agronomy

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Supplementary Material

1. Supplementary Tables

Table S1. *Fritillaria* species with medicinal activity in the world

Species	Specimen collection places	Species	Specimen collection places
F. anhuiensis [75]	Anhui in China	*F. persica* [145]	Turkey and Iran
F. camschatcensis [134]	Washington State in America	*F. pinardii* [9]	Eastern Mediterranean
F. cirrhosa [26]	Southwest China and Pakistan	*F. przewalskii* [146]	Western China
F. collina [135]	Caucasus	*F. pudica*[147]	Western North America
F. crassicaulis [136]	Yunnan in China	*F. raddeana* [148]	Pakistan
F. davidii [137]	Sichuan in China	*F. recurva* [149]	California in America
F. delavayi [37]	Southwest China	*F. roderickii* [150]	California in America
F. ebeiensis [138]	Hubei in China	*F. ruthenica* [96]	European Russia
F. ferganensis [139]	Xinjiang Uygur Autonomous region in China	*F. taipaiensis* [31]	Shanxi, Gansu, Sichuan and Hubei in China
F. karelinii [52]	Xinjiang Uygur Autonomous region in China and Central Asia	*F. thunbergii* [65]	Zhejiang and Jiangsu in China and Japan
F. liliacea [140]	California in America	*F. tortifolia* [56]	Xinjiang Uygur Autonomous region in China
F. maximowiczii [53]	Hebei in China	*F. unibracteata* [30]	Sichuan and Qinghai in China
F. meleagroides [141]	Xinjiang Uygur Autonomous region in China and Russia	*F. ussuriensis* [76]	Northeast China and Russia
F. meleagris [142]	Western Asia and Northwestern Europe	*F. verticillata* [54]	Xinjiang Uygur Autonomous region in China and Kazakhstan
F. monantha [143]	Zhejiang and Henan in China	*F. wabuensis* [151]	West China
F. ojaiensis [144]	California in America	*F. walujewii* [22]	Xinjiang Uygur Autonomous region in China and Russia
F. pallidiflora [38]	Xinjiang Uygur Autonomous region in China and Russia		

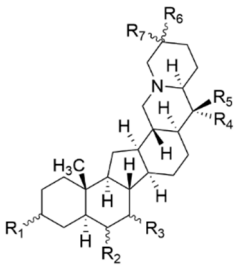
Table S2. Other *Fritillaria* species in the world (*Fritillaria* species with E as superscript were endangered)

