Journal of Applied Botany and Food Quality 85, 159 - 167 (2012)

[1] Institute of Botany and Landscape Ecology, University of Greifswald, Germany
[2] Faculty of Science and Technology, Free University of Bozen-Bolzano, Italy
[3] Faculty of Textile and Clothing Technology, Niederrhein University of Applied Sciences, Mönchengladbach, Germany
[4] Institute of Resource and Environmental Sciences, Xinjiang University, China
[5] Republican Research Center of Forestry and Ornamental Garndening, Uzbekistan

Apocynum venetum L. and *Apocynum pictum* Schrenk (Apocynaceae) as multi-functional and multi-service plant species in Central Asia: a review on biology, ecology, and utilization

N. Thevs[1], S. Zerbe[2], Y. Kyosev[3], A. Rozi[1], B. Tang[1], N. Abdusalih[4], Z. Novitskiy[5]

(Received March 20, 2012)

Summary

During the second half of the 20th century cotton was strongly promoted along the rivers of Central Asia. The irrigation agriculture resulted in wide spread soil salinization and severe water shortages within the river systems. Most prominent example is the desiccation of the Aral Sea. The natural vegetation along the rivers of Central Asia is adapted to periods of water shortage, is very productive, and contains plant species with valuable utilization opportunities. We reviewed the literature about *Apocynum venetum* L. and *A. pictum* Schrenk, two plant species of those riparian ecosystems, which are used as fibre and medicinal plants. *A. venetum* and *A. pictum* yield fibres, which can be used as textiles, though the fibres best are blended with cotton and/or chemical fibres. Though, the fibre extraction process needs more research attention. Furthermore, the literature shows that *Apocynum* leafs are used to produce anti-hypertonic tea and medicine. Both species grow under the arid climate of Central Asia without irrigation, because they exploit groundwater. Furthermore, both species can withstand higher soil salinization levels than cotton. Both species can be used and provide an income to local people under conditions, which are unfavourable to grow crops under irrigation. Such conditions are unreliable water supply for irrigation systems and/or saline soils.

1. Introduction

Central Asia, which stretches from the Caspian Sea over Kazakhstan, Turkmenistan, and Uzbekistan to Northwest China (i.e. Xinjiang, Gansu, Qonghai, Inner Mongolia, Ningxia, Shanxi, and Shaanxi), and Mongolia, is largely covered by steppes, semi-deserts, and deserts. There, the most productive ecosystems are part of the riparian vegetation along the rivers (THOMAS et al., 2006; THEVS et al., 2007; 2011). But, vast areas of those productive ecosystems have been degraded due to enlarging the area for irrigation agriculture in Central Asia. Furthermore, river runoffs have dropped and fields have become subject to severe soil salinization. In the Aral Sea Basin, i.e. along the Amu Darya and the Syr Darya, planting of cotton was strongly promoted from the 1960ies onward. As a consequence the Aral Sea has nearly vanished (GLANTZ, 1999). In the Tarim Basin, the oases area was enlarged from the 1950ies onward leading to the complete desiccation of the Lakes Lop Nor and Taitema, the former end-lakes of the Kenqi and Tarim River, respectively (SONG et al., 2000). In both basins, the lower reaches of the rivers turned into episodic river courses or fell dry completely. Under those conditions, the natural riparian vegetation and the irrigation agriculture, especially along the lower reaches, suffered and suffers water shortage leading to ecological degradation and economic losses, respectively (HOPPE, 1992; SPOOR, 1993; GLANTZ, 1999; TRESHKIN, 2001; ZHU et al., 2006; THEVS et al., 2007; WESTERMANN et al., 2008). Along with the enlargement of irrigation area and periods of water shortage, soil salinization has become a major concern for farmers in the area (KUZMINA and TRESHKIN, 1997; FORKUSTA, 2006; IBRAKHIMOV et al., 2007).

In Xinjiang, Gansu, and Inner Mongolia, there are attempts to reduce the area under irrigation and shift the land use to perennial plants, which are adapted to the local environmental conditions, e.g. fruit trees, fodder plants, or medicinal plants (GAO et al., 2006). The two species *Apocynum venetum* L. and *Apocynum pictum* Schrenk (Fig. 1 and 2) are promising candidates for a sustainable land use away from irrigation.

The genus *Apocynum* comprises nine species, which are distributed in temperate regions of North America, Europe, and Asia. The two species *Apocynum venetum* and *Apocynum pictum* occur in Central Asia (ROYAL BOTANIC GARDENS, 2012). *A. venetum* and *A. pictum* are perennial plants with rhizomes, while the stems die yearly, i.e. life form geophytes according to (RAUNKIAER, 1934). New stems grow out of the roots every spring (PAVLOV, 1942).

A. venetum and *A. pictum* are adapted to survive even under the extreme arid climate of the Tarim Basin or Aral Sea Basin with less than 50 mm mean annual precipitation by exploiting the groundwater to cover their water demand. Thus, these two species are phreatophytes (GRIES et al., 2003; CHEN et al., 2006; THOMAS et al., 2006). Consequently, *A. venetum* and *A. pictum* provide utilization options without irrigation. The two species offer opportunities as fibre and medicinal plants.

In this paper, we present a comprehensive review on the two species *Apocynum venetum* and *Apocynum pictum*, focusing on biology, phytogeography, ecology, planting techniques, and utilization. We will draw conclusions on the utilization potential of these two species and point out open research questions. The term Apocynum is used, when we refer to both species *A. venetum* and *A. pictum*

Fig. 1: *A. venetum* stand, flood plain of the Ulungush River, Aleghak, Altay Prefecture, Xinjiang, China (Photo: N. Thevs, Sept. 2008).

Fig. 2: *A. pictum* stand, flood plain of the Layi River, i.e. a river branch of the Tarim River, Qongaral, Korla, Xinjiang, China (Photo: N. Thevs, Sept. 2008).

2. Biology of *A. venetum* and *A. pictum*

2.1 Taxonomy, nomenclature, and morphology

The genus *Apocynum* belongs to the family *Apocynaceae*, order *Gentiales*, class *Dicotyledonae*. Today, only the two *Apocynum* species *A. venetum* (Fig. 1) and *A. pictum* (Fig. 2) are distributed in Central Asia (Royal Botanic Gardens, 2012) and thus reviewed in this paper. *A. venetum* furthermore is split into several sup-species, from which *A. venetum* subsp. *lancifolium* Russanov and *A. venetum* subsp. *scabrum* Russanov are distributed in Central Asia. The synonyms for the two *Apocynum* species and two sub-species of *A. venetum* are given in Tab. 1 for Central Asia.

In the Russian literature, today's sub-species *A. venetum* subsp. *lancifolium* and *scabrum* are considered as species next to *A. venetum* (Pavlov, 1942; Romanovich, 1951). Furthermore, *A. sibiricum* is a synonym of today's *A. venetum* subsp. *lancifolium* (Prozorovskii, 1932). In our review, we will only refer to the species names *A. venetum* and *A. pictum*. If there appears uncertainty regarding the species names, we use *Apocynum*. A detailed history of the *Apocynum* taxonomical classification is provided by Zhang et al. (2006a).

In the Russian literature, Kendyr (Кендыр) is used as trivial name for *Apocynum* (Berljand, 1950; Romanovich et al., 1951). In China, the trivial names Luobuma, translated into English as Lop Kendyr (or Lop Kendyr), is used for the genus *Apocynum*, while Luobuhongma (罗布红麻) and Luobubaima (罗布白麻) refer to *A. venetum* and *A. pictum*, respectively (Zhang et al., 2006a; b).

