The Extreme Search for Tomato Genetics

BY CARL M. JONES

Arica, Chile. We are bouncing along a sandy track and squinting into the midday sun when Roger stops and shouts, spotting the yellow flowers. When I first see them it takes my breath away.

I've been working with their cousins for more than 10 years but this is the first time I have seen these tomatoes growing in the wild. They seem strangely out of place. They should be growing in pots in a greenhouse, not as volunteers in a long since harvested onion field high up in remote Chile. Yet here they are scattered around the field within earshot of the Pacific Ocean and the Humboldt Current.

The C.M. Rick Tomato Genetics Resource Center (TGRC) is a genebank of wild relatives, monogenic mutants and miscellaneous genetic stocks of tomato. The TGRC collection is a vital resource for tomato breeders around the world and provides critical *ex situ* conservation of wild tomato populations.

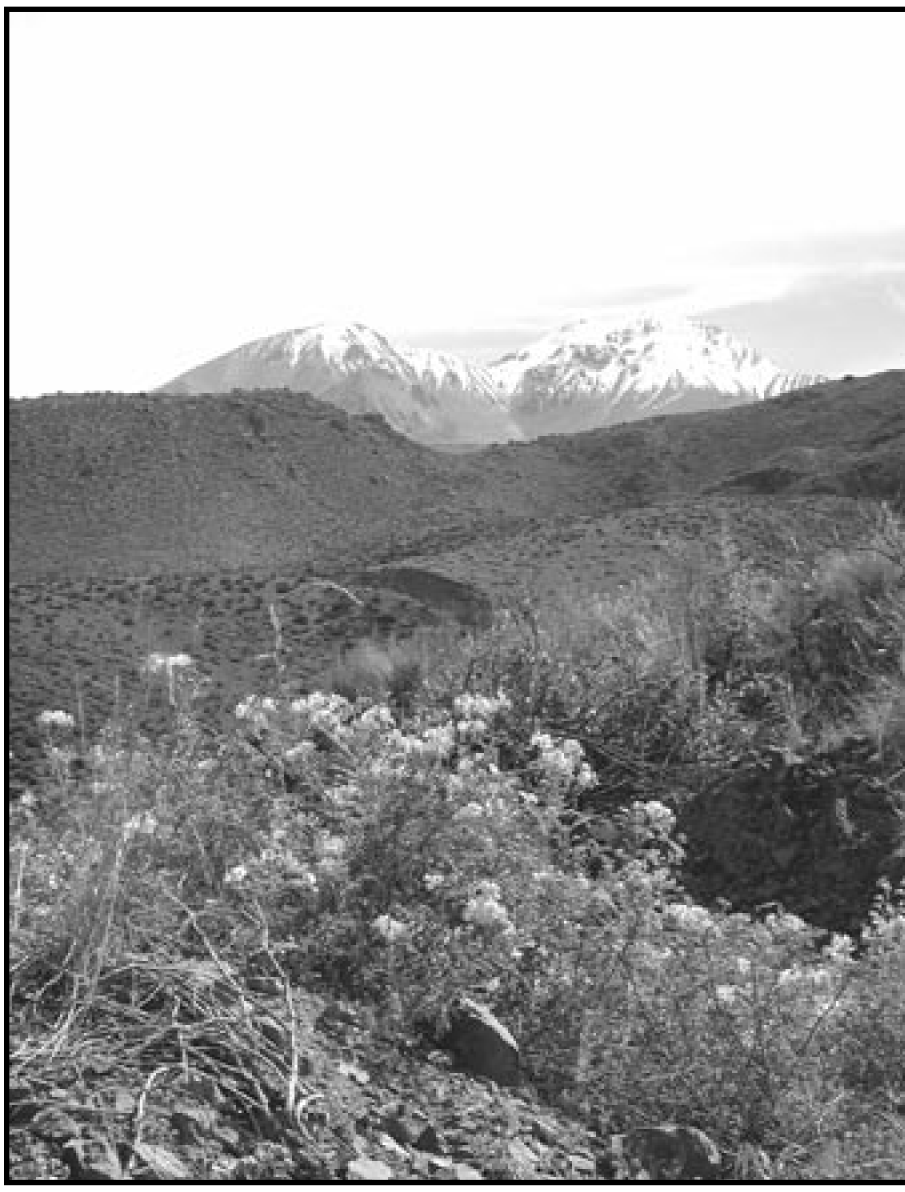

Photo by Carl Jones

S. lycopersicoides grows above 12,000 feet in the Andes, here with Los Nevados de Putre in the background.

We've come here to collect seeds as part of an ongoing effort to preserve and characterize the genetic diversity of one of our most important vegetable crops. A narrow strip along the western coast of South America provides the habitat that gave the world the tomato and provides us today with the genetic reserve upon which our agricultural systems (organic and conventional) rely.

Roger Chetelat is the Director of TGRC at UC Davis. This collecting trip is a collaboration between the TGRC and researchers Ricardo Pertuzé and Luis "Chino" Faudez at the Universidad de Chile in Santiago, Chile.

