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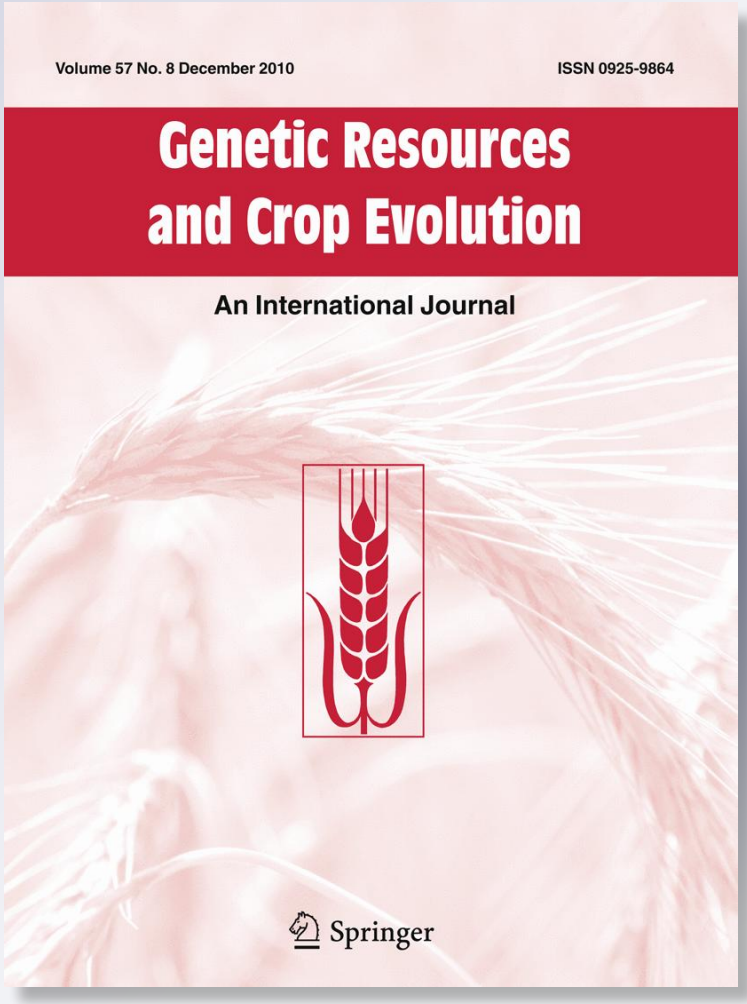

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SHORT COMMUNICATION

Reports on establishing an *ex situ* site for 'beautiful' vavilovia (*Vavilovia formosa*) in Armenia

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Abstract Vavilovia (*Vavilovia* Fed.) is one of the five genera in tribe Fabeae and consists of only one species, 'beautiful' vavilovia (*Vavilovia formosa* (Stev.) Fed.). The main centre of distribution is the Central and Eastern Caucasus, with a disjunct distribution among high alpine areas in the region, extending as far as West Turkey, Lebanon and Iran. In Armenia, *in situ* studies on *Vavilovia* started in the late 1930s. In July and August 2009, three expeditions were conducted to two locations: two to the Ughtasar Mountain and one to the Geghama Mountains. The first expedition to Ughtasar resulted in fresh plant collections and soil analysis for one of the sites. The expedition to Geghama established the existence of *Vavilovia* in the region of Lake Aknalitch. The second expedition to Ughtasar provided immature fruits and seeds. Collected plant material was transplanted into the *Flora and Vegetation of Armenia* plot of the Yerevan Botanic Garden established in 1940. Today, along with other plants the plot contains more than 200 species of wild relatives of cultural plants from 130 genera, including indiginous species of tribe *Fabeae* such as *Vavilovia.* The transplanted plants will continue to be monitored to see if the plants go on to successfully flower and set seed or whether further sites, possibly at higher altitudes might need to be tested to meet the long term conservation requirements of this iconic legume. These co-ordinated efforts provide a good example of an *ex situ* conservation strategy for *Vavilovia formosa*, which, if successful will improve access and utility for the whole legume research community.