A. venetum is taller and bigger than *A. pictum*. The former can grow as tall as 4 m, while the latter only reaches 2 m. In open vegetation, i.e. grassland, *A. venetum* usually grows 2 m high and each plant branches into 5-10 stems, but as an understory plant in Central Asian floodplain forests it grows up to 4 m and hardly branches off (Prozorovskii, 1932; Berljand, 1950; Romanovich et al., 1951; Zhang et al., 2006a; b). The most obvious feature to distinguish the two species is that *A. venetum* has opposite leafs, while *A. pictum* has alternate leafs (Flora of China, 2011). The further morphological characteristics of the two *Apocynum* species are given in Tab. 2.

The root system consists of vertical and horizontal roots and rhizomes. The vertical roots connect to the groundwater and thus secure the water supply of the plant. Each autumn, buds start to grow at the upper part of the vertical rhizome, from which the new stems emerge in the following spring. Nutrients are stored in the upper part of the vertical rhizome and in the entire horizontal rhizome. The horizontal rhizomes carry dormant buds (2-3 per cm), from which vertical roots and root suckers grow, when the horizontal rhizome has been cut off its mother plant. The horizontal roots of an *Apocynum* plant can extend up to 5-6 m (Berljand, 1950; Romanovich et al., 1951). There are whitish to yellowish mycorrhiza knots on the roots of *Apocynum* (Berljand, 1950). Vascular arbuscular mycorrhiza was described for the plant order *Gentiales*, including Apocynaceae (Zhang et al., 2003).

2.2 Life history

The stems emerge from the rhizomes in March to April. Flowering season is from June to August followed by fruit season from September to October (Zhang et al., 2005). The stems show the fastest length growth before onset of the flowering period. During

Tab. 1: Subspecies and synonyms of *A. venetum* and *Apocynum pictum* with their distribution (Royal Botanic Gardens, 2012).

Species / sub-species	Synonym
Apocynum venetum L.	Homotypic synonyms: *Trachomitum venetum* (L.) Woodson
Apocynum venetum subsp. *lancifolium* Russanov (distribution: Siberia to China)	Homotypic synonyms: *Apocynum lancifolium* Russanov, *Trachomitum lancifolium* (Russanov) Pobed. Heterotypic synonyms: *Nerium sibiricum* Medik., *Apocynum compressum* Moench, *Nerium antidysentericum* Lepech., *Apocynum sibiricum* Pall. ex Roem. & Schult, *Apocynum venetum* var. *microphyllum* Bég. & Beloserky, *Trachomitum venetum* var. *microphyllum* (Bég. & Beloserky) Woodson
Apocynum venetum subsp. *scabrum* Russanov (distribution: Asia to Pakistan)	Homotypic Synonyms: *Apocynum scabrum* Russanov, *Trachomitum scabrum* (Russanov) Pobed., *Trachomitum venetum* subsp. *scabrum* (Russanov) Rech.f. Heterotypic Synonyms: *Apocynum venetum* var. *turkestanicum* Bég. & Belosersky
Apocynum pictum Schrenk. (distribution: Central Asia to Mongolia)	Homotypic synonyms: *Poacynum pictum* (Schrenk.) Bail. Heterotypic Synonyms: *Apocynum hendersonii* Hook, *Apocynum grandiflorum* Danguy, *Poacynum hendersonii* (Hook) Woodson

Tab. 2: Morphological characteristics of *A. venetum* and *A. pictum* (FLORA OF CHINA, 2011).

	Apocynum venetum	*Apocynum pictum*
Stem	Up to 4 m tall, glabrous except for inflorescences; branches and branchlets whitish gray, terete, finely striate	Up to 2 m tall, branchlets pubescent when young, soon glabrous
Leaves	Usually opposite; petiole 3-6 mm; leaf blade narrowly elliptic to narrowly ovate, 1-8 x 0.5-2.2 cm, base rounded or cuneate, margin denticulate, apex acute or obtuse, mucronate	Usually alternate; petiole 2-5 mm, rarely shorter; leaf blade oblong to ovate, 1.5-4 x 0.2-2.3 cm, closely denticulate, granulose
Flowers	Sepals narrowly elliptic or narrowly ovate, ca. 1.5 mm; corolla purplish red or pink; tube campanulate, 6-8 mm, granulose; lobes 3-4 mm; disc fleshy, 5-lobed; lobes rounded, base adnate to ovary	Sepals ovate or triangular, 1.5-4 mm; corolla pink or purplish red, often with distinct darker markings; tube basin-shaped, 2.5-7 mm; lobes broadly triangular, 2.5-4 mm; corona inserted at base of corolla tube, lobes broadly triangular, apex long acuminate
Fruits	Follicles slender, 8-20 cm x 2-3 mm	Follicles slender, pendulous, 10-30 cm x 3-4 mm
Seeds	Ovoid or ellipsoid, 2-3 mm, coma 1.5-2.5 cm	Narrowly ovoid, 2.5-3 mm; coma 1.5-2.5 cm

and after the flowering period, the length growth ceases (BERLJAND, 1950). *Apocynum* plants reach an age of 30 years (PROZOROVSKII, 1932). *Apocynum* is not very prone to pests and illnesses (TANG, 2008).

3. Phytogeography and phytosociology

A. venetum is distributed over a vast area in Eurasia, i.e. from Southeast Europe over Turkey, Iran, Turkmenistan, Uzbekistan, Kazakhstan, and Southern Sibiria to Mongolia, Northern China, and Japan. In Central Asia, *A. venetum* is distributed in the floodplains and valleys along the rivers, e.g. Amu Darya, Pandzh, Vakhsh, Syr Darya, Chu, Talas, Ili, Irtysh, Tarim with its tributaries, and Heihe (ROMANOVICH et al., 1951). In Central Asia, only the sub-species *A. venetum* subsp. *lancifolium* and *scabrum* (Tab. 1) occur. In Kazakhstan, i.e. Syr Darya and Chu river basins, *A. venetum* subsp. *lancifolium* is found, while the sub-species *A. venetum* subsp. *scabrum* is recorded in the Amu Darya Basin (PAVLOV, 1942; BERLJAND, 1950).

A. pictum's distribution is restricted to southern Kazakhstan, the Ili Basin, Xinjiang, Gansu, and Inner Mongolia (PAVLOV, 1942). Both species are part of the riparian vegetation along the rivers and streams in the drylands of Central Asia. So, they are distributed along perennial and episodic river courses, on alluvial plains, and at desert margins (PAVLOV, 1942; ZHANG et al., 2003; 2005).

In China, the two *Apocynum* species are mainly recorded in Xinjiang, Qinghai (Caidam Basin), Gansu, Inner Mongolia, Shanxi, Shaanxi, Hebei, Jilin, and Heilongjiang. Within this area *A. venetum* occurs in the semi-arid, semi-humid, and humid part, i.e. with an annual mean precipitation of more than 250 mm. In contrast, *A. pictum* is restricted to the arid climate, i.e. with an annual precipitation of less than 250 mm (ZHANG, 2002; ZHANG et al., 2006a; b). Only in the Caidam Basin with a mean annual precipitation of less than 200 mm, but at an elevation of higher than 2,600 m, *A. venetum* is dominant over *A. pictum* (TIE and LIU, 2006; TANG, 2008). Within Xinjiang, *A. pictum* is restricted to the more arid parts, e.g. the Tarim Basin and the southern rim of the Zhungar Basin, while *A. venetum* occurs in the less arid northern part of the Zhungar Basin and the foothills of the Altay Mountains, as shown in Fig. 1 (ZHANG, 2002; ZHANG et al., 2006a; b).

