

Germplasm exploration for the genera *Capsicum* and *Phaseolus*
in south central Bolivia.

FINAL REPORT FOR USDA/ UC-DAVIS/ CIF-PAIRUMANI/ CIAT/ IPGRI
SUPPORTED MISSION
MAY 1994

REPORT PREPARED BY

D.G. DEBOUCK
CIAT-IPGRI

FOR

CENTRO DE INVESTIGACIONES FITOGENETICAS
PAIRUMANI, BOLIVIA

UNIVERSITY OF CALIFORNIA
DAVIS, USA

UNITED STATES DEPARTMENT OF AGRICULTURE
BELTSVILLE, USA

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL
CALI, COLOMBIA

INTERNATIONAL PLANT GENETIC RESOURCES INSTITUTE
ROME, ITALY

Germplasm exploration for the genera *Capsicum* and *Phaseolus* in south central Bolivia.

SUMMARY

A germplasm exploration has been carried out in the departments of Cochabamba, Chuquisaca and Tarija in southern Bolivia, for native species of the genera *Capsicum* and *Phaseolus*. Germplasm has been found for the following species: *C. annuum* (1), *C. baccatum* (6), *C. chacoense* (3), *C. eximium* (2), *P. augusti* (2), *P. lunatus* (2), *P. vulgaris* (27, cultivated forms; 7, wild populations). These findings are discussed in relation to the evolution of these crops and the possibilities of conservation in the area.

RESUMEN

Se realizo una exploración de germoplasma para especies nativas de los géneros *Capsicum* y *Phaseolus* en los departamentos de Cochabamba, Chuquisaca y Tarija, en el sur de Bolivia. Se encontro germoplasma para las siguientes especies: *C. annuum* (1), *C. baccatum* (6), *C. chacoense* (3), *C. eximium* (2), *P. augusti* (2), *P. lunatus* (2), *P. vulgaris* (27, cultivados; 7, silvestres). Se discuten los resultados en cuanto a la evolución de estos cultivos y la conservación de los mismos en la zona.

1. OBJECTIVES

This trip was undertaken in order to gain more information on diversity and evolutionary aspects for three crops native to South America and possibly Bolivia, *Capsicum* spp. and *Phaseolus* spp.. The background detailed hereafter provides elements about the questions that await answer from this field work.

2. BACKGROUND

For clarity, we shall provide elements of background organized per genus under study.

2.1. For *Capsicum* spp.:

When trying to understand crop evolution, one of the first points to clarify is the ancestry of the crop, and thus to identify which wild plant evolves into the cultivated form under domestication. The second question is related to the place(s) where domestication took place, being understood that plant domestication is a continuing process often difficult to limit to a single locality. Authors would agree on the existence of at least three domesticated species in the genus *Capsicum*: *C. annuum* L., *C. baccatum* L. (formerly *C. pendulum* Willd.), and *C. pubescens* Ruiz & Pavón (Eshbaugh, 1993; Heiser, 1985; Pickersgill, 1989). As far as *C. annuum* is concerned, given the fact that its wild form is

distributed from Texas, USA down to Colombia (Pickersgill, 1971), it seems possible that domestication took place somewhere in Central America (Conicella et al., 1990; Pickersgill, 1989).

As far as *C. baccatum* is concerned, a taxon recently confirmed as distinct from the *annuum* complex (Lefebvre et al., 1993), it seems plausible that this species was domesticated within the range of the wild ancestral form, in a range from central Peru to southern Brazil crossing the Bolivian Andes foothills (Eshbaugh, 1970; 1993). What is still unclear about *C. baccatum* is whether it arises from a single domestication event, or from multiple domestications, let us say in the range from Ayacucho, Peru down to Santa Catarina (namely through Cochabamba, Chuquisaca and Santa Cruz in Bolivia). The answer to this question will have some immediate bearing on the extension of the genetic basis for future breeding work in this crop.

The case of the third species, *C. pubescens*, is still unsolved. Which is its wild relative?, is the first unanswered question to date. Because of morphology, one has to look in the available purple-flowered taxa: *C. cardenasi* Heiser & Smith, *C. eximium* A.T. Hunziker and *C. tovarii* Eshbaugh, Smith & Nickrent, the former two being known worldwide (or so) as 'ulupicas' (Naj, 1992). Crossing experiments and electrophoretic studies (McLeod et al., 1983; Zijlstra et al., 1991) have shown that the 3 taxa have little in common with *C. pubescens* in spite of claims of the contrary (Eshbaugh, 1993). Thus, for *C. pubescens*, as pointed out by Pickersgill (1986), we are still missing a good candidate as wild ancestor. However, it is likely to be found in the original range of the cultigen, from southern Peru to southern Bolivia. In this regard, one has to remember the likely historic extension of the range of *C. pubescens* into the northern Andes and Central America (D'Arcy and Eshbaugh, 1974; Heiser, 1969).