Species	Specimen collection places	Species	Specimen collection places
***Fritillaria* species in Asian (65; 26 medicinal *Fritillaria* species in Table S1; 91 in all)**			
F. acmopetala	Turkey	*F. imperialis*	China, Turkey and Iran
F. alburyana	Turkey and Iran	*F. japonica*	Japan
F. *alfredae*	Turkey	*F. kiusiana*	Japan
F. amabilis	Japan	*F. koidzumiana*	Turkey
F. amana	Turkey	*F. kotschyana*	Northern Iran
F. ariana	Central Asia	*F. kurdica*	Turkey
F. armena	Turkey	*F. lagodechiana*	Russia
F. asumaniae	Turkey	*F. latifolia*	Turkey, Iran and Russia
F. atrolineata	Iran	*F. melananthera*	Turkey
F. aurea	Turkey	*F. meleagris*	Russia
F. avromanica	Iran	*F. michailovskyi*	Turkey
F. ayakoana	Japan	*F. minima*	Turkey
F. baisunensis	Uzbekistan	*F. minuta*	Turkey
F. bithynica	Turkey	*F. muraiana*	Japan
F. bucharica	Turkey	*F. olgae*	Russia
F. carica^{E}	Turkey	*F. olivieri*	Iran
F. caucasica	Turkey and Russia	*F. orientalis*	Russia
F. chitralensis	Chitral and Pakistan	*F. ozdemir-elmasii*	Turkey
F. chlorantha	Iran	*F. regelii*	Asia
F. chlororhabdota	Iran	*F. reuteri*	Turkey
F. crassifolia	Turkey	*F. sewerzowii*	Kyrgyzstan and China
F. dagana	Mongolia	*F. serpenticola*	Turkey
F. dzhabavae	Russia	*F. shikokiana*	Japan
F. eduardii	Central Asia	*F. sibthorpiana*^{E}	Turkey
F. enginiana	Turkey	*F. sonnikovae*	Russia
F. fleischeriana	Turkey	*F. stenanthera*	West to Central Asia
F. forbesii	Southwestern Turkey	*F. straussii*	Turkey
F. frankiorum	Turkey	*F. sororum*	Turkey
F. fusca^{E}	China	*F. tubaeformis*	Alps
F. gibbosa	Iran and Pakistan	*F. tunievii*	Russia
F. grandiflora^{E}	Russia	*F. uva-vulpis*	Turkey, Iraq and Iran
F. hakkarensis	Turkey and Iraq	*F. zagrica*	Iran and Turkey
F. hermonis	Lebanon		
***Fritillaria* species in European (40; 1 medicinal *Fritillaria* species in TableS1; 41 in all)**			
F. assyriaca	Turkey	*F. montana*^{E}	Europe
F. baskilensis	Turkey	*F. mughlae*	Turkey
F. burnatii	France and Italy	*F. mutabilis*^{E}	Greece
F. byfieldii	Turkey	*F. obliqua*^{E}	Athens and Greece

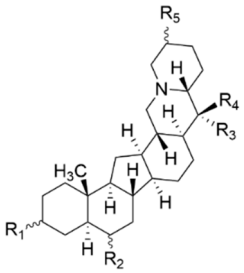
F. conica[E]	Greece	*F. phitosii*	Greece
F. davisii[E]	Greece	*F. pontica*	Greece and Turkey
F. drenovskii[E]	Greece	*F. pyrenaica*	France and Spain
F. ehrhartii[E]	Greece	*F. rhodia*[E]	Greece
F. elwesii	Southwestern Turkey	*F. rhodocanakis*[E]	Greek island Hydra
F. euboeica[E]	Greek island of Evvoia	*F. rixii*	Greece
F. gencensis	Turkey	*F. serpenticola*	Turkey
F. graeca[E]	Albania and Greece	*F. skorpili*	Bulgaria
F. gussichiae[E]	Bulgaria and Greece	*F. species*	European
F. involucrata	France	*F. stribrnyi*	Bulgaria and Turkey
F. kittaniae	Turkey	*F. thessala*	Greece
F. legionensis	Spain	*F. tubiformis*	Southern French Alps
F. lusitanica	Andalucía	*F. tuntasia*	Greek Island
F. macedonica	Albania	*F. viridiflora*	Turkey
F. messanensis[E]	Mediterranean	*F. wendelboi*	Turkey
F. milasensis	Turkey	*F. whittallii*	Southwest Turkey
***Fritillaria* species in North American (15; 6 medicinal *Fritillaria* species in Table S1; 21 in all)**			
F. affinis	North America	*F. glauca*	Oregon and California
F. agrestis	California	*F. micrantha*	California
F. atropurpurea	West America	*F. pinetorum*	California
F. biflora	California	*F. pluriflora*	California
F. brandegeei	California	*F. purdyi*	Northern California
F. eastwoodiae	Northern California	*F. striata*	California
F. falcata[E]	California	*F. viridea*	California
F. gentneri	California		
Miscellaneous *Fritillaria* species (5)			
F. latakiensis	Syria and Turkish mountains	*F. oranensis*[E]	Mediterranean
F. kaiensis[E]	Unknown	*F. epirotica*[E]	Europe and Mediterranean
F. macrocarpa	Morocco		

Note: *Fritillaria* species in endangered (with E as superscript) were based on the IUCN Red List of Threatened Species; Turkey refers to the regions within its territory, including the Asian and the European regions.