All over China, the area of *Apocynum* vegetation, natural or artificial, amounts to 1,330,000 ha (TANG, 2008). One third to half of this area is located in Xinjiang, i.e. approximately 600,000 ha (ZHANG et al., 2003). In the Caidam Basin, 91,000 ha of natural *Apocynum* vegetation is recorded (TANG, 2008). Within this area, *Apocynum* is often accompanied by *Nitraria* spec. L. and *Phragmites australis* Trin. ex Staud.

The areas stated here for China as well as for Xinjiang and the Caidam Basin do not represent *Apocynum* dominated or even single species vegetation, but they may represent the area within which *Apocynum* is distributed as accompanying species or dominant species (HONG et al., 2002). This is further illustrated by the distribution of *Apocynum* in Aksu Prefecture, Xinjiang (ZHANG et al., 2003): *Apocynum* is distributed along the Tarim River as grassland on higher river terraces and in a mosaic with Tugai forests. In Aksu Prefecture, the area of *Apocynum* vegetation is 50,600 ha comprising reed and *A. venetum* with 17,100 ha, *A. pictum* with 800 ha, *A. venetum* and *Glycyrrhiza* L. with 1,600 ha, *Tamarix ramosissima* Ledeb. and *A. venetum* with 4,400 ha, *Tamarix ramosissima* and *A. venetum* and *Alhagi* spec. Gagnebin with 11,900 ha, *Tamarix ramosissima*, *A. pictum*, and *Alhagi* spec. with 3,600 ha, and *Populus euphratica* Oliv. and *A. venetum* with 11,200 ha.

4. Ecology of *A. venetum* and *A. pictum*

4.1 Climate adaptation

The above-ground parts of *A. venetum* do not withstand frost and die off under frost. However under a snow cover, the root can withstand strong frost up to -30 °C. The seedlings do not withstand frost at all (BERLJAND, 1950; ROMANOVICH et al., 1951).

4.2 Soil conditions: water and salt

Apocynum is adapted to arid climate or dry periods as being a phreatophyte (BERLJAND, 1950). The most productive sites of *A. venetum* are found on a groundwater not deeper than 3 m with salt contents between 1 g/l and 10 g/l (BERLJAND, 1950; ZHANG, 2002). Along the lower reaches of the Tarim River, which had been dry from the 1970ies to 2000 (SONG et al., 2000), *A. pictum* is mainly found on groundwater levels of 4-6 m below surface, with a maximum groundwater depth of 8 m (HAO et al., 2008). *A. venetum* in contrast, is restricted to groundwater levels not deeper than 4 m below surface (ZHANG, 2002).

Within its distribution area, *Apocynum* forms island-like mono-species stands or dominates stands, but mostly occurs as accompanying species in various plant communities (PROZOROVSKII, 1932; HONG et al., 2002; ZHANG, 2002). Thus, it often growths together with *Phragmites australis*, *Glycyrrhiza inflata*, *Alhagi sparsifolia*, and *Tamarix* shrubs (ZHANG, 2002; HONG et al., 2002; CHEN et al., 2006), with halophytes on salinized soils (ROMANOVICH et al., 1951), or as understory in floodplain forests, e.g. built up by *Populus euphratica* (PROZOROVSKII, 1932). *A. pictum* bears deeper groundwater levels than *Phragmites australis* (THEVS et al., 2008a), similar groundwater levels as *Glycyrrhiza inflata* (CHEN et al., 2006), but cannot exploit the groundwater as deep as *Populus euphratica*, *Tamarix ramossissima*, or *Alhagi sparsifolia* (Chen et al., 2006; Fan et al., 2006). Next to the ability to use groundwater, the stems and branches and leafs are covered with a wax layer, which reduces evaporation (Romanovich et al., 1951).

Apocynum can withstand periods of submergence. However, prolonged submergence or water logged soil inhibits its growth (Berljand, 1950). Under such conditions, the majority of the roots is concentrated at the upper boundary of the reduced gleyic horizon, in order to avoid prolonged anoxic conditions (Prozorovskii, 1932). *Apocynum* is most productive on sandy (Romanovich et al., 1951) and silty (Prozorovskii, 1932), well drained soils (Berljand, 1950). It cannot grow on clayey soils (Prozorovskii, 1932).

The topsoil under *Apocynum* stands often is salinized, reaching salt contents of up to 20 %. However, 30 cm below surface the salt content drops to only 1 % and less (Zhang et al., 2003). This shows that *Apocynum* can grow on sites with a pronounced surface salinization, as long as the subsoil and the groundwater are not strongly salinized. Under such conditions, flooding is harmful for *Apocynum*, because the flood leaches salt into the subsoil, where it damages the roots. *A. pictum* has a stronger ability to bear salinization than *A. venetum* (Zhang, 2002).

Apocynum seedlings do not tolerate salt. Older plants with deeper roots reach non- or low-saline soil layers so that they can withstand saline top soils, as resulted from irrigation or natural soil salinization (Berljand, 1950; Zhang, 2002). The adult *Apocynum* plants tolerate salt better than cotton (Berljand, 1950).

4.3 Plant nutrient status

Apocynum needs considerable amounts of nutrients from the soil, because it grows rather fast. From the second half of the summer onward, *Apocynum* stores nutrients in its root system (Berljand, 1950). The net primary production of vegetation dominated by *Apocynum* in the Tarim Basin amounts to 0.93 t/ha (Hong et al., 2002). In *A. venetum* leaves from Xinjiang, the contents of the nutrients K, Ca, and Mg are 8.1 mg/g, 1.13 mg/g, and 5.01 mg/g, respectively. The Na content is 6.2 mg/g (Fan et al., 2006).

5. Reproduction and planting techniques

5.1 Natural reproduction and germination

Under natural conditions, *Apocynum* predominantly recruits vegetatively through root suckers. Seed germination and successful seedling establishment rarely occurs (Romanovich et al., 1951). The seeds require moist, non-saline, well drained sandy to loamy sediments (Romanovich et al., 1951). Such sites only can be found along river banks after flood events. After germination, the seedlings grow slowly above ground, but invest strongly into the root system which is typical for phreatophytes. The seeds germinate easily, but the establishment of the seedlings by accessing a continuous connection to the groundwater poses a bottleneck for the generative recruitment (Prozorovskii, 1932; Tang, 2008). Thus, the recruitment of *Apocynum* is similar to that of *Populus euphratica* Oliv. (Thevs et al., 2008b; Wiehle et al., 2009).

The fruits are 12-20 cm long and have a diameter of 3-4 mm. When ripe, they turn brown. Each fruit contains 100-150 seeds. The seeds are 2.5 mm long with a diameter of 0.5 mm. The 1,000-grain weight of *Apocynum venetum* ranges from 350 mg to 1,000 mg in the former Soviet Union (Romanovich et al., 1951). In Shaanxi, i.e. the more humid part of the Apocynum distribution area in China the 1,000-grain weight of *A. venetum* is 500-600 mg (Hu et al., 1988). In the more arid regions of the distribution area, i.e. Xinjiang and southern part of Central Asia, the seeds of *Apocynum* are less than 1 mm long. There, the 1,000-grain weight of *A. venetum* ranges from 332 mg (Bai et al., 2005) to 469 mg (Berljand, 1950). The 1,000-grain weight of *A. pictum* was measured as 264 mg (Bai et al., 2005). The seeds carry pappus-like hair. The light weight and the hair enable an anemochorous dispersion (Berljand, 1950; Bai et al., 2005).