Keywords Armenia · 'Beautiful' vavilovia · *Ex situ* conservation · Genetic resources · *In situ* conservation · *Vavilovia formosa*

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Taxonomy, morphology and distribution

The legume tribe *Fabeae* (syn. Vicieae) contains five genera. Two of them, vetchlings (*Lathyrus* L.) and vetches (*Vicia* L.) contain more than 100 species each, while two, lentil (*Lens* Mill.) and pea (*Pisum* L.), are much less speciose, with four and two species respectively. The fifth genus in tribe Fabeae, vavilovia (*Vavilovia* Fed.), consists of only one species, 'beautiful' vavilovia (*Vavilovia formosa* (Stev.) Fed.). It was reported for the first time by Steven in 1812 under the name of *Orobus formosus* Stev. The taxonomy of this species was critically revised by Andrey Fedorov (1939, 1952), who separated it into an independent genus *Vavilovia* Fed. naming it to honor N. I. Vavilov, the prominent Russian scientist who was the first to recognize the importance of crop wild relatives. More contemporary research approaches such as molecular markers define the status of *Vavilovia* as a separate genus (Kenicer et al. 2008; 2009; Mikić et al. 2009; Sinjushin and Demidenko 2009; Sinjushin et al. 2009; Smýkal et al. 2009), a close relative to pea.

Vavilovia is a perennial herbaceous species. It has long roots and underground rhizomes that form an important part of the plants biology and are possibly crucial to its conservation strategy as they may enable established plants to survive grazing and stone deposition on movable screes. Stems project between 5–15 cm above ground and are slender, sprawling or creeping, not winged and glabrous throughout. The leaf of *Vavilovia* is compound, with small, semi-sagittate, foliaceous stipules, one pair of broadly, cuneate-obovate to suborbicular, thick and glabrous leaflets with entire margins and a mucronate rachis tip. Flowers of *Vavilovia* are large and attractive, pink or purple in colour and are almost certainly insect-pollinated, albeit with no detailed data available. Pods are linear-oblong and dehiscent, 20–35 mm long and bearing from 3 to 5 seeds (Davies 1970). Seeds are globose or oval and smooth, usually with dark blotches on the surface.

The geographical distribution of *Vavilovia* is widespread, but rather limited by the species' ecology. The centre of its range is the Central and Eastern Caucasus, with a disjunct distribution across neighbouring montane areas (Grossheim 1952; Galushko 1980). In the Russian Federation, *Vavilovia* may be found in isolated habitats in Kabardino-Balkaria, Karachevo-Cherkessia, Dagestan and Northern Ossetia (Dzyubenko and Dzyubenko 2009). It is also found in Armenia (Gabrielyan ETs 1962) Azerbaijan (Carjagin 1954); (Kolakovskiy 1958; Arabuli 1981), Iran, Iraq, Lebanon, Syria and Turkey (Maxted and Ambrose 2001). *Vavilovia* is typically found in high-mountaineous areas, at altitudes of 1,500–3,500 m, and prefers shale or rocky substrates, such as loose limestone scree.

History of research in Armenia

In Armenia, the *in situ* studies on *Vavilovia* commenced in the late 1930s. It was collected in southern Armenia on the slopes of Kaputjukh Mountain in the alpine zone of the Zangezur Mountain Range, at altitudes of 3,200 m up to 3,500 m, during an expedition launched by the Nature and History Museum of Armenia led by A. Shelkovnikov in 1929 (Fig. 1) and subsequently in the same area in 1937 by Fedorov, who gave a detailed description of its natural habitats in Armenia and revealed the narrow specialization to the areas of moving screes (1939).

The second Armenian site for *Vavilovia* is in the centre of the country, in the Geghama Mountains. The species was found at the top of the volcanic mountain of Sevsar and in the region of Lake Aknalitch in 1929 by E. Kazaryan, D. Sosnovskyi and A. Maghakyan and subsequently by Fedorov and A. Takhtadjan. Since 1940s, *Vavilovia* has been repeatedly collected at both sites in southern and central Armenia by researches of the Institute of Botany of Armenian Academy of Sciences—A. Akhverdov and N. Mirzoeva, Ya. Mulkijanyan, V. Avetisyan, E. Gabrielyan, V. Manakyan, I. Arevshatyan and others.

