Diversity of wild and cultivated tomatoes: perspectives for conservation and sustainable use

Iris Edith Peralta

Chacras de Coria Botanical Garden, National University of Cuyo. Mendoza and Instituto Argentino de Investigaciones de las Zonas Áridas - Consejo Nacional de Investigaciones Científicas y Técnicas (IADIZA-CONICET), Mendoza, Argentina

Wild tomatoes are native of western South America, distributed from Ecuador to northern Chile, and with two endemic species in the Galápagos Islands (Darwin et al. 2003; Peralta & Spooner 2005; Peralta et al. 2005). They grow in a variety of habitats, from near sea level to over 3,300 m in elevation, in arid coastal lowlands and adjacent hills or "lomas" where the Pacific winds drop scarce rainfall and humidity; in isolated valleys in the high Andes, and in arid regions like the severe Atacama Desert in northern Chile. Andean geography, diverse ecological habitats, and different climates have all contributed to wild tomato diversity (Figure 1). A recent taxonomic revision of the tomatoes and their relatives (Peralta et al. 2007) provides new species definitions, illustrations, descriptions and distributions, revises and updates the nomenclature, summarizes several morphological and molecular studies and discusses phylogenetic relationships.

Figure 1. Distribution of wild tomato species in western South America, different habitats in isolated Andean valleys, coastal lowlands and adjacent hills or "lomas", and in arid regions like the severe Atacama Desert.

This treatment, that is part of the genus *Solanum* Planetary Biodiversity Inventory project, uses data from approximately 5000 specimens from 49 herbaria and observations of 900 germplasm accessions of all species grown in common gardens. These evidences confirm the earlier (Spooner et al. 1993) inclusion of tomatoes in the genus *Solanum*. Based on morphological characters, phylogenetic relationships, and geographic distribution, 13 species of wild tomatoes (*Solanum* section *Lycopersicon*) have been recognized, including *S. galapagense* and *S. cheesmaniae* endemics to the Galápagos Islands (Darwin et al. 2003) and the cultivated tomato (*Solanum lycopersicum*) and its weedy escaped forms that are distributed worldwide. Closely related to wild tomatoes are two species in *Solanum* section *Juglandifolia*, *S. juglandifolium* and *S. ochranthum*, distributed in Colombia, Ecuador, and Peru, and two species of *Solanum* section *Lycopersicoides*, *S. lycopersicoides* and *S. sitiens*, distributed in southern Peru and northern Chile (Table 1, Figure 2).

Name	Fruit colour	Distribution and habitats
Solanum lycopersicoides Dunal	Green-yellow when maturing, black when ripe	Southern Peru to northern Chile on the western slopes of the Andes on dry rocky hillsides, 2800-3700 m.
Solanum sitiens I.M. Johnst.	Green-yellow when maturing, brown when ripe	Northern Chile, western Andean slopes on rocky hillsides and dry quebradas, 2350-3500 m.
Solanum juglandifolium Dunal	Green to yellow-green	Northeastern Colombia to southern Ecuador, on the edges of forest clearings, open areas and roadsides, 1200-3100m.
Solanum ochranthum Dunal	Green to yellow-green	Central Colombia to southern Peru, in montane forests and riparian sites, 1400-3660 m.
Solanum pennellii Correll	Green	Northern Peru to northern Chile, in dry rocky hillsides and sandy areas, from sea level to 2850 m.
Solanum habrochaites S. Knapp and D.M Spooner	Green with darker green stripes	Central Ecuador to Central Peru. In premontane forests to dry forests on the western slopes of the Andes, occasionally in lomas formations in northern Peru, 400-3600 m.
Solanum chilense (Dunal) Reiche	Green to whitish green with purple stripes	Southern Peru to northern Chile. On western slopes of the Andes, hyper-arid rocky plains, dry river beds, and coastal deserts, from sea level to 3000 m.
Solanum huaylasense Peralta	Typically green with dark green stripes	Northern Peru (Department of Ancash). On the rocky slopes along rivers, 1700-3000.
Solanum peruvianum L.	Typically green to greenish-white, sometimes flushed with purple	Central Peru to northern Chile. In lomas formations and occasionally in coastal deserts from sea level to 600 m, sometimes growing as a weed at field edges in coastal river valleys.