The seeds lose their germination ability rapidly. However, when stored at dry conditions, i.e. moisture content of 3-6 %, in air-sealed containers, 60 % of seed samples retained germination ability even after 8 years. When the moisture content exceeds 8 %, the seeds lose their germination ability within two years. Under non-sealed conditions, the seeds also lose their germination ability within 2-3 years, even under a moisture content of 4 %. It is not necessary to store the seeds under dark conditions (Hu et al., 1988). Those results were obtained from seeds from Shaanxi, which ripened under moist and hot conditions and therefore did not develop a very hard shell. *A. venetum* requires at least 10 °C for its germination. Frost then kills saplings (Prozorovskii, 1932; Berljand, 1950).

The influence of NaCl solution on the germination of *A. venetum* and *A. pictum* is shown in Tab. 3 (He et al., 1997; Chen et al., 2007).

Tab. 3: Germination rate of *Apocynum venetum* and *A. pictum* under different NaCl concentrations. Sources: (Chen et al., 2007)[1] and (He et al., 1997)[2], - = no data.

NaCl concentration [%]	Germination rate [%]		
	A. venetum[1]	*A. venetum*[2]	*A. pictum*[2]
0	86.0	-	-
0.2	87.5	-	-
0.4	96.0	91.3	-
0.6	100.0	91.3	-
0.8	87.5	-	-
0.9	-	85.7	-
1	82.5	-	-
1.6	78.0	-	-
< 1.8	-	-	89.3 - 96.7
2	44.0	-	-
2.1	-	-	86.7
2.5	8.6	0	-
3	-	-	0

When the NaCl concentration was increased from 0.2 % to 0.4 %, the length growth of the *A. venetum* seedlings, measured after 38 days, decreased significantly from 5.7 cm to 2.7 cm. With increasing NaCl concentration, the length growth dropped further to 0.5 cm under 2 % NaCl concentration. In germination experiments, the first seedlings of *A. venetum* appear after three days, while most seedlings appear after 7 days and all seeds have germinated after 28 days. Under salt concentrations around 2 %, the germination rate of *A. pictum* is double as high as that of *A. venetum* (Tab. 3), corresponding with the higher ability of *A. pictum* to withstand salinized soil conditions than *A. venetum* (Chen et al., 2007).

5.2 Cultivation and planting techniques

There are two reproduction methods for cultivation, i.e. seed propagation and vegetative propagation from root or plant parts (Berljand, 1950; Zhang et al., 2005). Direct seeding is the most labour saving method to cultivate *Apocynum*. But, better results are obtained, if *Apocynum* seeds are sown in a nursery and the saplings are transplanted after the second year (Berljand, 1950; Tang, 2008). The most suitable seeding time is mid April to May, in order to avoid spring frosts (ROMANOVICH et al., 1951; TANG, 2008). During the first year, 7-15 times irrigation with a total amount of 10,000 m³/ha to 12,000 m³/ha of water is needed for *A. venetum*. Fields on which *A. venetum* is sown should have a groundwater level not deeper than 2 m. On the other hand, the soil must be well drained, in order to avoid wet conditions (ROMANOVICH et al., 1951).

Apocynum germinated from seeds grows 30-40 cm high until the end of the vegetation season of the first year. The root system grows faster than the above ground part. After the first vegetation season, the roots reach 70-75 cm deep into the soil. In the second year, the sprouts grow out of the soil in March. At the end of the second vegetation season, *Apocynum* reaches a height of 100 cm. These stems start to yield fibres.

Fruits are formed only after the second year. In the fourth year, the stems reach a height of 2 m. In the third year and afterwards, the stems can be harvested before the onset of the flowering time. The horizontal roots penetrate the whole plantation area in the third year. The root system of *A. venetum* reaches a groundwater level of 1.5 m during the second year. In the third year, the roots reach a groundwater level of 2 m (BERLJAND, 1950).

For the establishment of *Apocynum* plantations root parts can be used, too. The roots can be taken from wild *Apocynum* stands, though over-exploitation must be avoided. Root pieces of 10-15 cm length are planted 10 cm deep into the soil. The work load is high, because 60,000 to 70,000 root pieces, i.e. 1-2 t are needed per hectare. The planting time can start a bit earlier than seeding time, i.e. end of March, but spring frosts also hamper root sprouting. During the first and second year, irrigation is necessary under the arid climate of Central Asia. Water has to be applied 5-6 times per year, which sums up to 4,000 m³ to 5,600 m³ water per year. If root pieces have been planted instead of seeds, the plant development is faster. At the end of the first vegetation season, the stems grow as high as 40-50 cm. At the end of the third year, the stems reach a height of 2 m (BERLJAND, 1950).

Insect pests do not pose a problem in the *Apocynum* cultivation, but the fungus *Septaria* leaf spot damages *Apocynum* under moist and rainy conditions (ZHANG et al., 2005). As the most important pests on *Apocynum* the fungus *Fusarium* spec. and the snail *Septaria* spec. are considered.

6. Utilization of *A. venetum* and *A. pictum*

A. venetum and *A. pictum* are used as medicinal plant and as fibre plant. The leaves, harvested in June/July, serve as raw material for tea and drugs, while the stems, harvested in summer or autumn, serve as raw material for the fibre extraction. Furthermore, *Apocynum* as part of the natural riparian vegetation is grazed (ZHANG et al., 2003). In an experimental scale natural rubber was extracted from *A. venetum*. But due to its poor quality, this utilization was given up rapidly (PAVLOV, 1942). In this paper, we will focus on the utilization of *Apocynum* as fibre plant and as medicinal plant.

The fibres of *Apocynum* are bast fibres (Fig. 3), like hemp or flax (ROMANOVICH et al., 1951). The fibre bundles of *Apocynum* are stronger, i.e. 30-40 fibres, than the bundles of flax, i.e. 10-30 fibres (PAVLOV, 1942). The strong bast fibres obtained from the inner bark are used in making cloth, strings, sails, fishing nests, and high-quality paper (ZHANG et al., 2006b). Next to the fibres from the stem, *A. venetum* yields a floss fibre from the seeds (ZHANG et al., 2006b). The fibre quality from both *Apocynum* species reviewed here are similar (HE et al., 1997).

The cultivation of *A. venetum* for fibre production started as early as 1930 in the former USSR. Just after World War II, there were plans in the USSR to set aside large areas for the cultivation of *A. venetum* as fibre plant. In China, *Apocynum* fibres are used for textiles, mainly for underwear.

In China, *A. venetum* grows as high as 3.6 m. In the Caidam Basin the above ground biomass fresh weights was measured with 1798 kg/ha and 1964 kg/ha for *A. pictum* (TANG, 2008). From a plantation near Tashkent, an average yield of 5-6 t/ha with a stem density of 300,000 plants per hectare was reported (PAVLOV, 1942). The annual demand for *Apocynum* fibres of whole China has been estimated at 50,000 kg over the past years. This demand is covered by the *Apocynum* stands in China. In contrast to that, the demand for leaves as raw material for tea and medicine cannot be covered (TANG, 2008).

In the first year after planting, *A. venetum* can be harvested once during that year. Afterwards, it can be harvested twice, i.e. in June before or at the beginning of the flowering period and a second time in September (ZHANG et al., 2005). In contrast, (BERLJAND, 1950) states that *Apocynum* can be harvested after 2-3 years. Only after 10 years, the productivity and yields decrease (PAVLOV, 1942).

6.1 Fibre extraction and fibre content

After harvest, the stems are dried on the field and roasted. Then, the bark and woody parts have to be removed mechanically from the fibres (BERLJAND, 1950).

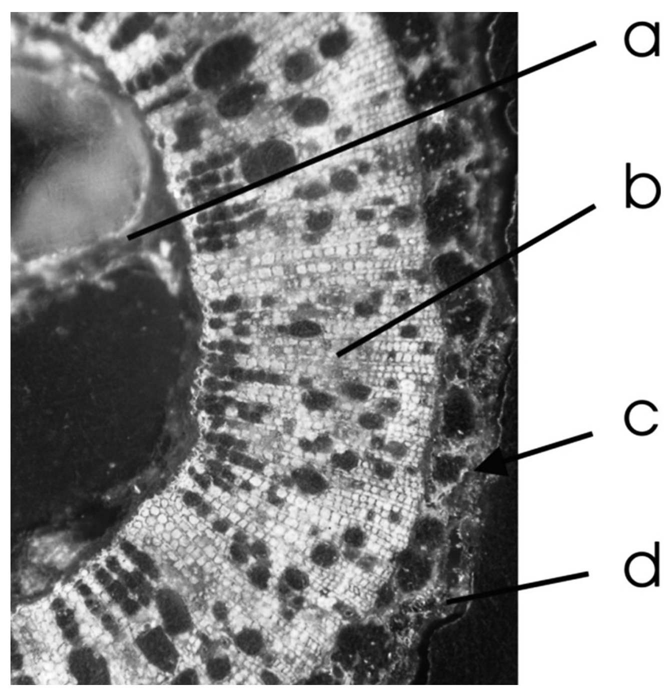

Fig. 3: Cross section of an *A. venetum* stem, a) pith, b) xylem, c) fibre bundle, d) epidermis

In a second step, the pectin, cellulose, and lignin, in which the fibre cells are embedded has to be digested (degumming), in order to yield the pure fibres (WANG et al., 2007). Chemical degumming (WANG et al., 2007) and biological (bacterial) degumming (can be applied to extract *Apocynum* fibres. The fibre properties do not vary between the two degumming methods (WANG et al., 2007), though bacterial degumming avoids pollution and thus is regarded superior to chemical degumming (BAO et al., 2002). The fibres can be extracted better from *A. venetum* compared to *A. pictum*, because the internodes of *A. venetum* are longer as the leaves and branches are opposite. But, the fibre extraction and the dying of *Apocynum* is more difficult than cotton (LIU and ZHOU, 2002).

The bark amounts for 20-22 % of the stem weight for *A. venetum*

(Romanovich et al., 1951). The fibre content of dry stems of *A. venetum* ranges from 10.2 % (Zhang et al., 2006b) to 17 % (Berljand, 1950). *A. pictum* has lower fibre contents, i.e. 7.6 % as shown in Tab. 4 (Zhang et al., 2006b).

Tab. 4: Stem height, bast and fibre contents, and fibre lengths (mean and standard deviation) of *A. venetum* and *A. pictum* in Xinjiang (Zhang et al., 2006b). The asterix indicates significant differences between the two means at p <= 0.05, calculated with t-test.

Plant parameter	*Apocynum venetum*	*Apocynum pictum*	
	Mean ± standard deviation		
Stem height [cm]	244.1 ± 78.0	112.0 ± 22.2	*
Bast content of stem [%]	22.4 ± 4.4	23.7 ± 4.7	
Bast content of branches [%]	19.6 ± 3.5	27.3 ± 5.0	*
Percentage of stem bark from total bark [%]	66.0 ± 17.1	47.0 ± 10.2	*
Fibre content [%]	10.2 ± 2.9	7.6 ± 1.9	*
Fibre length of stem [mm]	36.3 ± 8.4	29.4 ± 8.0	*
Fibre length of branches [mm]	20.2 ± 5.9	20.8 ± 5.4	

The longest fibres were found in the upper part of the lower half of the stem. The fibre length correlates with the stem height (Zhang et al., 2006b). The stem heights of *A. venetum* growing as understory in a floodplain forest and growing on an open site are 379.4 cm and 192.8 cm, respectively (Zhang et al., 2006b).

6.2 Fibre properties

The *Apocynum* fibres resemble cotton but are stronger than cotton. In the cross-section the *Apocynum* fibres are round, elongated, or even triangular. The fibres yield a pure white yarn, which is very similar to flax yarn. *Apocynum* fibres have small openings, which increase the turnover of air into the fibre and keep the fibre dry (Han, 2006; Li and Li, 2006). Compared to cotton, *Apocynum* textiles keep warmer, have a higher aeration, and absorb a higher proportion of UV light (Wei, 2004). The properties of *Apocynum* fibres are given in Tab. 5. In Tab. 6 and 7, the *Apocynum* fibre properties are compared with Ramie and Flax as two other bast fibre plants and with cotton.

Tab. 5: Fibre properties of *Apocynum* fibres.

Fibre parameter	Size of parameter
Fibre length [mm]	15-25, max. 70 (Prozorovskii, 1932)
	50-55, min. 5, max. 120 (Pavlov, 1942)
	20-25, min. 10, max. 40 (Li and Li, 2006)
Average	26 (Zhang et al., 2001)
Diameter [µm]	45 (Pavlov, 1942)
Fineness [dtex]	4.15 (Xu, 2005)
	3-4 (Li and Li, 2006)
	4.7 (Zhang et al., 2001)
Strength [cN/dtex]	3.7-4.4 (Li and Li, 2006)
	3-7 (Zhang et al., 2001)

However, between the *Apocynum* fibres and cotton there are considerable differences. The modulus of all *Apocynum* fibre from the three treatments is higher than 300 cN/dtex, while that of cotton is only 96 cN/dtex. Thus, textiles from *Apocynum* might be less soft than from cotton. Furthermore, the work of rupture of the *Apocynum* fibres with 11.82-13.72 µJ/dtex is lower than the corresponding value of cotton being 16.77 µJ/dtex. *Apocynum* fibres thus might be less durable than cotton fibres (Wang et al., 2007). Still, the *Apocynum* fibres extracted through the three degumming methods all can be readily processed in normal textile machinery and are suitable for blending with other commonly used fibres (Wang et al., 2007). Though, the low breaking elongation, the variance in fibre length, and the smooth surface of the Apocynum fibres may lead to difficulties during the spinning process (Pavlov, 1942; Liu and Zhou, 2002). Therefore, *Apocynum* fibres usually are blended with cotton or chemical fibres (Wei, 2004). The blend ratio usually is 65 % cotton and 35 % *Apocynum* (Zhang et al., 2001).

Tab. 6: Comparison of fibre properties between *Apocynum* and the bast fibres Ramie and Flax

Specifications	*Apocynum*	Ramie	Flax	Source
Fibre length [mm]	20-25	50-120	15-20	(Xu, 2005)
Fibre diameter [µm]	14-15	20-45	12-17	(Xu, 2005)
Fineness [dtex][1]	3	4.5	2	(Li and Li, 2006)
Strength (dry) [cN/dtex]	3-7	6.5	6.3	(Li and Li, 2006)
Breaking elongation (dry) [%]	2.5	2.3	1.8	(Li and Li, 2006)
Divergence rate [%]	100	100	88	(Li and Li, 2006)

[1] The unit tex is equivalent to 1 g/km. Thus, an *Apocynum* fibre of 3 dtex has a weight of 0.3 g per 1 km fibre length.

