we found that often more than 50% of the plants produce alkaloids. The total number of plants and ACPs are highest in the floras of the Tien Shan (1177 species) and Pamir-Alai (1165 species) mountains. The high number of alkaloid-producing plants may indicate a need for chemical protection against herbivores under the harsh conditions of the mountain environment. We assume that the pressure from herbivores is high in the Central Asian mountains. Since many alkaloids are neurotoxins or have cytotoxic properties, they are well-suited for chemical defense against herbivores [3]. It would certainly be interesting to study the ecosystems of Central Asia more deeply in this aspect which has not been done before.

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