Relatively recently, a third habitat located in the Syunik upland region (south-eastern Armenia) was identified at an altitude of 3,300–3,400 m: *Vavilovia* was found on the eastern slope of the mountain Mets-Ishkhanasar in 2003 by Heinz Parker and in the neighborhood of Mount Ughtasar in 2006 by H. Kazaryan, where the species was collected again in 2007 and 2009 by the teams led by J. Akopian, I. Gabrielyan, N. Sarukhanyan, A. Vanyan and N. Alexanyan (Sarukhanyan et al. 2009).

The Geghama and Syunik upland populations of *Vavilovia* were studied in 2006–2007 within the framework of the UNEP/GEF funded Crop Wild Relatives projects and some data on the species

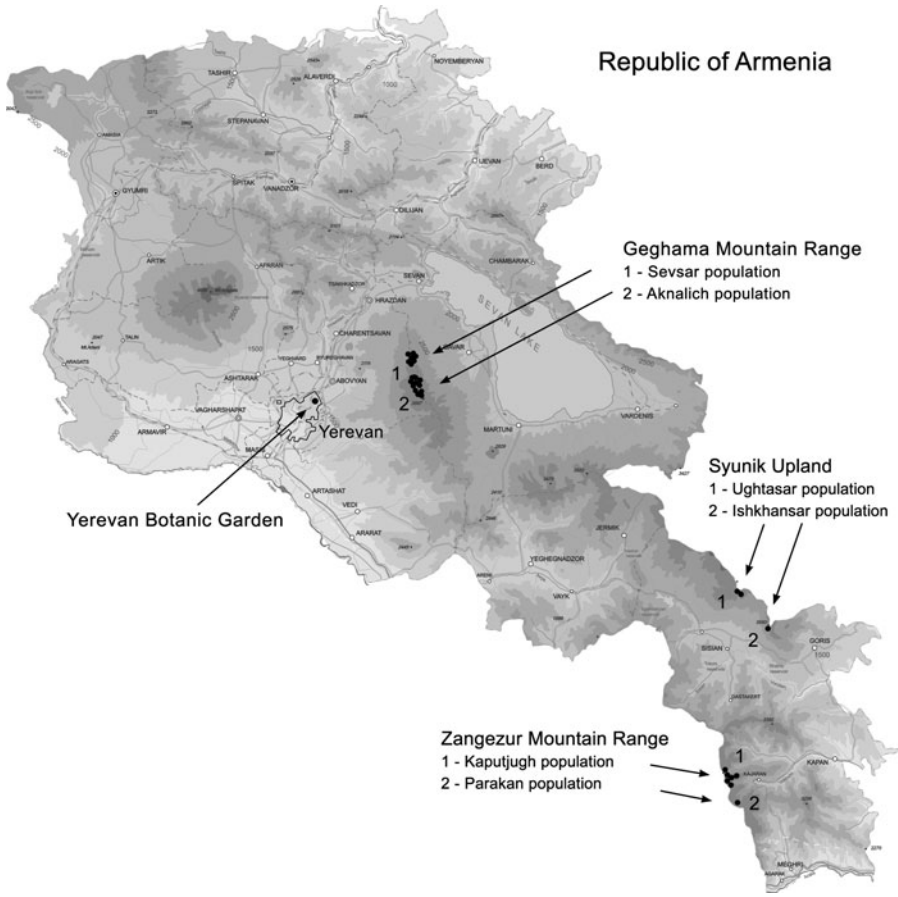

Fig. 1 Map of Armenia with the localities of *Vavilovia formosa* marked with black spots

distribution in Armenia, populations' size and to explore the possibilities of *ex situ* conservation (Akopian and Gabrielyan 2008).