Tab. 7: Comparison of fibre properties of *Apocynum venetum* (three extraction treatments) and cotton (Wang et al., 2007)

Fibre parameter	Machine bast pealing + chemical degumming	Hand bast pealing + chemical degumming	Machine bast pealing + bacterial degumming	Cotton
Modulus (cN/dtex)	318.9	383.7	394.5	96.6
Breaking elongation (%)	4.06	3.58	3.26	10.69
Work of rupture (µJ/dtex)	12.36	13.72	11.82	16.77

The chemical composition of *Apocynum* is little different from other hemp fibre. The pectin content of *Apocynum* is 13.14 % .The water soluble content is 17.22 % It is the highest ranking among the hemp fibre. The lignin content of is 12.14 %, higher than ramie, flax, abaca and sisal. The cellulose content ranges from 40.82 %, which is the lowest of all hemps, to 72 %, i.e. the same as flax fibre (Li and Li, 2006).

6.3 Hygiene and medicinal effects of *Apocynum* fibres

Apocynum fibres show an anti-microbial effect. The inhibition rates of *Apocynum* fibre on *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Escherichia coli*, and *Candida albicans* is 47.7 %, 69.0 %, 56.6 %, and 40.1 %, respectively, compared to cotton fibres. Under an electron microscope, it was visible that the cell walls of the bacteria were destructed upon contact to the *Apocynum* fibres (Lü et al., 2006). This can be attributed to the finding that the stem cells of *Apocynum* contain tanning agents, which makes the fibres resistant against microbial decomposition (Romanovich et al., 1951).

6.4 Medicinal applications of *A. venetum* and *A. pictum*

Tea from *A. venetum* and *A. pictum* is used as a traditional Chinese medicine, which mainly is consumed in Northwest China. Anti-hypertensive and anti-hyperlipidemic effects are attributed to *Apocynum* tea (MA and CHEN, 1999). In 1977, *Apocynum* was listed as Chinese medicine in China (ZHANG, 2004).

A. venetum leaves are rich in ash elements and minerals, such as Ca, Fe, and Na, but differ from green tea leaves in that they contain no caffeine (YOKOZAWA et al., 2002). The leaves of *A. venetum* and *A. pictum* have a high flavonoid content (SAKUSHIMA et al., 1978; KAMATA et al., 2008).

Aqueous *A. venetum* extracts showed an anti-hypertensive effect on hypertensive rats. This anti-hypertensive effect was observed after treatment with aqueous extracts from roasted and non-roasted leaves (KIM et al., 2000). The anti-hypertensive effect was mainly attributed to an improved kidney function, i.e. increased excretions of urine volume and urine electrolytes. Such a diuretic effect of aqueous *A. venetum* extracts had been reported before (QING et al., 1988). Furthermore, a vascular relaxation effect after treatment of rat aortas with an *A. venetum* extract in an in vitro experiment was found. This vascular relaxation effect plays a role regarding the anti-hypertensive effects of *Apocynum* tea (KWAN et al., 2005). *Apocynum* extract caused vasodilation on tissues (TAGAWA et al., 2004).

Aqueous *A. venetum* extracts decreased the serum total cholesterol and LDL-cholesterol levels and the atherogenic index, as well as the hepatic total cholesterol level in an experiment with hyper-cholesteraemic rats, but they increased the HDL cholesterol level. The decrease of cholesterol values was stronger when using roasted *Apocynum* leaves to prepare the extract (KIM et al., 1998).

The leaves yield up to 5 % gum, which is used for making rubber, and a medicine used as a sedative and to treat hypertension (ZHANG et al., 2006a).

An extract of *A. venetum* leaves reduced significantly the immobility of rats in an forced swimming test. Therefore, it was concluded that such an *A. venetum* extract shows antidepressant activity in the forced swimming test. (BUTTERWECK et al., 2001; BUTTERWECK et al., 2003; ZHOU et al., 2007).

Furthermore, *A. venetum* extracts contain anti-oxidants. The anti-oxidative effect was attributed to condensed tannin compounds. The radical scavenging activity of *A. venetum* extracts was determined to be similar to *Gingko biloba* L. Thus, *A. venetum* extracts may serve as protective reagents against the oxidative stress in nerve cells due to lipid peroxidation (CAO et al., 2003; YOKOZAWA and NAKAGAWA, 2004; SHIRAI et al., 2005).

7. Conclusions

The literature reviewed shows that *A. venetum* and *A. pictum* yield fibres, which can be used as textiles, though the fibres best are blended with cotton and/or chemical fibres. Such yarns have good aeration and warming properties due to the hollow structure of the *Apocynum* fibres and are mostly used to produce underwear. Furthermore, the literature shows that *Apocynum* leafs are used to produce anti-hypertonic tea and medicine.

Both species yield fibres and leafs on considerable areas under the arid climate of Central Asia without irrigation, because they use the groundwater. Furthermore, both species can withstand higher soil salinization levels than cotton. *A. pictum* can withstand more saline and more arid conditions than *A. venetum*. Both species can be used and provide an income to local people under conditions, which are unfavorable to grow crops under irrigation. Such conditions are unreliable water supply for irrigation systems and/or saline soils.

Though, a number of research questions still are open. The area, from which *Apocynum* currently could be harvested, and the potential annual yields of fibres and leafs are unknown. Furthermore, the water consumption and water use efficiency must be measured, in order to make sure that *Apocynum* utilization does not consume more water than current utilizations. Currently, in China mostly natural *Apocynum* stands are harvested. These stands are not fertilized. Therefore the nutrient exports due to *Apocynum* harvest and possible stand degradations must be investigated.

The current used degumming methods require longer process time (bacterial degumming), are not very environment friendly and require water resources, which are usually not available in the cultivation regions. Therefore, more efficient and environmental friendly degumming method need to be investigated.

The fibres demonstrate technological properties similar to the other cellulosic fibres (flax, cotton), but with significantly lower braking elongation and larger length variations. These two features disturb the classical spinning process of pure apocynum yarns and are one of the reasons the apocynum fibres to be blended with cotton. The development of an adjusted spinning process and equipment for apocynum fibres can allow the production of yarns with higher apocynum content, which can extend the application areas for textiles. Due to its high strength, it has to be investigated if the fibres are suitable for other than clothing applications, as for instance for natural fibre composites. In such case the fibres can be used directly without or after only partial degumming procedure, which will reduce their price as well.

Acknowledgements

We thank the Bauer-Hollmann Foundation and the Helene and Rudolf Glaser Foundation for funding personal costs within the Junior Research Group Adaptation Strategies to Climate Change and Sustainable Land Use in Central Asia (Turkmenistan and Xinjiang, China). Furthermore, we thank the Robert-Bosch-Foundation, the Federal Ministry for Education and Research, Germany, and the German Academic Exchange Service (DAAD) for funding travel costs to China and Uzbekistan, respectively.

References

BAI, L., LUO, M.B., CHUAN, L.C., WANG, S.L., A, M.N., 2005: Short Report on planting techniques of *Apocynum venetum*. Chinese Wild Plant Resources 24, 65-68.

BAO, M.D., CHEN, Z., LIU, Z.G., REN, J.P., 2002: Study on biological degumming for *Apocynum venetum*. Shandong Agriculture Science 6, 11-13.

BERLJAND, S.S., 1950: Agro-Technology of Kendir. NAUK, Moscow.

BUTTERWECK, V., NISHIBE, S., SASAKI, T., UCHIDA, M., 2001: Antidepressant effects of *Apocynum venetum* leaves in a forced swimming test. Pharmaceutical Society of Japan 24, 848-851.

BUTTERWECK, V., SIMBRAY, K., SEO, S., SASAKI, T., NISHIBE, S., 2003: Long-term effects of an *Apocytum venetum* extract on brain monoamine levels and b-AR density in rats. Pharmacol. Biochem. Behaviour 75, 557-564.

CAO, Y., CHU, Q., YE, J., 2003: Determination of hydroxyl radical by capillary electrophoresis and studies on hydroxyl radical scavenging activities of Chinese herbs. Anal. Bioanal. Chem. 376, 691-695.

CHEN, Y.N., ZILLIACUS, H., Li, W.H., ZHANG, H.F., CHEN, Y.P., 2006: Groundwater level affects plant species diversity along the lower reaches of the Tarim river, Western China. J. Arid Environ. 66, 231-246.

CHEN, Y., LI, G., MENG, J., CAO, J., 2007: Effect of sodium chloride stress to the seed germination and seedling growth of *Apocynum venetum* L.. Chinese Wild Plant Resources 26, 49-51.

FAN, W.G., YAO, H.J., ZHANG, L., WU, G.L., 2006: Determination of trace elements in *Apocynum venetum* L. of Xinjiang by microwave digestion. Chinese Journal of Spectroscopy Laboratory 23, 1174-1176.

FLORA OF CHINA, URL http://www.efloras.org/browse.aspx?flora_id=2& name_str =Apocynum&btnSearch=Search (accessed on 02. February

2012)

Forkusta, I., 2006: Modeling water and salt dynamics under irrigated cotton with shallow groundwater in the Khorezm region of Uzbekistan. Center for Development Research, Bonn.

Gao, J., Liu, Y.S., Chen, Y.F., 2006: Land cover changes during agrarian restructuring in Northeast China. Appl. Geogr. 26, 312-322.

Glantz, M.H., 1999: Creeping environmental problems and sustainable development of the Aral Sea Basin. Cambridge University Press, Cambridge.

Gries, D., Zeng, F., Foetzki, A., Arndt, S.K., Bruelheide, H., Thomas, F.M., Zhang, X.M., Runge, M., 2003: Growth and water relation of *Tamarix ramosissima* and *Populus euphratica* on Taklamakan desert dunes in relation to depth to a permanent water table. Plant Cell Environ 26, 725-736.

Han, X., 2006: Development of blended yarn with refined cotton, Apocynum and far infrared viscose fibre. Maofang Keji 2, 33-35.

Hao, X.M., Chen, Y.N., Li, W.H., 2008: Indicating appropriate groundwater tables for desertriver-bank forest at the Tarim River, Xinjiang, China. Environ. Monit. Assess. 52, 167-177.

He, R.Y., Chu, J.P., Chen, G.L., 1997: Chinas Fibre Crops. China's fibre crops, 19, 21-23.

Hong, Z., Shangyu, G., Qiuhong, Z., 2002: Responses of NPP of salinized meadows to globalchange in hyperarid regions. J. Arid Environ. 50, 489-498.

Hoppe, T., 1992: Chinesische Agrarpolitik und Uygurische Agrarkultur im Widerstreit. Das sozio-kulturelle Umfeld von Bodenversalzungen und -alkalisierungen im nördlichen Tarim-Becken (Xinjiang). Institut für Asienkunde, Hamburg.

Hu, R., Zhang, S., Guan, Q., Qian, X., Zhu, H., Hao, Y., Jiang, L., 1988: Studies on seed storage of *Poacynum hendersonii* and *Apocynum venetum*. Acta Agronomica Sinica 14, 28-35.

Ibrakhimov, M., Khamzina, A., Forkutsa, I., Palusheva, G., Lamers, J.P.A., Tischbein, B., Vlek, P.L.G., Martius, C., 2007: Groundwater table and salinity: Spatial and temporal distribution and influence on soil salinization in Khorezm region (Uzbekistan, Aral Sea Basin). Irrigation Drainage Systems 21, 219-236.

Kamata, K., Seo, S., Nakajima, J.I., 2008: Constituents from leaves of *Apocynum venetum L.*. J. Natural Medicines 62.

Kim, D.W., Yokozawa, T., Hattori, M., Kadota, S., Namba, T., 1998: Effects of aqueous extracts of *Apocynum venetum* leaves on hypercholesterolaemic rats. Phytoth. Res. 12, 46-48.

Kim, D.W., Yokozawa, T., Hattori, M., Kadota, S., Namba, T., 2000: Effects of aqueous extracts of *Apocynum venetum* leaves on spontaneously hypertensive,renal hypertensive and NaCl-fed-hypertensive rats. J. Ethnol. Pharmacol. 72, 53-59.

Kuzmina, Z.V., Treshkin, S.Y., 1997: Soil salinization and dynamics of Tugai vegetation in the southwestern Caspian Sea region and in the Aral Sea coastal region. Eurasian Soil Sci. 30, 642-649.

Kwan, C.Y., Zhang, W.B., Nishibe, S., Seo, S., 2005: A novel in vitro endothelium-dependent vascular relaxant effect of *Apocynum Venetum* leaf extract. Clinical and Experimental Pharmacology and Physiology, 2005, vol. 32, 789-795.

Li, H., Li, Y., 2006: The King of wild Fibre – *Apocynum Verteura* L., Shandong Fangzhi Jingji 134, 80-81.

Liu, Z., Zhou, Y., 2002: Study on technological bases about biological decomposition of non – cellulose from Apocynum raw fibre. Plant fibre and products 24, 30-33.

Lü, R., Su, D.M., Meng, L., Zheng, L.S., 2006: Antibiotic properties of *Apocynum venetum*. Acta Academiae Medicinae Qingdao Universitatis 42, 71-72.

Ma, Y.X., Chen, S.Y., 1999: Observation on the antiaging, anti-hypertensive and anti-hyperlipidemic effect of *Apocynum venetum* leaf extract. Chin. J. Mod. Develop. Traditi. Med. 9, 335-337.

Pavlov, N.V., 1942: Dikie poleznye i tehnicheskie rastenija SSSR. Kazahskij Gozudarstbennyi Universitet im. S.M. Kirova and Kazahskij Filial Akademii, Nauk, Moscow.

Prozorovskii, A.W., 1932: Iliyskiy Kendyr. Kazahskij Institut Udobrenii i Agropochvovedehija, Almaty.

Qing, Z.N., Song, L.H., Gu, Z.L., 1988: An experimental observation on the diuretic effect of an extract of Luobuma (*Apocynum venetum*) leaves. Bull Chin Mater Med 13, 44-46.

Raunkiaer, C., 1934: The life forms of plants and statistical geography. Clarendon Press, Oxford.

Romanovich, V.V., Sharii, N.J., Zubzova, Z.D., Kazenas, L.D., 1951: Kendyr v Kasahstanie. Kazah. Goz. Ezd., Almaty.

Royal Botanic Gardens, 2012: URL http://apps.kew.org/wcsp (accessed on 02. February 2012)

Sakushima, A., Nishibe, S., Hisada, S., 1978: Studies on the constituents of Apocynaceae plants. Isolation of flavonol glycosides and other components from the leaves of *Apocynum venetum* L. var. basikurumon Hara. Pharmaceutical Society of Japan 98, 1395-1397.

Shirai, M., Kawai, Y., Yamanishi, R., Terao, J., 2005: Approach to novel functional foods for stress control. 5. Antioxidant activity profiles of antidepressant herbs and their active components. J. Medical Investigation 52, 249-251.

Song, Y.D., Fan, Z.L., Lei, Z.D., Zhang, F.W., 2000: Research on water resources and ecology of Tarim River, China. Xinjiang Peoples Press, Urumqi.

Spoor, M., 1993: Transition to market economies in former Soviet Central Asia: Dependency, cotton, and water. URL http://repub.eur.nl/res/pub/18862/wp160.pdf (accessed on 02. February 2012)

Tagawa, C., Kagawa, T., Nakazawa, Y., Onizuka, S., Nishibe, S., Kawasaki, H., 2004: Studies on antihypertensive effect of Luobuma (*Apocynum venetum* L.). Leaf Extract (3). Pharmaceutical Society of Japan 124, 851-856.

Tang, X.Q., 2008: Study on the resource of Wild P Pictum Ball. and Planting Technology in Chaidam Basin. Qinghai Agriculture 17, 48-50.

Thevs, N., Zerbe, S., Gahlert, F., Mijit, M., Succow, M., 2007: Productivity of reed (*Phragmites australis* Trin. ex. Staud.) in continental-arid NW China in relation to soil, groundwater, and land-use. J. Appl. Bot. Food Qual. 81, 62-68.

Thevs, N., Zerbe, S., Peper, J., Succow, M., 2008a: Vegetation and vegetation dynamics in the Tarim River floodplain of continental-arid Xinjiang, NW China. Phytocoenologia 38, 65-84.

Thevs, N., Zerbe, S., Schnittler, M., Abdusalih, N., Succow, M., 2008b: Structure, reproduction and flood-induced dynamics of riparian Tugai forests at the Tarim River in Xinjiang, NW China. Forestry 8, 45-57.

Thevs, N., Buras, A., Zerbe, S., Kühnel, E., Abdusalih, N., Ovezberdyyeva, A., 2011: Structure and wood biomass of near-natural floodplain forests along the Central Asian rivers Tarim and Amu Darya. Forestry, doi:10.1093/forestry/cpr056.

Thomas, F.M., Foetzki, A., Arndt, S.K., Bruelheide, H., Gries, D., Zeng, F.J., Zhang, X.M., Runge, M., 2006: Water use by perennial plants in the transition zone between river oasis and desert in NW China, Basic Appl. Ecol. 7, 253-267.

Tie, G., Liu, H., 2006: Characters and utilization value of wild *Apocynum venetum*. Pratacultural Science 23, 46-47.

Treshkin, S.Y., 2001: The Tugai Forests of floodplain of the Amudarya River: Ecology, dynamics and their conservation. In: Breckle, S.W., Veste, M., Wucherer, W. (eds.), Sustainable land use in deserts, 95-102. Springer, Heidelberg.

Wang, L., Han, G., Zhang, Y., 2007: Comparative study of composition, structure and properties of *Apocynum venetum* fibres under different pretreatments. Carbonhyd Polym. 69, 391-397.

Weber, H.C., 2003: Endomycorrhizas in the Gentiales: Structures and evolution of the vesicular-arbuscular mycorrhiza (VAM). In: Heldmaier, G., Werner, D. (eds.), Environmental signal processing and adaptation, 57-70. Springer, Heidelberg.

Wei, C., 2004: Growth, physical and chemical properties, and utilization of Apocynum fibres. Pinzhi Xingneng Fenxi 9, 25-26.

Westermann, J., Zerbe, S., Eckstein, D., 2008: Age structure and growth of degraded *Populus euphratica* floodplain forests in NW China and perspectives for their recovery. J. Integrat. Biol. 50, 536-546.

Wiehle, M., Eusemann, P., Thevs, N., Schnittler, M., 2009: Root suckering patterns in *Populus euphratica* (Euphrates poplar, Salicaceae). Trees 23, 991-1001.

Xu, H., 2005: Brief introduction of Xinjiang Apocynum's species characteristics and its manufacture. Maofang Jishu 6, 37-40.

Yokozawa, T., Kashiwada, Y., Hattori, M., Chung, H.Y., 2002: Study on the components of Luobuma with Peroxynitrite-Scavenging Activity. Biol. Pharm. Bull. 25, 748-752.

Yokozawa, T., Nakagawa, T., 2004: Inhibitory effects of Luobuma tea and its components against glucose-mediated protein damage. Food Chem. Toxicol. 42, 975-981.

Zhang, S., 2002: The division of geographical on distribution region of Kendyr in China. Plant J. Northwest China 22, 1-5.

Zhang, Z., Ni, Y., Wang, Y., 2001: The development of Kender Health Care Towel Yarn. Shandong Fangzhi Keji 4, 11-12.

Zhang, L., Li, H.Q., Yi, H.Y., 2003: Botanical characteristics, distribution and application of Lopnur Kender resources in Aksu prefecture. Xinjiang Agricultural Sciences 40, 172-174.

Zhang, Z.J., 2004: Therapeutic effects of herbal extracts and constituents in animal models of psychiatric disorders. Life Sci. 75, 1659-1699.

Zhang, G., Qian, X., Gu, G., 2005: *Apocynum venetum* L. Resources in Shanxi, Hubei, Henan and Shandong Provinces and its cultivation techniques. Chinese Wild Plant Resources 25, 26-28.

Zhang, W.M, Xiao, Z.C., Gu, G.P., Zhang, G.L., Qian, X.S., 2006a: Study on morphology and anatomy of Apocynum – and discuss the classification of *Apocynum pictum*. Chinese Wild Plant Resources 26, 11-15.

Zhang, W.M., Xiao, Z.C., Zhang, G.L., Gu, G.P., 2006b: Study on ecotype of Apocynum in Xinjiang and its fibre quality. Chinese Wild Plant Resources 25, 33-37.

Zhang, X., Li, R., Shi, F., 2007: Effects of salt stress on the seed germination of *Apocynum venetum.* Acta Scientiarum Naturalium Universitatis Nankaiensis 40, 13-18.

Zhou, B., Feng, Q., Li, X., Wang, H., Liu, M., Huang, G., Hu, X., 2007: Screening of antidepresent fractions of the leaves of *Apocynum venetum* L.. China Pharmacist 10, 1173-1175.

Zhu, X., Wu, L., Obul, O., Habibulla, Ä., 2006: The regulation of the Tarim River system. In: Hoppe, T., Kleinschmit, B., Roberts, B., Thevs, N., Halik, Ü. (eds.), Watershed and floodplain management along the Tarim River in China's Arid Northwest, 77-90. Shaker, Aachen.

Address of the authors:

Dr. Niels Thevs (corresponding author), Ahmedjan Rozi and B. Tang, Institute of Botany and Landscape Ecology, University of Greifswald, Grimmer Strasse 88, 17487 Greifswald, Germany.

Prof. Dr. S. Zerbe, Faculty of Science and Technology, Free University of Bozen-Bolzano, Universitätsplatz 5, 39100 Bozen, Italy.

Prof. Dr. Yordan Kyosev, Faculty of Textile and Clothing Technology, Niederrhein University of Applied Sciences, Webschulstrasse 31, 41065 Mönchengladbach, Germany.

Nurbay Abdusalih, Institute of Resource and Environmental Sciences, Xinjiang University, 14, Sheng Li Road, Urumqi, Xinjiang, China.

Zinovy Novitskiy, Republican Research Center of Forestry and Ornamental Gardening, Kartatal Street 21, Tashkent, Uzbekistan.