Wild tomatoes grow primarily in Chile, Peru, Ecuador and the Galapagos Islands. The Chilean collections on this trip are made in close agreement and collaboration with the Chilean government and funded by the USDA. The collecting team is composed of Chilean and U.S. researchers and a portion of all seed remains in Chile for researchers there.

The TGRC performs the long, difficult and expensive task of regenerating the seed and then makes it freely available to researchers anywhere in the world. From collections at the TGRC, tomatoes have been bred for resistance to nearly every disease, or environmental stress. From drought tolerance in Africa to flooding tolerance in Asia many tomatoes of the world can trace their pedigree back to TGRC collections. In addition to disease resistance there are wild tomatoes with dramatically higher levels of sugars, beta carotene, lycopene, vitamin C and other important antioxidants. Tomatoes carrying the gene for high beta-carotene levels from wild tomatoes are distributed to areas suffering from a lack of Vitamin A.

Our goal is to expand the collections of four closely related wild tomatoes particularly *Lycopersicon chilense* and our trip will cover nearly 5000 km of difficult terrain in some of the remotest regions of northern Chile. To understand why we go to such effort for a small, essentially inedible green-fruited cousin of the tomato it is important to understand something about tomato domestication and their migratory history.

Tomatoes began their journey from South America by traveling north to Central America and Mexico where it is believed they were first domesticated by humans thousands of years ago. It was here that the first larger-fruited red tomatoes are found. Essentially all the wild species of South America have fruit no bigger than small cherry tomatoes. This leap to Mexico left behind a great deal of the genetic diversity present during tomato evolution, creating what geneticists call a bottleneck or founder effect. The tomato wasn't done traveling yet though, as it soon caught a ride to Europe with the Spanish explorers and a few centuries later returned to the Americas with the colonists; two more bottlenecks. By the beginning of the 20th century farmers and gardeners across the United States and Europe were growing an astounding array of tomato cultivars, many of which we preserve today as heirlooms. While these tomatoes provide us with an impression of great diversity, their varied types are based upon a precariously small genetic base, vulnerable to pathogen attack and environmental stress.

A lack of genetic diversity at this level is a feature all too common in many of our crop plants. Consequently in the United States there are germplasm collections for most crops operated by the USDA's National Plant Germplasm System. There are two centers for tomatoes: the USDA Plant Germplasm Unit in Geneva, New York and The TGRC that is run by the University of California and is integrated with the USDA system. The USDA collection is focused on the North American, Central American and European collections while the TGRC collection is focused on wild species from South America and genetic stocks of interest to plant biologists. The collection was founded by the late Dr. Charles M. Rick in the Dept. of Vegetable Crops, UC-Davis, who collected many of the wild species accessions and produced a large proportion of the marker and cytogenetic stocks. His pioneering work is maintained and continued by the center that bears his name. Over time, many other researchers contributed germplasm to the TGRC, resulting in one of the world's most comprehensive collections of genetic stocks and wild relatives of tomato.

Tomatoes evolved during a time when the climate in South America was different than it is today. The climatic evolution in South America has left us with tomato species which have adapted to inhabit some of the most diverse conditions imaginable. Tomatoes grow wild from the moist tropical regions of the upper Amazon basin to the driest places on earth in the deserts of Northern Chile. They sprout in the salt mist of the Pacific up to above 12,000 foot elevation in the forbidding Andes mountain range. This plethora of genetic diversity represents great opportunity for tomato breeders and for scientists seeking to understand important processes in plant evolution. To conserve the tomatoes genetic biodiversity, researchers began collecting seeds of these wild relatives in the first half of the 20th century.

Depending on the current taxonomic revision. Wild tomatoes are divided into nine *Lycopersicon* and four *Solanum* species. These are the relatives of tomatoes which with varying degree of difficulty, can be crossed to tomato, and represent the non-GMO gene pool available for tomato improvement.

In northern Chile we were hoping to find four of these, *L. peruvianum, L. chilense, Solanum sitiens* and *S. lycopersicoides*. These are species well adapted to the dry climates and rocky ground of this intense desert habitat. The Atacama Desert is dry. Some scientists suggest that within this desert one can find places "too dry for life." In places no rainfall has ever been recorded, and in other places the sporadic rain is measured in millimeters per year. NASA uses the Atacama as an analog to a waterless Mars.

Residents of the Pacific Northwest find it hard to imagine how a place along the coast on the west side of the mountains could be so dry. Along northern Chile and southern Peru the Humboldt Current forces up frigid cold water from the Antarctic ocean as the land rises. The resulting cold air contains skant moisture and so by the time it moves inland there is enough moisture for fog but little else.

The yellow flowers we stop for that first day in the onion field belong to *L. peruvianum* and like all four species we will find, it has very specific habitat preferences. *Lycopersicon peruvianum* is often found as a weed in fields or along irrigation ditches. Towering above the dry Atacama are the peaks of the Andes whose snowmelt snakes its way through deep canyons out to the Pacific. On these canyon floors the agriculture of northern Chile exists as small green strips separated by vast, barren mountains.