Recent *in situ* research expeditions

Vavilovia is a close relative of a number of important domesticated legumes with a high research value especially for taxonomical and breeding purposes and has been the focus of scientific and practical interest by a number of Armenian institutions, emphasizing the importance and necessity for more detailed observation and study on this plant. To this ends, further *in situ* observations were carried out in July and August 2009. Three expeditions were organized: two to the Syunik upland region of the Mount of Ughtasar and one to the Geghama Mountains in the area of Lake Aknalitch. In both areas *Vavilovia* occurs on the slopes of the Upper Quaternary volcanic gravel cones with volcanic gravel particle size varying from several millimeters to 10 cm. The expeditions were undertaken by scientists and researchers from the Agricultural Reform Support Project Implementation Unit (ARSPIU) of the Ministry of Agriculture of Armenia, Syunik Agricultural Support Regional Center, Institute of Botany of the Armenian National Academy of Sciences and Green Lane NGO.

The first expedition was conducted on 17 July 2009 in the Syunik upland region at altitudes of 3,305–3,453 m. The team located plants over an area of about 75,000 m^2 including a population in good condition, covering about 800 m^2 on western, southern to eastern slopes with some individual plants in flower (Fig. 2).

The first plants were found at altitudes of 3,305–3,315 m on the south-east aspect slope. The developmental stage of this *Vavilovia* population was at the onset of flowering (Fig. 3), with some plants found with open flowers.

The slopes with *Vavilovia* populations were sunlit and sun-warmed. The population is narrowly adapted

Fig. 2 Populations of *Vavilovia formosa* (Mount Ughtasar, 17 July 2009)

Fig. 3 Flowers of the *Vavilovia formosa* population (Mount Ughtasar, 17 July 2009)

to the conditions of the high alpine and subnival zones and is part of the rubble moving mound vegetation. At altitudes of about 3,350–3,400 m the density of plants in the population was higher than the one identified at the foot of the slope. The plants reproduce mainly clonally, probably as a result of being permanently covered by detritus, the over-ground offshoots develop roots by means of numerous extremely thin secondary roots that not only spread in topsoil (20–30 cm) but also go down to the soil layer underlying the detritus. It was noted that first year seedlings with 5–7 leaves occurred sporadically, as evidenced by the presence of retained seed coats.

In the Ughtasar population, the *Vavilovia* plants found were 2–6 cm tall, with 4–8 off-shoots, leaves and flower-bearing stems being vivid green with violet spots. Both the vegetative organs of *Vavilovia* plants and their flowers were very low growing and remained in close contact with substratum. The air temperature on the slope, and in particular, at the surface of sun-warmed scree near the plants, was 30–32°C, while, on the same slope fragment, the air temperature in the shade was about 16°C. After 19:00 the air temperature dropped to 10–12°C while the surface temperature of the sun-warmed stones was 15–16°C. Winds with speed of 15–20 m per second and more are frequent in this region (over 85 days a year).

Samples of plants were removed for transplanting into the nursery of the Yerevan Botanic Garden. Additionally, soil samples were taken following standard practice. The samples were analyzed at the Scientific Center for Soil, Agro-Chemistry and Melioration. The results of the analysis presented below (Table 1) are of fundamental importance to any future *ex situ* cultivation of *Vavilovia*.

The second expedition to the Geghama Mountains was conducted on 20 August 2009. The cones with Upper Quaternary volcanic gravel deposits are most clearly visible in the Geghama highland, where the second observed site is located. The watershed of the Hrazdan River and Sevan Basin is dominated by about 30 large cones. Mount Sevsar (3258.5 m) is situated 1 km north of Lake Aknalitch. In the Sevsar area, *Vavilovia* populations cover an area of around 700 m in length and 100 m altitudinal range, that is, about 70,000 m^2. On the western, south-western and southern slopes starting at an altitude of 3,111 m and continues up to 3,203 m. The slopes of Sevsar are covered with an incoherent volcanic gravel blanket in two colors: the western part is red and the eastern part is black. *Vavilovia* occurs in both areas, though on the slopes coated with reddish volcanic gravel the number of plants is much larger.