Solanum corneliomuelleri J.F. Macbr. (1 geographic race: Misti, Arequipa)	Typically green with dark green or purple stripes, sometimes flushed with purple	Central to southern Peru. On western slopes of the Andes, (400) 1000-3000 m, and on lower slopes on the edges of landslides towards the southern range of the species distribution.
Solanum arcanum Peralta (four geographic races: 'humifusum', lomas, Marañon, Chotano-Yamaluc)	Typically green with dark green stripes	Northern Peru. Coastal and inland Andean valleys, on dry rocky slopes, 100 to 2500 m.
Solanum chmielewskii (C.M. Rick, Kesicki, Fobes and M. Holle) D.M. Spooner, G.J. Anderson and R.K. Jansen	Typically green with dark green stripes	Southern Peru to northern Bolivia (Sorata). In high dry Andean valleys, 2300-3000m.
Solanum neorickii D.M. Spooner, G.J. Anderson and R.K. Jansen	Typically green with dark green stripes	Southern Ecuador to southern Peru. In dry Andean valleys, 1950-3000 m, often growing over rocky banks and roadsides. Sometimes found in sympatry with *S. chmielewskii*
Solanum pimpinellifolium L.	Red	Apparently native to coastal areas from central Ecuador to southern Peru, although populations are found in Vallenar, Chile, 0-500 m. Grows in humid places and on the edges of cultivated fields throughout its native range and has apparently escaped from cultivation in the Galápagos.
Solanum lycopersicum L.	Red	Apparently native to Peru; the domesticated form of *S. lycopersicum* now occurs worldwide. The cherry tomato, *S. lycopersicum* var. *cerasiforme,* is the possible ancestor of cultivated tomato and can often be found growing as a weed in temperate habitats and the edges of cultivated fields, where it is not necessarily native.
Solanum cheesmaniae (L. Riley) Fosberg	Yellow, orange	Endemic to the Galápagos Islands (Ecuador) from sea level to 1350 m.
Solanum galapagense S.C. Darwin and Peralta	Yellow, orange	Endemic to the Galápagos Islands, particularly the western and southern islands, mostly occurring on coastal lava and on volcanic slopes, sea level to 650m, exceptionally up to 1,500m in Fernandina and Santiago Islands

Table 1. Species list for tomatoes along with characteristic fruit colour, distribution and habitats.

Figure 2. Diversity of wild tomatoes; upper left: inflorescence of Solanum arcanum*, upper right: fruits of* Solanum chilense*, middle left: bilocular and multilocular fruits of* Solanum lycopersicum*; middle right leaves of* Solanum habrochaites*, and* Solanum chilense *(grey); lower left: inflorencences and leaves of* Solanum peruvianum*; lower right: pubescent fruits of* Solanum corneliomulleri

Tomatoes were introduced into Europe from America about the middle of the sixteenth century, and latter distributed worldwide. Breeding have produced a great diversity of cultivated tomatoes, but the traditional selection for pure lines has narrowed its genetic base (Stevens and Rick 1986). Fortunately, genetic resources from the primary center of diversity provide a wealth of useful genetic traits to improve the crop (Rick 1982, 1995). All wild tomato species are diploid (2n = 2x = 24) and can be crossed to the cultivated tomato (Rick 1979). They are of great use in breeding programs as sources of disease resistances and agronomic traits (Esquinas Alcazar 1981, Stevens et Rick 1986). The International Board for Genetic Resources (IBPGR) recognized the need for maintaining valuable vegetable genetic resources, and nominated tomatoes for priority conservation status. Ross (1998) considered that the diversity of tomato is likely to be well conserved "*ex situ*", and cited 62,832 accessions maintained in gene banks around the world, although most of these accessions are from the cultivated species *Solanum lycopersicum*.

It is important to protect wild species in their natural habitat, especially the endemic species *S. galapagense* and *S. cheesmaniae* that are threatened by environmental changes and the introduction of invasive plants in the Galápagos Islands (Darwin et al. 2003). Other species are also threatened in the continent, by habitat modification, urban and agricultural expansion. It is a conservation priority to study natural populations of species with narrow distributions, adapted to extreme arid conditions or high altitudes in the Andes (Table 1). I consider also a priority to collect new wild species samples, especially from endangered populations, and maintain them in germplasm bank and botanical gardens. Recently, two herbarium specimens of *S. chmielewskii* documented the presence of this species in Bolivia, and draw attention to explore the area of Sorata and San Pedro to find more populations in the Eastern range of distribution of *S. chmielewskii*. Similarly, three herbarium specimens of *S. pimpinellifolium* found in Vallenar, Chile, documented the most Southern populations of this species. It will be important to study and characterize them for their value as genetic resources related to the crop, for example evaluate the drought resistance properties.

I would also like to point out my concern about the conservation of traditional local varieties that people cultivate and maintain in different regions of the world. Social, economic and ecological factors are affecting the conservation "in situ" of these genetic resources. A current project in Argentina (Peralta 2007) is focused in the recover and evaluation of tomato landraces traditionally maintained by local communities in Andean valleys. These landraces (Figure 3) were incorporated in the Argentinean Vegetable Crop Germplasm Bank for their conservation and potential use in breeding programs. Our aim is to preserve, reproduce and return these locally adapted varieties to their communities for a sustainable maintenance.

Figure 3. Argentinean landraces of cultivated tomatoes: platense and corazón de buey

Botanical Gardens in association with Germplasm Banks could assure the "ex situ" conservation of wild tomatoes, maintaining and reproducing living collections. Botanical Gardens could also play an important role supporting research and "in situ" conservation of these valuable genetic resources.

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