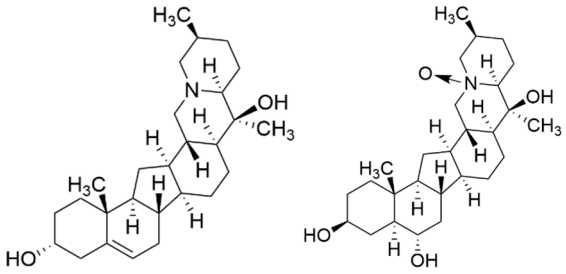
2. Supplementary Figures



Chemical components	R1	R2	R3	R4	R5	R6	R7
3-*O*-acetoxyverticinone	β-OAc	O		Me	OH	β-Me	
3-*O*-acetylverticine	β-OAc	α-OH		Me	OH	β-Me	
dongbeinine	β-OH	O			Me	β-Me	
ebeiedine	β-OH	β-OH		Me		β-Me	
ebeiedinone	β-OH	O		Me		β-Me	
ebeinine	β-OH	α-H		Me	H	β-Me	
hupeheninoside	α-OGlc	α-OH		Me		β-Me	
isobaimonidine	α-OH	α-OH		Me	OH	β-Me	
isopeimine	β-OH	β-OH		Me	OH	β-Me	
isopeiminine	β-OH	O		OH	Me	β-Me	
peimine	β-OH	α-OH		Me	OH	β-Me	
peiminine	β-OH	O		Me	OH	β-Me	
peiminoside	β-OGlc	α-OH		Me	OH	β-Me	
yibeinone E	β-OH	O		H_2	Me	α-Me	
zhebeinine	β-OH	α-OH		Me	OH	α-Me	
petilidine	β-OH	α-OH		Me		α-Me	
pingpeimine A	β-OH	α-OH		Me	OH	β-Me	
pingpeimine C	β-OH	O	α-OH	Me	OH	β-Me	
puqiedine	β-OH	β-OH		Me	H	α-Me	
taipainine D	β-OH	α-OH		Me		β-Me	α-OH
verticinedinone	O	O		Me	OH	β-Me	
zhebeinone 3β-D-glucoside	β-OGlc	O		Me	OH	α-Me	
zhebeirine	β-OH	O		Me		α-Me	
eduardine	β-OH	O		Me		β-Me	
isoforticine	β-OH	α-OH			Me	β-Me	
puqiedinone-3-*O*-β-D-glucopyranoside	β-OGlc	O		Me		α-Me	

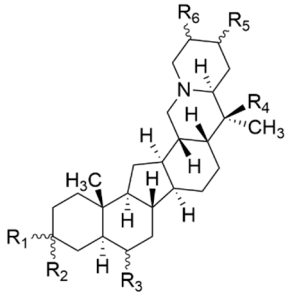


Chemical components	R_1	R_2	R_3	R_4	R_5
wanpeinine A	β-OH	α-OH	Me	OH	β-Me
yibeinone C	β-OH	O	Me	OH	α-Me
yibeinone D	β-OGlc	O	OH	Me	β-Me
zhebeininoside	β-OGlc	α-OH	Me	OH	α-Me
yibeirine	β-OH	β-OH	Me	OH	β-Me

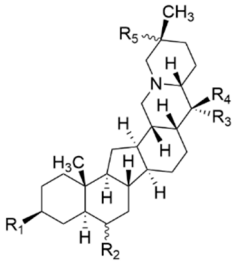


fritillarizine verticine-N-oxide

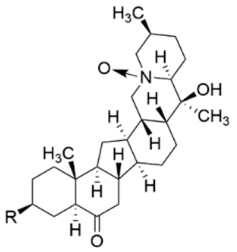
Figure S1: The chemical structures of 5α-Cevanine isosteroidal alkaloids with *trans*-configuration.



Chemical components	R_1	R_2	R_3	R_4	R_5	R_6
5α, 14α, 17β-cevanin-6-oxo-3β, 20β, 24β-triol		β-OH	O	OH	β-OH	β-Me
delavine		β-OH	β-OH			β-Me
delavinone		β-OH	O			β-Me
frititorine A		α-OH	O	OH		β-Me
hupehenizioiside		β-OGlc	O			β-Me
imperialine		β-OH	O	OH		β-Me
imperialine-3β-D-glucoside		β-OGlc	O	OH		β-Me
imperialinol		β-OH	β-OH	OH		β-Me
isodelavine		β-OH	α-OH			β-Me
persicanidine B		β-OH	β-OH			α-Me
sinpeinine A		β-OH	O			β-Me
3β-acetylimperialine	β-OAc	α-Me	O	OH		β-Me
yibeinoside A	α-H	β-OGlc	O	H		β-Me
yubeinine		α-OH	O	OH		β-Me

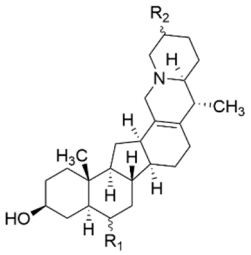


Chemical components	R_1	R_2	R_3	R_4	R_5
taipaienine	OH	O	Me		α-OH
tortifoline	OH	β-OH		Me	
walujewine B	OGlc	β-OH		Me	
walujewine C	OH	α-OH		Me	
walujewine D	OGlc	α-OH		Me	
walujewine E	OGlc-Glc	O	Me		
chuanbeinone	OH	O	Me		

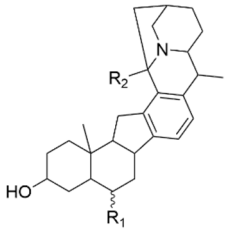


Chemical components	R
frititorine B	OGlc
imperialine-β-N-oxide	OH

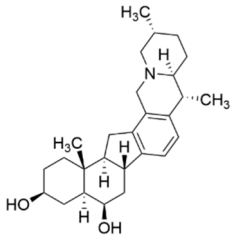
Figure S2. The chemical structures of 5α-Cevanine isosteroidal alkaloids with *cis*-configuration.



Chemical components	R_1	R_2
27-epiebeienine	β-OH	β-Me
ebeienine	β-OH	α-Me
ebeinone	O	α-Me

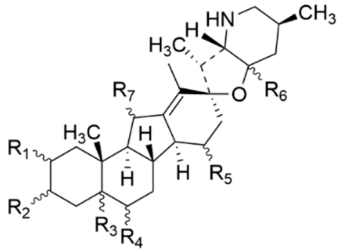


Chemical components	R_1	R_2
ussuriedine	OH	OH
ussuriedinone	O	OH
ussurienine	OH	OMe
ussurienone	O	OMe

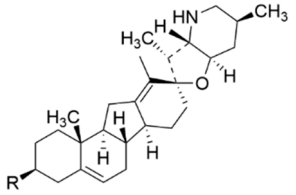


heilonine

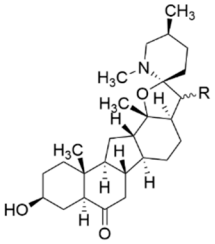
Figure S3. The chemical structures of other 5α-Cevanine isosteroidal alkaloids.



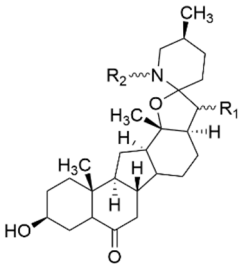
Chemical components	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**
ebeiensine		β-OH	α-H	O		α-H	
frititorine C		α-OH	α-H	O		α-H	
karelinine	β-OH	α-OH	β-H	O	α-OH	α-H	
kuroyurinidine	β-OH	α-OH	α-H	β-OH		α-H	
peimisine		β-OH	α-H	O		α-H	
peimisine-3-*O*-β-D-glu-		β-OGlc	α-H	O		α-H	
songbeisine		β-OH	α-H	H_2		α-H	O
yibeissine		β-OH	α-H	O		α-H	β-OH
23-isokuroyurinidine	β-OH	α-OH	α-H	β-OH		β-H	



Chemical components	**R**
cyclopamine	β-OH
cycloposine	β-OGlc



Chemical components	**R**
pengbeimine B	α-Me
pengbeimine D	β-Me



Chemical components	R_1	R_2
pengbeimine A	β-Me	H
pengbeimine B	α-Me	H
pengbeimine D	α-Me	Me

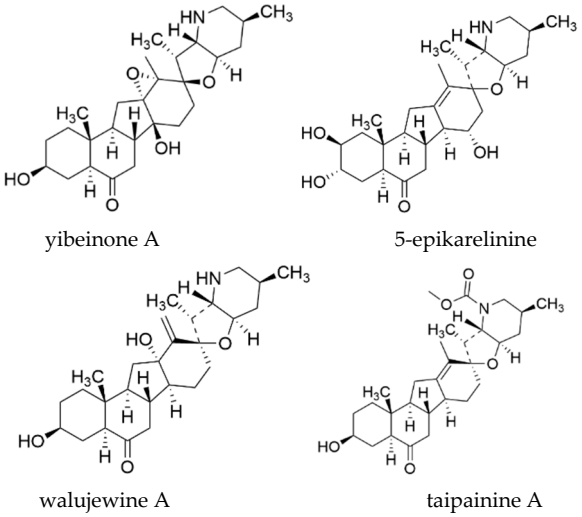
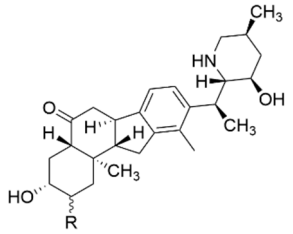
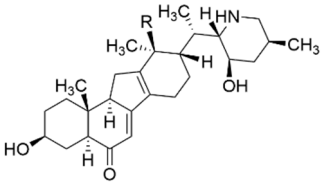


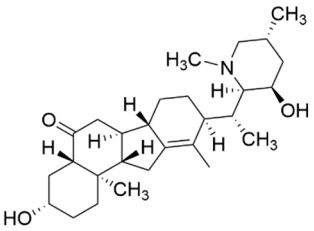
Figure S4: The chemical structures of Jervine isosteroidal alkaloids.



Chemical components	R
pingbeimunone A	β-OH
yibeinone B	

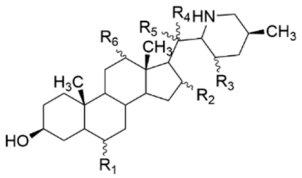


Chemical components	R
(3β, 5α, 13α, 23β)-7, 8, 12, 14-tetradehydro-5, 6, 12, 13-tetrahydro-3, 23-dihydroxyveratraman-6-one	H
(3β, 5α, 13α, 23β)-7, 8, 12, 14-tetradehydro-5, 6, 12, 13-tetrahydro-3, 13, 23-trihydroxyveratraman-6-one	OH

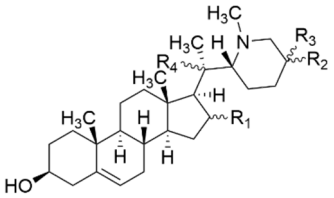


puqienine B

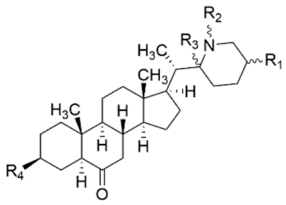
Figure S5. The chemical structures of Veratramine isosteroidal alkaloids.



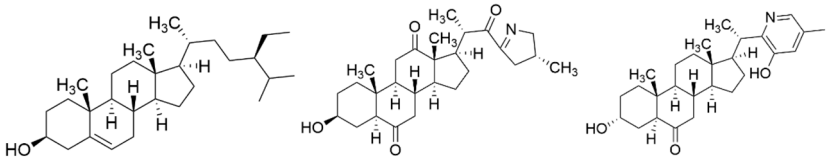
Chemical components	R_1	R_2	R_3	R_4	R_5	R_6
cirrhosinine A		β-OH		α-Me	β-OH	β-OH
cirrhosinine B	O		α-OH	β-Me		α-OH



Chemical components	R_1	R_2	R_3	R_4
pingbeidinoside	α-OH	OGlc	β-Me	β-OH
pingbeinine	β-OH	α-Me	β-OH	

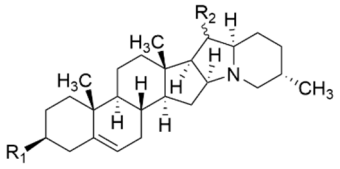


Chemical components	R_1	R_2	R_3	R_4
N-demethylpuqietinone	β-Me	H	β-H	β-OH
puqietinone	α-Me	Me	α-H	β-OH
yibeinoside C	β-Me	H	β-H	OGlu-Glu

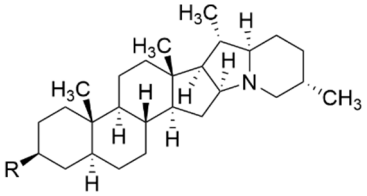


sitosterol delavidine fetisinine

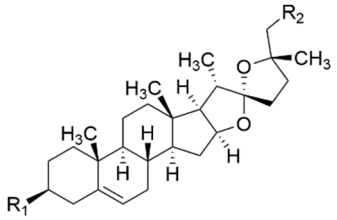
Figure S6. The chemical structures of Verazine steroidal alkaloids.



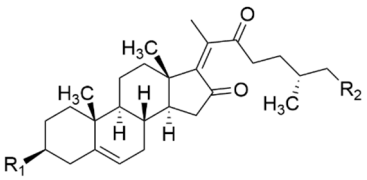
Chemical components	R_1	R_2
solanidine	OH	α-Me
(22S,25S)-solanid-5,20 (21)-dien-3β-ol	OH	CH_2
solanidine-3-*O*-α-L-rhamnopyranosyl-(1→2)-[β-D-glucopyranosyl-(1→4)]-β-D-glucopyranoside	OGlc-(1→2)-Rha-(1→4)-Glc	α-Me



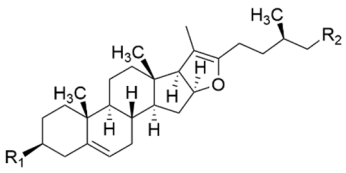
Chemical components	R
demissidine	OH
demissidine-3-*O*-β-D-glucopyranosyl (1→4) glucopyranoside	OGlc-Glc



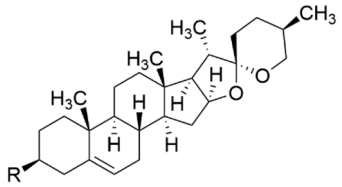
Chemical components	R_1	R_2
avenacoside C	OGlc-(1→2)-Rha	OGlc



Chemical components	R_1	R_2
(25R)-26-[β-D-glucopyranosyl]oxy]-3β-[(*O*-α-L-rhamnopyranosyl-(1→2)-β-D-glucopyranosyl)oxy]-cholesta-5,17-diene-16,22-dione	OGlc-(1→2)-Rha	OGlc



Chemical components	R_1	R_2
26-*O*-β-D-glucopyranosyl-3,26-dihydroxy-(25R)-5β-furost-12-on-20(22)-ene-3-*O*-α-L-rhamnopyranosyl-(1→2)-β-D-glucopyranoside	OGlc-(1→2)-Rha-(1→4)-Glc	OGlc



Chemical components	**R**
aspidistrin	OGal-(1→4)-Glc-(1→3-)Xyl-(1→2)-Glc

Figure S7. The chemical structures of solanidine steroidal alkaloids.