Results obtained by the expeditions organized within the framework of the UNEP/GEF funded Crop Wild Relatives Project in 2007, in the vicinity of Aknalitch, on the slopes on the southern bank of the lake, report several hundred *Vavilovia* plants in an area of 5,000 m^2. During our follow-up expedition to the same location in August 2009, no *Vavilovia* plants were found in the area, which had become

Table 1 Physical and chemical composition of aqueous extract of the soil under a population of *Vavilovia formosa* on the Ughtasar Mountain

pH	Saline (%)	(%/mg-eq, in 100 g of soil)						
		CO_3	Total NCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	$Na^+ + K^+$
7.7	0.118	–	0.039–0.64	0.0034–0.96	0.008–0.17	0.010–0.24	0.003–0.24	0.024–1.03
Carbonate content				$CaCO_3$—1.3%; $MgCO_3$—1.3 %				
Exchange of ions in the clay-humus complex (mg-eq/100 g)				Ca—16.5; Mg—4.5 l; Na—0.4; K—0.4				
Absorption capacity				21.8 mg-eq/100 g				
Mechanical composition				Light loamy soil				
Nutrient supply (mg/100 g)				N—2.7 (poor); P_2O_5—3.8 (average); K_2O—35.3 (high); humus (%)—4.4				
Heavy metal mobile forms (mg/kg of humus)				Cu—5 mg/kg; Ni—15 mg/kg; Cr—7 mg/kg; Pb—6.1 mg/kg; Co—4.1 mg/kg				

temporarily converted into high altitude grazing for hundreds of cattle and sheep.

The second population of *Vavilovia* in the Aknalitch area was discovered over an area of about 4–4.5 ha and at altitudes of 3,045–3,170 m, to the north-east of the lake, on the northern slopes of a hill, facing a small waterlogged hollow. The angle of the slope was 45–55°. The plants and flowers found in this area were already touched by frost (night air temperature of −3 to −2°C) and the expedition found few flowers and dry pods. In contrast to the Ughtasar population, plants found in the region of Aknalitch were less conspicuous and mostly deep green, without purple spotting. The number of mature leaves on each plant varied from 3 to 11. The exact sizes of the stem as well as those of the main and lateral roots were not measured, but the total length of plants was about 90–115 cm from flower to root tip. Nodules (presumably with nitrogen fixing *Rhizobium* bacteria inside) were found on all roots. On 27 August 2009, a third expedition was conducted in the Ughtasar mountain area. These were expected to be at a later developmental stage, with the aim to collect seeds. A high frequency of frost-killed flowers and flower buds were observed with very few pods mostly bearing only immature seeds. Empty, dehisced pods with seeds already fallen from the pods were found, as well as some pods evidently gnawed by animals. The number of frost-killed flowers was also quite large. The area was overrun with mice, with about ten mouse holes per m^2, suggesting in all probability that *Vavilovia* and other legume seeds form part of their diet.

Ex situ conservation and applied research

Many attempts have been made at *ex situ* conservation of *Vavilovia*, especially in the USSR with the majority of them being unsuccessful due to inadequate management of soil aeration and water flow (Zhukovskyi 1971; Makasheva et al. 1973). Some success was achieved in the UK, namely in the Official Seed Testing Station in Edinburgh and at Southampton University (Cooper and Cadger 1990) but these were relatively short lived and did not result in the production of new seeds or in multiplication of the plants. More promising results were produced in the N. I. Vavilov Institute of Plant Industry during 1974–1981 combining growing the plants in the field and in climatic chambers. Some plants survived for some years, bloomed and even formed fruits with seeds (Golubev 1990).

According to earlier records, *Vavilovia* has periodically been grown in the research and display plot *Flora and Vegetation of Armenia* in the Yerevan Botanic Garden since 1940 (Akhverdov and Mirzoeva 1949). This living exhibition reflects the botanical diversity of the country (Akopian 2009). The creation of the alpine rock habitat was preceded by a period of long-term research into the biology and ecology of the alpine plants, which facilitated their introduction into relatively low-altitude cultivation from their native 2,800–3,500 m.

The data obtained by Akhverdov and Mirzoeva (1964) after the autumn sowing suggests that seeds of *Vavilovia* germinate in the following spring, under the influence of winter cold stratification. The seeds germinate underground and the plants remain vegetative into

their second year. The first leaves of plants appear at the beginning of April and by the end of May, all alpine plants have finish flowering. According to the unpublished data from the plot archives, *Vavilovia* bore mature fruits and seeds in June 1942 and in June 1962.

In July and August of 2009 an attempt was made at introducing *Vavilovia* specimens into the plot. Plant specimens were collected from *Vavilovia* populations from two natural populations in the Geghama Mountains and Tskhuk Mountain Range, Ughtasar, for planting in the alpine hill with artificial scree. The plants were planted at a depth of 15–17 cm on the sloping surface, with sand and a small amount of detritus added to provide good soil drainage and areation. The planting was done to mimic how the plants were observed to grow *in situ,* namely with the rhizomes oriented almost horizontal to the ground or at a small decline but never directed vertically downwards. Roots and the rooting underground shoots were spread out in all directions. Initially, the planted specimens were surrounded by the detritus brought from their original habitat. It was then noticed that the plants were developing better in the vicinity of large stones, hence a quantity of big stones was added. Plants were observed not to tolerate high moisture level in *ex situ* conditions and required only moderate watering. It became necessary to create artificial shading to protect against direct sunlight, especially during July and August. Summer-time replanting from altitudes of 3,100–3,400 m into the dry continental zone of wormwood semi-desert at altitude of 1,200 m is a severe stress for alpine plants. Thus, some transplanted *Vavilovia* plants had dried out completely by the second or third day, while about 12 plants successfully established. 10 days after replanting, the plants showed the first signs of rooting and the first new leaves appeared (Fig. 4).

As plants became established, their original anthocyanin hue (the result of low night temperatures) vanished and the leaves became light green in colour while the internodes on the shoots began to elongate (Fig. 5). Although the plants were introduced to the plot bearing flower buds, these flower buds dried within a few days of the plants establishing and new ones failed to develop, with plants passing into a vegetative state.

In the Yerevan Botanical Garden high summer temperatures of 25–30°C and the dryness of the air affect the growth and development of alpine plants deleteriously. During this period the growth of

Fig. 4 Details of the leaves of replanted plants of *Vavilovia formosa* (the plot *Flora and Vegetation of Armenia*, Yerevan)

Fig. 5 Replanted plants of *Vavilovia formosa* (the plot *Flora and Vegetation of Armenia*, Yerevan)

Vavilovia specimens slowed down and some foliage became dry. It was difficult to assess whether above ground plant parts seemingly dried had lost the ability of full renewal. After the rainy period during September through to the beginning of October, autumn renewal of some specimens *Vavilovia* was observed, and these plants remained green until the end of November. The success of these *Vavilovia ex situ*

introductions will be carefully monitored and evaluated in the spring following overwintering.

Further progress has recently been reported in the area of in vitro propagation on successfully recovering small plantlets based on seed material from Mount Ughtasar (pers. comm. Petr Smýkal).

Conclusions

Despite its narrow distributional range and restricted habitats, *Vavilovia formosa* has consistently raised interest in the wider legume community as characteristics such as frost tolerance and perenniality are of great practical interest to breeders and geneticists. The lack of availability of fresh seed and plant material for study has been and continues to be a severe limitation to these aims.

The establishment of an *in situ* genetic reserve for Vavilovia at Akna Lich (Geghama mountain ridge), Yerevan province in Armenia was suggested by Akopian and Gabrielyan (2008). The site being identified during the recent UNEP/GEF project, '*In situ* conservation of crop wild relatives through enhanced information management and field application', and thus already has a level of protection (Maxted and Kell 2009). While the establishment of such reserves is important, it is not sufficient in itself to secure long term conservation as the accounts of animal grazing and predation by high populations of mice reported here testify. These points only increase the need for a viable complementary *ex situ* conservation strategy sampling from different natural populations across the distributional range. These trials will continue to be monitored to see if transplanted plants go on to successfully flower and set seed or whether further sites, possibly at higher altitudes might need to be tested that better match the long term conservation requirements of this iconic legume.

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