From the above, and as far as *C. baccatum* and *C. pubescens* are concerned, there is little doubt that Bolivia is a key place, for a better understanding of pepper evolution. This country was even proposed as the nuclear zone of evolution of the whole genus (McLeod et al., 1982), even if some more recent findings moderate this statement (Eshbaugh, 1993). As pointed it out by Andrews (1984), this scenario is still speculative, but it is beyond doubt that more material and more data, namely from molecular studies, on Bolivian material would be of decisive importance to make progress on these questions.

2.2. For *Phaseolus* spp.:

The following *Phaseolus sensu stricto* species (as per the generic definition revised by Debouck, 1991; Delgado Salinas, 1985; Maréchal et al., 1978) have been reported for Bolivia: *P. augusti* Harms, *P. lunatus* L., *P. vulgaris* L.. As wild especies, one could expect to find: *P. augusti*, since all other species reported by Foster (1958) have been put in synonymy of species of *Macroptilium* and American *Vigna*; the case of *P. boliviensis* Piper is discussed under *P. augusti* below.

The presence of wild *P. vulgaris* in Bolivia was first reported by Berglund-Brücher (1967). Additional information was provided by Berglund-Brücher and Brücher (1976), who wrote: "The existence of *Ph. aborigineus* in Bolivia was not reported prior to our explorations in the provinces of Tarija and Cochabamba in the fifties (Berglund-Brücher 1967). We found the wild bean growing along the rivers which flow eastward. In the company of Prof. Cardenas we found it near Liriuni; it is rather common near 'Aguas Calientes' and in the vicinity of Quillacollo. An easy place to collect it is in the area surrounding the German brewery outside the town of Cochabamba where it abounds in the shrubs nearby" (op. cit. p. 263). While the report of 1967 might refer to wild common bean, one can have serious doubts about the populations reported for Liriuni and Taquiña in the valley of Cochabamba (see below, under *P. augusti*). Two herbarium specimens seen by the author in the early 1980s in La Paz (LPB) and in Buenos Aires (SI) confirmed however the presence of wild *P. vulgaris* in southern Tarija only. These findings were extended by the exploration of Debouck and Rios of 1988 (Debouck, 1988). They found germplasm for the first time for four populations: # 2484 in the department of Cochabamba, # 2491 and 2497 in Chuquisaca and # 2501 in Tarija (Toro et al., 1990).

When one knows about the potential of wild forms in solving crop origin problems and in tracing evolutionary pathways (see Gepts, 1993, for a review), it was highly desirable to extend these collections to more locations, if possible between the population sites already reported for Bolivia (see Map 1). Finally, when one knows about the erosion problems prevailing in some parts of Bolivia, it would be important to survey and document all attributes of this rich flora before it is too late (see Figure 1).



Figure 1 - Soil erosion close to Padilla, Dept. of Chuquisaca, 2,060 masl, 14 May 1994.

3. ITINERARY and TIMING

7-8 May 1994: travel Cali - Miami - La Paz - Cochabamba.

9 May: visit to Pairumani Experimental Station; meeting with Dr. G. Avila; Dept. of Cochabamba, Prov. of Quillacollo, collection of # 3000; Cercado, # 3001.

10 May: visit to herbarium 'M. Cárdenas' in Cochabamba; Dept. of Cochabamba: Cochabamba (2,500 m) - Punata (2,660 m) - Arani (2,690 m) - Estancia Totora (3,660 m) - Khewiña Khasa (3,260 m) - Tucma (2,190 m) - Mizque (1,950 m); 185 Km.

11 May: Mizque - Estancia Pucapilla (2,150 m) - Aiquile (2,180 m) - Villa Granado (2,060 m) - Peña Colorada (1,530 m) - Estancia Perereta (1,470 m) - Perez (1,440 m) - Aiquile - Estancia Novillero (2,090 m) - Sucre (2,790 m); 356 Km.

12 May: Dept. of Chuquisaca: Sucre - