

## CYTOGEOGRAPHY AND PATTERNS OF DISTRIBUTION OF THE GENUS ACANTHOPHYLLUM (CARYOPHYLLACEAE)

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On the basis of new floristic works, a distribution map of the genus *Acanthophyllum* is nearly identical to the distribution of Irano-Turanian Region. Three centers of diversity with high numbers of species are distinguished in the genus *Acanthophyllum*: the western and northern parts of Afghanistan (12 species belonging to 5 sections), southern parts of Turkmenistan (13 species belonging to 4 sections), and north-eastern parts of Iran (14 species belonging to 4 sections). According to the chromosome data, the maximum number of diploids, tetraploid and hexaploid species are found in S Turkmenistan, NE Iran, and W Afghanistan (centers of diversity). Furthermore, the areas far from the centers of diversity contain polyploid species, which are derived from diploid ancestors. The data obtained from the density and diversity of the species, endemics, sections, and chromosome counts seem to indicate that W Afghanistan, S Turkmenistan, and North-east Iran, are the centers of origin of the genus *Acanthophyllum*.

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**Keywords:** *Acanthophyllum*; Caryophyllaceae; center of diversity; chromosome number; cyto geography

جغرافیای سلولی و الگوهای پراکنش جنس چوبک (تیره میخک)

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براساس کارهای فلورستیک جدید نقشه پراکنش جنس چوبک منطبق با ناحیه ایرانی-تورانی است. سه مرکز تنوع با بیشترین تعداد گونه‌ها برای جنس چوبک تشخیص داده شد: نواحی شمال و غرب افغانستان (با ۱۲ گونه متعلق به ۵ بخش)، نواحی جنوبی ترکمنستان (با ۱۳ گونه متعلق به ۴ بخش) و ناحیه شمال شرقی ایران (با ۱۴ گونه متعلق به ۴ بخش). براساس یافته‌های کروموزومی بیشترین تعداد گونه‌های دیپلوئید، تتراپلوئید و هگزاپلوئید در نواحی جنوبی ترکمنستان، شمال شرقی ایران و غرب افغانستان یافت می‌شوند (مراکز تنوع). علاوه نواحی دور از مرکز تنوع شامل گونه‌های پلی‌پلوئید هستند که از اجداد دیپلوئید مشتق شده‌اند. یافته‌های به‌دست آمده از تراکم و تنوع گونه‌ها، گونه‌های انحصاری، بخشها و مجموعه کروموزومی آنها نشان می‌دهد که غرب افغانستان، جنوب ترکمنستان و شمال شرقی ایران مراکز پیدایش جنس چوبک باشند.

### INTRODUCTION

Meyer (1831) introduced the genus *Acanthophyllum* by the species *Acanthophyllum mucronatum* for the first time. The genus *Acanthophyllum*, remarkable in various respects, is one of the largest genera of the Caryophyllaceae Juss., comprising ca. 75 species in the world of which 58 are endemics to the area. *Acanthophyllum* is mainly distributed in the Irano-Turania Region. The genus is

distributed in China, Iran, Iraq, Afghanistan, Armenia, Azerbaijan, Mongolia, Syria, Pakistan, Kazakhstan, Tajikistan, Uzbekistan, Kyrgyzstan, Turkmenistan, and Turkey. These plants are normally found in dry areas, deserts, slopes of mountains, as well as temperate zones. Boissier (1810) recognized five groups within *Acanthophyllum*, delimited mainly on the basis of inflorescence and floral features. Schiman-Czeika (1988) encompasses the greater part of the genus,

containing 56 species belonging to 7 sections, but 16 species should be added to her account, based on Flora of the U.S.S.R. (Schischkin 1936), Flora of Uzbekistan (Vvedensky 1953), Flora of Tajikistan (Ovchinnikov 1968) and Flora of middle Asia (Vvedensky 1971). On the other hand, several synonymies have been suggested by regional studies in Iran and Pakistan (Ghazanfar & Nasir 1986, Basiri Esfahani & al. 2011). Regarding the infrageneric classification of *Acanthophyllum*, Pirani & al. (2014) showed that the 11 recognized sections of the genus are generally monophyletic, or rendered as monophyletic after removal of a few species. In her recent work, Pirani & al. (2020), increased the number of sections to 14. *Acanthophyllum kandaharicum* which was reported as an endemic species of S. Afghanistan with one reported locality in N. Pakistan is also recorded from Iran (Khorasan province, Nehbandan, Shosf) by Joharchi & Akhani (2006). Also, Joharch & Akhani (2006) recorded *A. stenostegium* from Northwest of Iran (Khorasan province, Kelat-e Naderi). Mahmoudi Shamsabad & al. (2012) introduced *A. ejtehadii* as a new endemic species and *A. maimanese* as a new record for the Flora of Iran from Khorasan Province. Pirani & al. (2013) introduced *A. yasamin-nassehiae* as a new endemic species from Iran (North Khorasan). Also, Aytac (2001) introduced *A. oppositiflorum* as a new endemic species for the flora of Turkey.

According to the previous chromosome counts (Nussbaumer 1964, Aryavand & Favarger 1980, Ghaffari, 1986, 1987, 1988, 2002, 2004, 2020, Turner 1994, Maleki Sadabadi & al. 2017), the basic chromosome numbers for the genus *Acanthophyllum* are  $x = 14$  and  $x = 15$ . In my previous surveys, three ploidy levels were distinguished for  $x = 15$  (Ghaffari 2004), diploidy ( $2n = 2x = 30$ ), which is common to the sections *Oligosperma* and *Macrostegia*, tetraploidy ( $2n = 4x = 60$ ), common to the section *Acanthophyllum*, and hexaploidy ( $2n = 6x = 90$ ), common to the section *Pleiosperma*. In this work, the centers of diversity and the possible origin of the genus *Acanthophyllum* are presented based on geographical distribution and ploidy levels of the species.