It is up and between these *quebradas* that we travel. We follow notes from previous herbarium collections, our knowledge of habitat preferences and by Chino whose knowledge of local flora is encyclopedic. As the *quebrada* narrows, the last remnants of agriculture give way to rocky washes where *L. peruvianum* is replaced by *L. chilense*. These are tough plants that don't seem to like the disturbances or soil of agricultural areas. We find populations of several to dozens of plants but rarely more.

When we see plants we stop and take exhaustive notes and photographs and collect fruit from as many plants as possible,

Continued page 11.

Hunting Wild Tomato in the Andes

Continued from page 10.

careful not to take too much from any one plant. Our goal is to preserve the best snapshot of the diversity present in the population at this time.

Several days later we are following an arrow on the GPS, headed towards the coast in search for some of the rarest *L. chilense* plants. There are very few of these "*loma" chilense* represented in any seed collections. The *lomas* are small areas of surprisingly rich plant life at the top of 3000 foot slopes overlooking the ocean. They form where steep slopes block the inward movement of thick banks of stratus clouds during the winter months.

Invaluable biologist Ricardo is also our white knuckled driver winding us over the vast slopes in the thickening fog. According to the GPS we have entered the ocean when we come to a stop at the edge of a cliff.

Here the lomas are nearly inaccessible from below, with a unique and rare community of plants completely dependent on the costal fog. We search in vain for *L. chilense*. Specimens have been collected here during an El Niño year when rains came to these hills. There are no tomato plants for us here this year.

We return to the Andes and spend the night at high elevation in the small town of Putre. In the morning we ascend the hills above town to be greeted by fields of yellow flowers, the *S. lycopersicoides*. In its many years of collecting the TGRC has found only 16 populations and this is their home. Most of the time the numbers of plants we see are so small one feels almost desperate, here with the Andes as a backdrop, these plants thrive and it is a joy to see. In these high elevations of the Andes they flower profusely and this is a meta-population, where truly significant numbers of plants survive.

Later that day we drive over the shoulder of the 16,000 foot. Los Nevados de Putre Peak. We've received location information on an herbarium specimen of *L chilense* near the border of Peru. This would represent the northernmost collection and would be a very isolated population. Pockets of plants found in the quebradas are like islands separated by expanses of hyper-arid mountainous terrain. This location would surely be unique, but it is a long journey. The plants were last collected there in the 1940's and our odds of finding plants in the same place seem remote. We manage to follow a gas pipeline over much of the terrain and get within about 8 km. when the pipeline road separates from the train track where the collection was made. We walk the final 5 km. It is late and we have been traveling hard all day to reach the location km. 21 on the tracks from Arica to La Paz. We are disappointed to have seen no plants. The sun is setting and we are a long hike and many hours drive from where we will spend the night. Then finally, twinkling in the light as if they have been waiting 60 years for us, are the *L. chilense* plants strung along the track.

Photos by Carl Jones

Roger Chetelat collects L. Chilense *fruit near the Salar de Atacama.*
Above: *Mature fruit of* L. Chilense.

Desert ecosystems are fragile. Wild tomato plants are a frequent snack of vicuna, a llama relative. In *quebradas* there is grazing of domesticated llamas, sheep and goats; wild tomatoes have been devastated. Some other populations held by the TGRC have vanished from the wild under intense grazing or urbanization pressures.

We scour *Quebrada* Camarones, an exquisitely beautiful and mammoth canyon but find only herds of llama.

Northern Chile is mining territory and home to the world's largest copper mines with areas of devastation nearly unfathomable in size. Near one mine we seek the rare *S. sitiens* for which we only have seeds from six populations available for distribution in our collection. It is a true *xerophyte* and seems to exist entirely without moisture; in the driest and rockiest of places, when the *Atriplex* and *Opuntia* have given up, when you really begin to think you are on Mars, that is where you find *sitiens* growing. To our dismay a pipeline from the copper mine has obliterated the prior population and we only see one remaining plant.

Luckily Ricardo and Roger know more about *sitiens* than anyone else. The seeds from the earlier collection will be used to regenerate plants and hopefully restore this population in the future.

Continuing along the coast south from Taltal we find some *L. chilense* plants, oddly growing within 100 feet of one another on the walls of a small wash. These plants are amazing in their ability to grow on nearly solid rock, but this population seems to be just hanging on. These are the southernmost tomatoes we have found in our collection.

Within a few miles the geography changes, the ground becomes sandier, the moiture greater and we've reached the bottom of the wild tomato habitat.

As a result of this expedition we have 20-some new accessions to add to the 950 wild species populations in the TGRC collection.

Perhaps some summer day in your garden you will bite into a tomato and taste a bit of its wild ancestors in the deserts of Atacama Desert.

Carl Jones is a former Tilth Certified Organic Farmer and is currently a PhD candidate in Genetics working with the C.M. Rick Tomato Genetics Resource Center at the University of California Davis. His research focuses on utilization of wild tomatoes for the improvement of nutritional content in tomatoes.