## MATERIALS AND METHODS

The genus *Acanthophyllum* contains about 74 species which are classified into nine sections. The sources for the present study are the treatments in comprehensive floras from almost the entire

distribution area of the genus, specimens collected in Iran during 6 years, and data from the literature (Post & Dinsmore 1932, Shishkin 1936, 1948, Vvedensky 1953, 1971, Grossheim 1956, Pavlov 1960, Nikitin, 1965, Huber-Morath 1967, Ovchinnikov 1968, Ghazanfar & Nasir 1986, Schiman-Czeika 1988, Aytac, 2001, Lu & Turland 2001).

In the maps, the grid system, introduced by Davis (1965) for the Flora of Turkey and then used by Wagenitz (1986) for *Centaurea* in South-west Asia was used. In this method, the area was divided into squares on the basis of equal degrees of latitude and longitude. Also, I made circular composition for exhibiting the number of endemics and common species in the centers of diversity, as previously used (Ghaffari, 1998). Classification of the sections of the genus *Acanthophyllum* was used according to Schiman-Czeika (1988) for the Flora Iranica and Schischkin (1936) for the Flora of U.S.S.R

## RESULTS AND DISCUSSION

The total number of species and sections of *Acanthophyllum* are shown in table 1, extracted from the floras of 14 countries. Iran with a total number of 38 species, belonging to 4 sections possesses the highest number of species in the world. Afghanistan and Turkmenistan are ranked second and third countries, with 34 and 20 species respectively. Syria with *A. verticillatum*, West of China (N Xinjiang) and NW of Mongolia with *A. pungens*, Armenia, and Azerbaijan with *A. mucronatum* are poor in the number of species. From the total number of species, which occur in each country, some of them are endemic for a single country and some endemic for two or more countries. As shown in table 2, Afghanistan with 12 endemics and 18 common endemic species (with Iran, Pakistan, Tajikistan, Turkmenistan) and Iran with 7 endemic and 18 common endemics (with Afghanistan, Iraq, Pakistan, Tajikistan, Turkmenistan) have the most narrow endemic and regional endemic species in the world respectively. Furthermore, the most important center of diversity is situated in the northeastern parts of Iran with 12-14 species in 4 sections (see squares E10, E11, and E9 in fig. 1). The northwest of Afghanistan is the second center of diversity with 10-12 species in 5-6 sections (see squares G13 and F16 in fig. 1). The third center of diversity is the southern part of Turkmenistan with 12-13 species and 4 sections (see squares D10 and D11 in fig. 1). Aside from the three

centers of diversity, Tajikistan, Uzbekistan and Pakistan with a total number of 11, 11 and 10 species, respectively, have the highest diversity among the countries of the region (table 2). Towards the western border of the distribution area of the genus, the number of species and of sections decreases to only a single species of each section (Syria with one species of *A. verticillatum*). Section *Oligosperma* has the highest number of species compared to the other sections. This section possesses 30 species, of which, 9 are narrow endemics (*A. aculeatum*, *A. albidum*, *A. andersonii*, *A. diezianum*, *A. ejtehadii*, *A. maimanense*, *A. mikeschinianum*, *A. speciosum*, *A. yasamin-nassehiae*), (table 1, fig. 2). The smallest section of the genus is sect. *Paniculata* with two species (*A. gypsophiloides*, *A. paniculatum*), which are endemic to Central Asia (Tajikistan, Kazakhstan, Kyrgyzstan). Section *Pseudacanthophyllum* possesses 3 species (fig. 3), two of them (*A. laxiflorum*, *A. Stewartii*) are endemic to Afghanistan and Pakistan, and *A. rapiophyllum* is a narrow endemic to Afghanistan, restricted to Panjshir with an altitude of 1900 to 3300m. The third-smallest section is *Versicoloria* with 3 species (*A. bungei* which is distributed to the Armenia and Iran, *A. transhyrcanum* which is endemic to Turkmenistan and *A. versicolor* which is endemic to Armenia and Azerbaijan). Section *Scapiflora* has 4 species (*A. anisocladum*, *A. bilobum*, *A. lamondiae*, *A. scapiflorum*), which was introduced by Schiman-Czeika (1988) for the first time (fig. 4). All species in this section are endemic, which is found in a limited area in E or C of Afghanistan. The habitat of *A. bilobum* is restricted to high altitudes (4000-4330m) of Baba Mountain in Afghanistan. Section *Macrodonia* with 6 species is endemic to Afghanistan and Pakistan (fig. 5). Four species of this section are narrow endemics (*A. fissicalyx*, *A. grandiflorum*, *A. pulcherrimum*, *A. xanthoporphyranthum*), (table 1). Section *Acanthophyllum* with 8 species, mostly occupies the western limit of the distribution of the genus (fig. 6), but *A. pleiostegium* is found in a restricted area in NE of Afghanistan (Kataghan). Furthermore, two widespread species (*A. mucronatum* and *A. microcephalum*) of this section are distributed from Turkey to Armenia, Iran, Azerbaijan, and Turkmenistan. Section *Pleiosperma* is represented in the area by 7 species (fig. 7), of which *A. chloroleucum*

is a narrow endemic to Iran. Section *Macrostegia* is characterized by a broad hyaline margin of bracteole, has 9 species, of which seven are endemics to Afghanistan, Iran, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan (fig. 8). Of the 75 species of the genus, 58 are endemics to the Irano-Turanian Region. In addition to endemic species, which belong only to a single country (table 1), there are some species common to two or more countries. Assessment of the species indicates that the greatest regional endemic species are found in Afghanistan, Iran, and Turkmenistan with 18, 18, and 9 species respectively (table 2). Fig. 9 indicates that 15 species are common between Iran and Afghanistan, 6 species are common between Afghanistan and Turkmenistan, 16 species are common between Iran and Turkmenistan and 6 species are common among Iran, Afghanistan, and Turkmenistan. The comparison of the total species and endemic species in each country indicates that northwest of Afghanistan, south of Turkmenistan, and northeast of Iran are the centers of diversity of the genus *Acanthophyllum*.

The results obtained from the chromosomal counts of 26 species out of a total of 75 species (Nussbaumer 1964, Aryavand & Favarger 1980, Ghaffari 1986, 1987, 1988, 2002, 2004, 2020, 2021, Maleki Sadabadi & al. 2017), showed an equal basic chromosome number of  $x = 15$  in all species of four sections except for *A. caespitosum* and *A. acerosum* ( $x=14$ ), (table 3). Three ploidy levels ( $2x = 30$ ,  $4x = 60$  and  $6x = 90$ ) are observed for  $x = 15$  and two ploidy levels ( $2x=28$ ,  $4x=56$ ) are observed for  $x=14$ , (table 3). According to figure 2, the maximum diploid, tetraploid and hexaploid species are found in S Turkmenistan, NE Iran, and W Afghanistan (centers of diversity). Furthermore, the areas which are far from the centers of diversity towards the west (Syria, Turkey, Armenia, Azerbaijan and Iraq) contain tetraploid species, which are derived from diploid ancestors (see squares E1, C2, F2, F4, C4, C5, C6, D1, D2, D3, G4 fig.10). The *A. gladulosum* which is a hexaploid species ( $2n=6x=90$ ) is distributed in the center, north, and east of the center of diversity of the genus *Acanthophyllum* (see squares D14, F4, G4, fig.10). Thus, it seems that the center of diversity with a maximum of diploid species to be the center of origin of the genus *Acanthophyllum*.

Table 1. The list of *Acanthophyllum* species in the world.

Sections & species	Distribution	Endemic
<b>Sect. <i>Acanthophyllum</i></b>		
<i>A. acerosum</i> Sosn.	Iran, Iraq, Turkey	
<i>A. crassifolium</i> Boiss.	Iran	Endemic
<i>A. kurdicum</i> Boiss. & Hausskn.	Iran, Iraq	Regional endemic
<i>A. microcephalum</i> Boiss.	Iran, Turkmenistan, Turkey	
<i>A. muronatum</i> C. A.Mey.	Iran, Armenia, Azerbaijan, Turkey, Turkmenistan,	
<i>A. oppositiflorum</i>	Turkey	Endemic
<i>A. pleiostegium</i>	Afghanistan	Endemic
<i>A. verticillatum</i> (Willd.) Hand.-Mzt.	Iran, Iraq, Turkey, Syria	
<b>Sect. <i>Macrodonia</i></b>		
<i>A. fissicalyx</i> Rech.f.	Afghanistan: Kandahar	Narrow endemic
<i>A. grandiflorum</i>	Pakistan: Quetta	Narrow endemic
<i>A. longicalyx</i> Hedge & Wendelbo	Afghanistan	Endemic
<i>A. marodon</i> Edgew.	Afghanistan, Pakistan	Regional endemic
<i>A. pulcherrimum</i> Hedge & Wendelbo	Afghanistan: Maimana	Narrow endemic
<i>A. xanthoporphyranthum</i> Hedege & Wendelbo	Afghanistan: Herat	Narrow endemic
<b>Sect. <i>Macrosteigia</i> Boiss.</b>		
<i>A. bracteatum</i> Boiss.	Iran, Pakistan	Regional endemic
<i>A. coloratum</i> Schischk.	Tajikistan	Endemic
<i>A. korolkowii</i> Regel & Schmalh.	Turkmenistan, Kazakhstan, Uzbekistan	
<i>A. gracile</i> Bunge ex Boiss.	Iran, Turkmenistan	
<i>A. kandaharicum</i> Gilli	Iran, Afghanistan, Pakistan	Regional endemic
<i>A. khuzistanicum</i> Rech.f.	Iran, Iraq	Regional endemic
<i>A. leucostegium</i> Schiman-Czeika	Iran	Endemic
<i>A. pachycephalum</i> Schiman-Czeika	Iran	Endemic
<i>A. serawschanicum</i> Golenk.	Tajikistan, Uzbekistan	Endemic
<b>Sect. <i>oligosperma</i> Schischk.</b>		
<i>A. aculeatum</i> Schischk.	Uzbekistan: Dzhizak	Narrow endemic
<i>A. adenophorum</i> Freyn	Iran, Turkmenistan	Regional endemic
<i>A. albidum</i> Schischk.	Uzbekistan: Margel river	Narrow endemic
<i>A. andarabicum</i> Podl. Ex Schiman-Czeika	Afghanistan	Endemic
<i>A. andersenii</i> Rech.f. & Schiman-Czeika	Iran: W Bojnurd	Narrow endemic
<i>A. borschowii</i> Litw.	Iran, Turkmenistan, Kazakhstan, Kyrgyzstan, Uzbekistan	
<i>A. brevibracteatum</i> Lipsky	Iran, Turkmenistan	Regional endemic
<i>A. caespitosum</i> Boiss.	Iran, Iraq	Regional endemic
<i>A. diezianum</i> Hand-Mzt.	Iran: E Khorasan. Afghanistan: NW Herat	Narrow endemic
<i>A. ejtehadii</i> Mahmoudi & Vaezi	Iran: Chenaran	Narrow endemic
<i>A. elatius</i> Bunge ex Boiss.	Iran, Afghanistan, Tajikistan	Regional endemic
<i>A. heratense</i> Schiman-Czeika	Iran, Afghanistan	Regional endemic
<i>A. heterophyllum</i> Rech.f.	Iran, Afghanistan, Pakistan	Regional endemic
<i>A. kabulicum</i> Schiman-Czeika	Afghanistan	Endemic
<i>A. korshinskyi</i> Schischk.	Iran, Afghanistan, Turkmenistan	
<i>A. krascheninnikovii</i> Schischk.	Uzbekistan	Endemic
<i>A. laxiusculum</i> Schiman-Czeika	Iran, Afghanistan, Turkmenistan	Regional endemic
<i>A. lilcinum</i> Schischk.	Iran, Afghanistan, Turkmenistan	Regional endemic

Table 1. Continued.

<b>Sections &amp; species</b>	<b>Distribution</b>	<b>Endemic</b>
<i>A. maimanense</i> Rech.f. & Schiman-Czeika	Iran: Torbat-e Jaam. Afghanistan: NW Maimana	Narrow endemic
<i>A. mikeschinianum</i> Yukhan. & Kuv.	Turkmenistan: Kopet Dagh	Narrow endemic
<i>A. pachystegium</i> Rech.f.	Iran, Afghanistan, Turkmenistan	Regional endemic
<i>A. pulchrum</i> Schischk.	Afghanistan, Tajikistan	Regional endemic
<i>A. pungens</i> (Bge.) Boiss.	Iran, China, Mongolia, Turkmenistan, Kazakhstan, Kyrgyzstan, Uzbekistan	
<i>A. speciosum</i> Rech.f. & Schiman-Czeika	Iran: Darreh Gaz. Turkmenistan: Kopet Dagh	Regional endemic
<i>A. squarrosum</i> Boiss.	Iran. Afghanistan	Regional endemic
<i>A. stenostegium</i> Fretn	Iran, Afghanistan, Turkmenistan, Middle Asia	
<i>A. stocksianum</i> Boiss.	Iran, Afghanistan, Pakistan	Regional endemic
<i>A. subglabrum</i> Schischk.	Kyrgyzstan, Turkmenistan, Tajikistan, Uzbekistan	
<i>A. tenuifolium</i> Schischk.	Uzbekistan	Endemic
<i>A. yasamin-nassehiae</i> Joharchi & Pirani	Iran: Khorasan, NE Jajarm	Narrow endemic
<b>Sect. <i>Paniculata</i></b>		
<i>A. gypsophiloides</i> Regel	Kazakhstan, Turkmenistan, Kyrgyzstan, Uzbekistan, Tajikistan,	Regional endemic
<i>A. paniculatum</i> Regel & Herder	Kazakhstan, Tajikistan, Kyrgyzstan,	Regional endemic
<i>A. tadshikistanicum</i> Schischk.	Tajikistan	Endemic
<b>Section <i>Pleiosperma</i> Boiss.</b>		
<i>A. chloroleucum</i> Rech.f. & Aell.	Iran: Mt. Hazar Masjed	Narrow endemic
<i>A. crassinodum</i> Yukhan. & Edmondson	Iran, Turkmenistan, Afghanistan	Regional endemic
<i>A. glandulosum</i> Bunge ex Boiss.	Iran, Afghanistan, Turkmenistan, Central Asia	
<i>A. knorringianum</i> Schischk.	Tajikistan, Uzbekistan	Regional endemic
<i>A. schugnaricum</i> Schischk.	Afghanistan, Tajikistan	Regional endemic
<i>A. sordidum</i> Bunge ex Boiss.	Iran, Afghanistan, Pakistan, Turkmenistan	Regional endemic
<i>A. spinosum</i> (Desf.) C. A.Mey.	Iran, Afghanistan	Regional endemic
<b>Sect. <i>Pseudacanthophyllum</i></b>		
<i>A. laxiflorum</i> Boiss.	Afghanistan, Pakistan	Regional endemic
<i>A. raphiophyllum</i> (Rech.f.) Barkoudah	Afghanistan: Panjshir	Narrow endemic
<i>A. stewartii</i> (Thoms.) Barkoudah	Afghanistan, Pakistan	Regional endemic
<b>Sect. <i>Scapiflora</i></b>		
<i>A. anisocladum</i> Schiman-Ceika	Afghanistan	Endemic
<i>A. bilobum</i> Schiman-Czeika	Afghanistan	Endemic
<i>A. lamondiae</i> Schiman-Czeika	Afghanistan: limited area of E	Narrow endemic
<i>A. scapiflorum</i> (Akhta) Schiman-Czeika	Afghanistan: Limited area of E	Narrow endemic
<b>Sect. <i>Versicoloria</i></b>		
<i>A. bungee</i> Trautv.	Armenia, Iran	
<i>A. transhyrcanum</i> Preober.	Turkmenistan	Endemic
<i>A. versicolor</i> Fisch. et Mey.	Armenia, Azarbaijan	Endemic

Table 2. The number of *Acanthophyllum* species in the flora of different countries.

Country	Total No. of species	No. of section	Endemic species	Regional endemic species
Iran	38	4	7	18
Afghanistan	34	7	12	18
Turkmenistan	20	4	1	8
Pakistan	10	5	1	9
Tajikistan	11	4	2	5
Uzbekistan	11	4	4	2
Kazakhstan	7	3	-	2
Kirgizstan	6	3	-	2
Iraq	5	3	-	3
Turkey	5	1	-	1
Azerbaijan	1	1	-	-
Syria	1	1	-	-
China	1	1	-	-
Mongolia	1	1	-	-

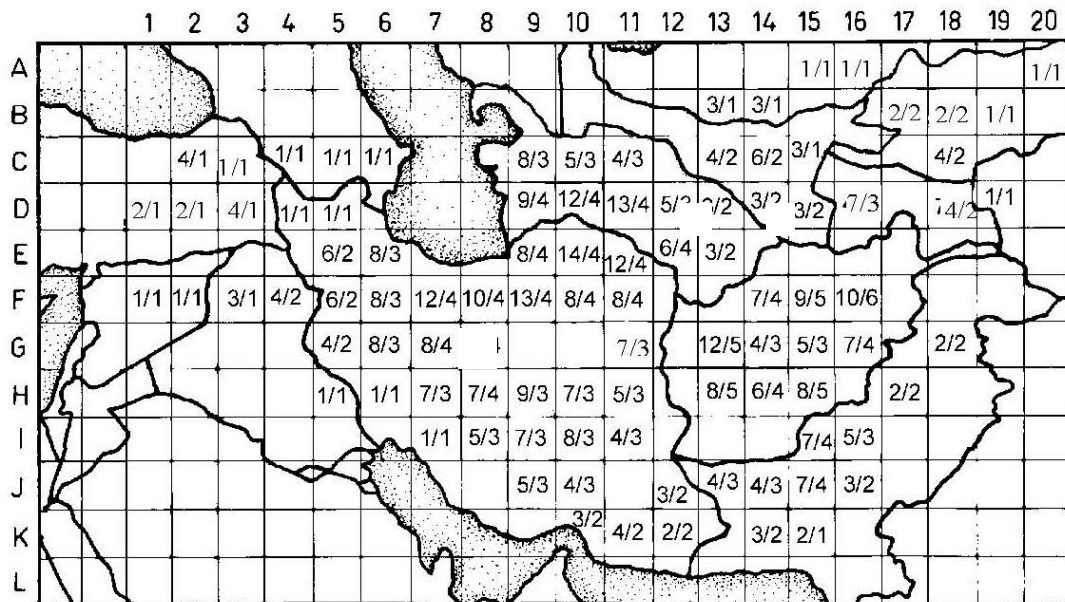


Fig. 1. Distribution of *Acanthophyllum* in the world. The number of species in each square is linked with the number of sections present.

Table 3. Chromosome numbers of *Acanthophyllum* species.

Taxon	Chromosome counts		References
	(n)	(2n)	
<b>Section <i>Oligosperma</i></b>			
<i>A. aculeatum</i>		30	Nussbaumer 1964
<i>A. albidum</i>		30	Nussbaumer 1964
<i>A. caespitosum</i>	14		Ghaffari 1988
<i>A. diezanum</i>	15		Ghaffari 1989
<i>A. ejtehadii</i>		30	Maleki Sadabadi et al. 2017
<i>A. elatius</i>	15	30+1B	Ghaffari 1988, 2021
<i>A. heratense</i>	15		Ghaffari 2004
<i>A. korshinskyi</i> (syn. <i>A. khorasanicum</i> )	15	30	Ghaffari 1988, 2020, 2021
<i>A. laxiusculum</i>	15+0-3B		Ghaffari 2004
<i>A. lilacinum</i>	15		Ghaffari 2004
<i>A. squarrosum</i>	15		Ghaffari 1986
<i>A. subglabrum</i>		30	Nussbaumer 1964
<b>Section <i>Macrostegia</i></b>			
<i>A. bracteatum</i>	15		Ghaffari 1986
<i>A. gracile</i>	15	30	Ghaffari 1987, 2021
<i>A. khuzistanicum</i>	15		Ghaffari 2004
<i>A. pachycephalum</i>	15	30	Ghaffari 2004, 2020, 2021
<b>Section <i>Acanthophyllum</i></b>			
<i>A. acerosum</i>	28		Ghaffari 2020, 2021
<i>A. crassifolium</i>	30		Ghaffari 1986
<i>A. mirocephalum</i>	30	60	Aryavand&Favarger 1980 Ghaffari 1986, 2020, 2021 Nussbaumer 1964
<i>A. mucronatum</i>	30		Ghaffari 2004
<i>A. verticillatum</i>	30		Ghaffari 2004
<b>Section <i>Paniculata</i></b>			
<i>A. gypsophiloides</i>		30	Nussbaumer 1964
<b>Section <i>Pleiosperma</i></b>			
<i>A. chloroleucum</i>	45		Ghaffari 1989
<i>A. crassinodum</i>	45	90	Ghaffari 2004, 2021
<i>A. glandulosum</i>	45	90	Ghaffari 1986, 2020, 2021 Nussbaumer 1964
<i>A. sordidum</i>	30	60	Ghaffari 1987, 2020, 2021

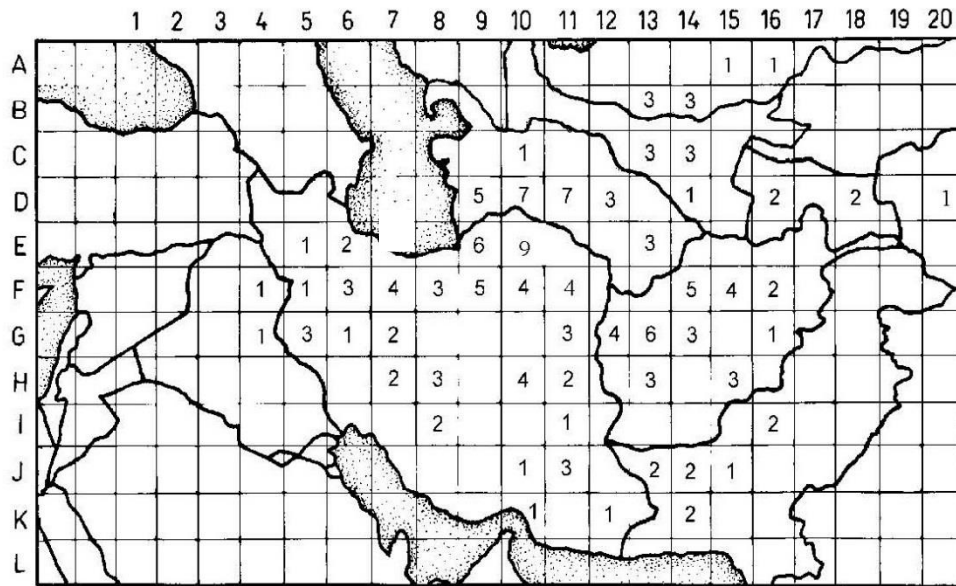


Fig. 2. *Acanthophyllum* sect. *Oligosperma*: species number per grid square.

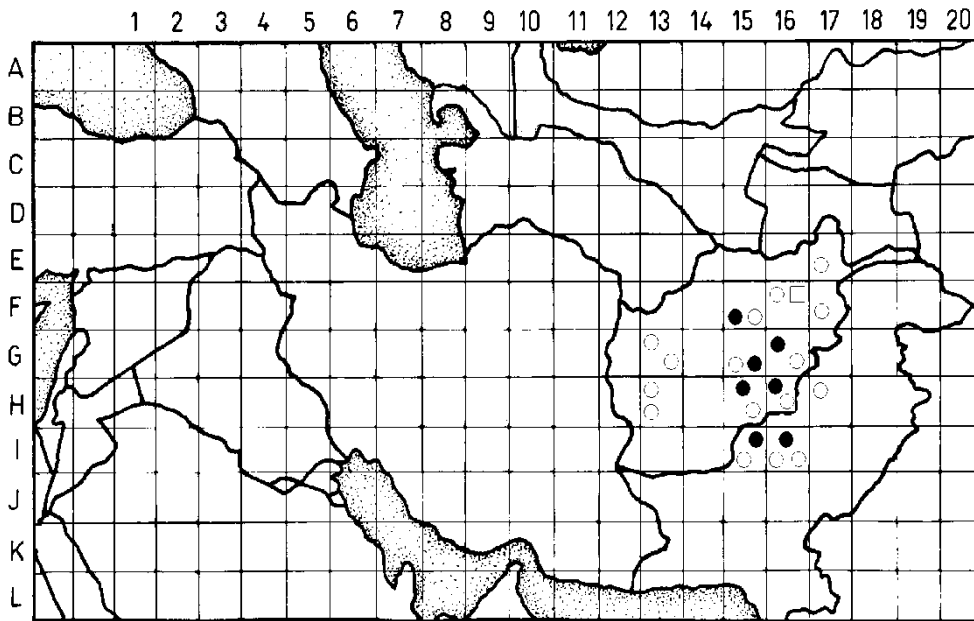


Fig. 3. Distribution of the species of *Acanthophyllum* sect. *Pseudacanthophyllum*  
 ○: *A. laxiflorum*. ●: *A. stewartii*. □: *A. raphiophyllum*.



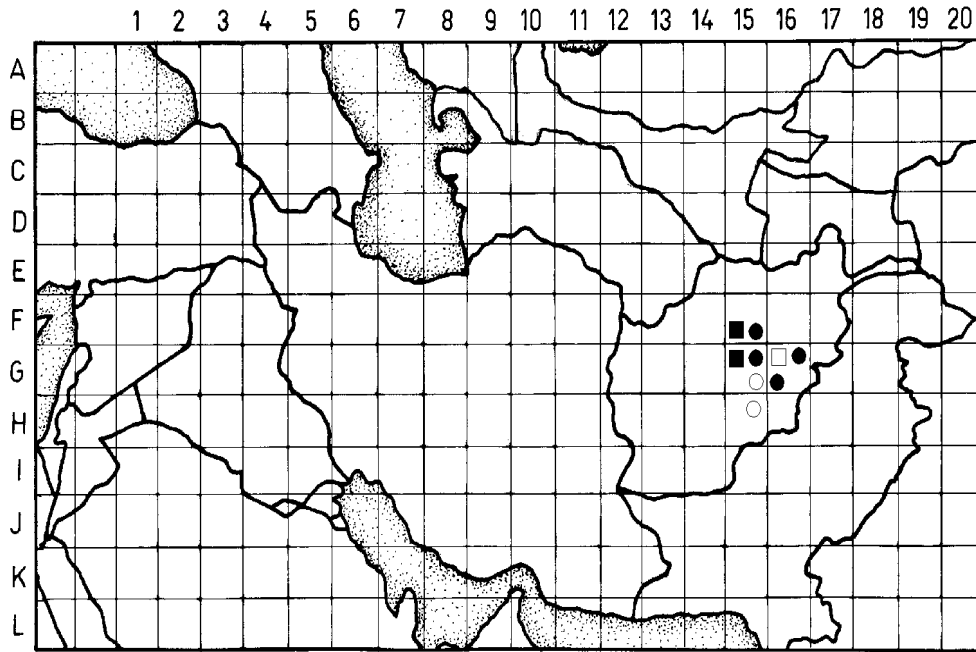


Fig. 4. Distribution of the species of *Acanthophyllum* sect. *Scapiflora*  
 ■: *A. bilobum*; □: *A. scapiflorum*; ●: *A. anisocladum*; ○: *A. lamondiae*.

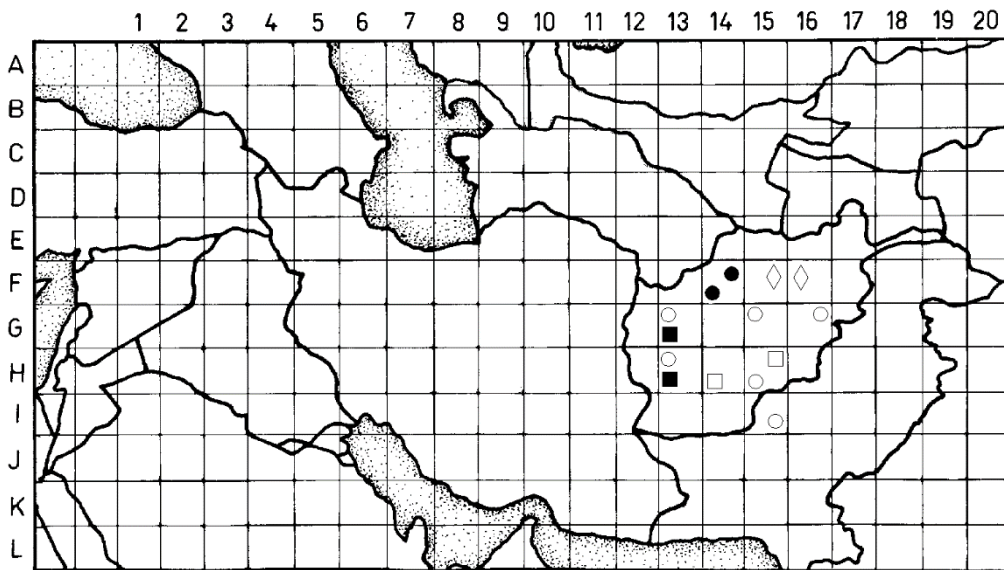


Fig. 5. Distribution of the species of *Acanthophyllum* sect. *Macrodonia*. ●: *A. pulcherrimum*; ○: *A. macrodon*; □: *A. fissicalyx*; ■: *A. xanthoporphyranthum*; ◇: *A. longicalyx*; ◆: *A. grandiflorum*.

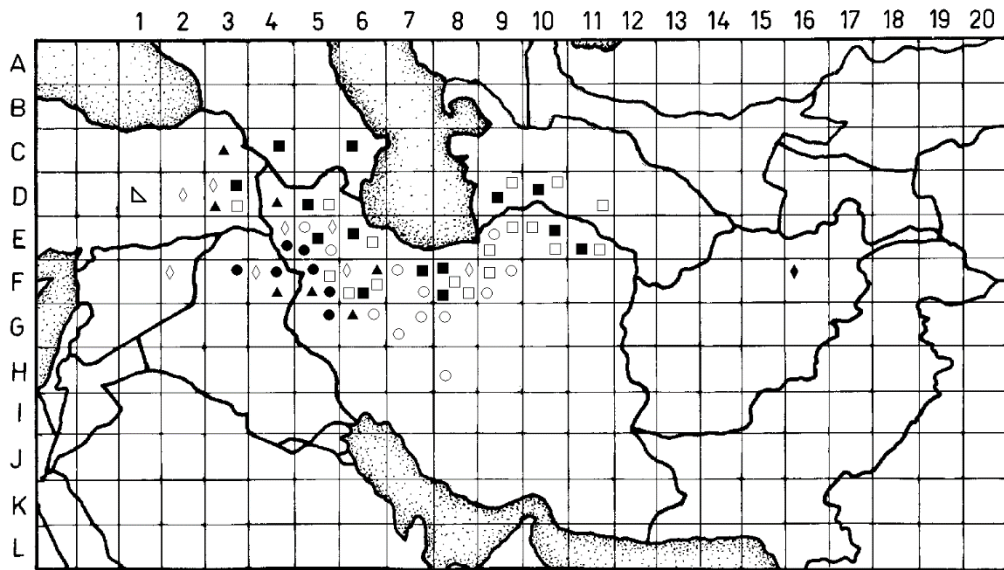


Fig. 6. Distribution of the species of *Acanthophyllum* sect. *Acanthophyllum*. ○: *A. crassifolium*; ●: *A. kurdicum*; □: *A. microcephalum*; ■: *A. mucronatum*; ◇: *A. varticillatum*; ◆: *A. pleiostegium*; ▲: *A. acerosum*; ▽: *A. oppositifolium*

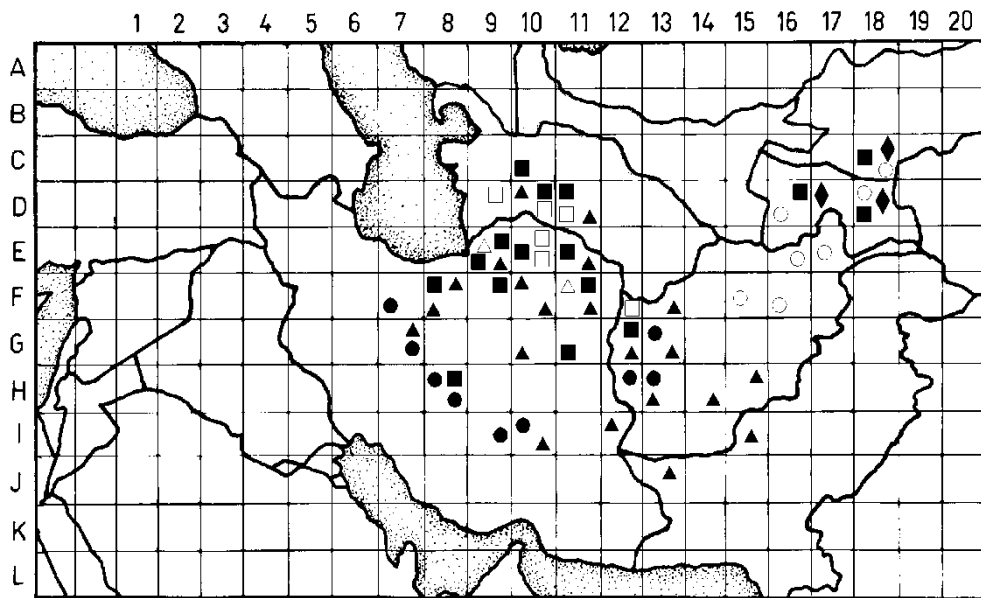


Fig. 7. Distribution of the species of *Acanthophyllum* sect. *Pleiosperma*. ○: *A. schugnanicum*; ●: *A. spinosum*; □: *A. crassinodum*; ■: *A. glandulosum*; △: *A. chloroleucum*; ▲: *A. sordidum*; ◆: *A. knorringianum*.

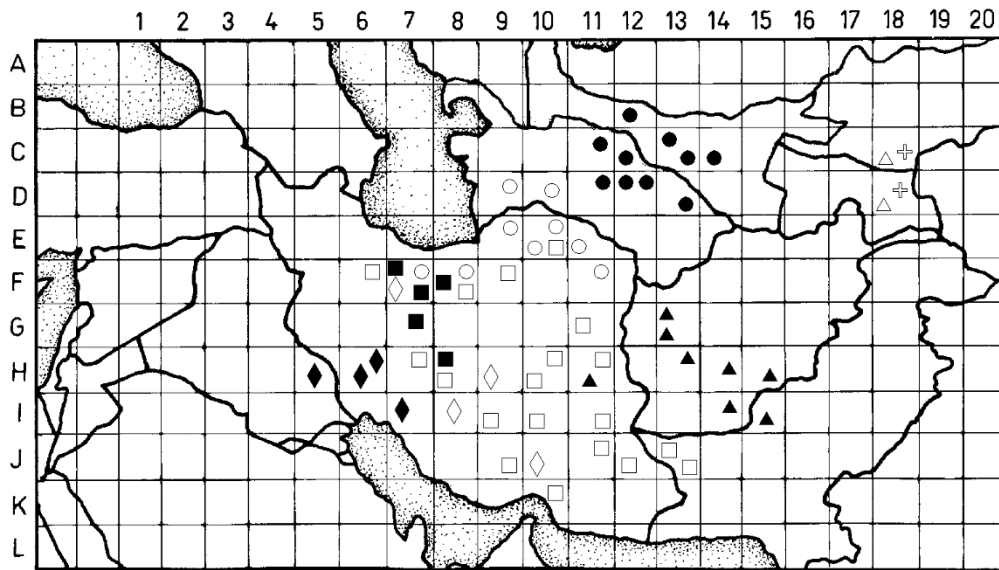


Fig. 8. Distribution of the species of *Acanthophyllum* sect. *Macrostegia*. ●: *A. korolkowii*; ○: *A. gracile*; ■: *A. pachycephalum*; □: *A. bracteatum*; ◇: *A. leucostegium*; ◆: *A. khuzistanicum*; ▲: *A. kandaharicum*; △: *A. serawschanicum*; ⊠: *A. coloratum*.

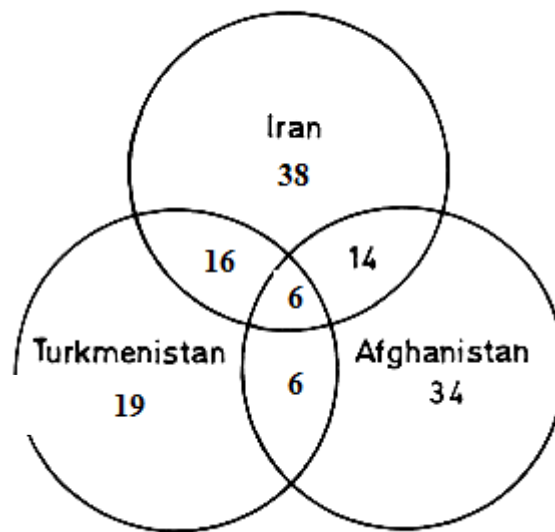


Fig. 9. Total species of *Acanthophyllum* in each country. Overlapping areas show the common species.

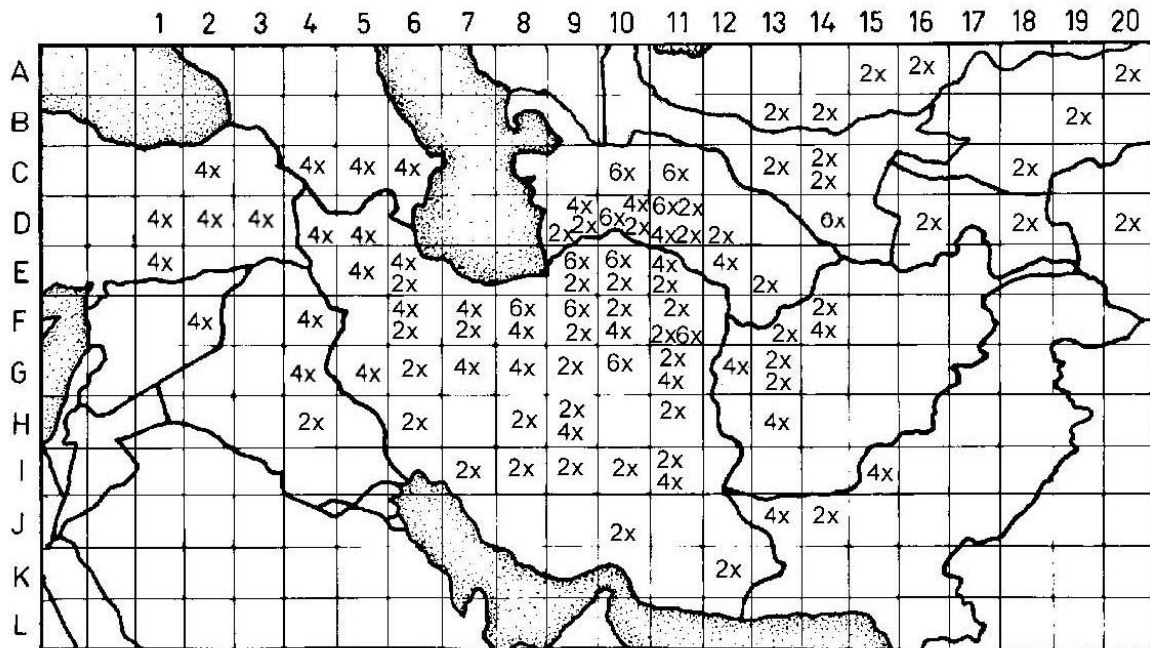


Fig. 10. Distribution of *Acanthophyllum* species according to ploidy levels.

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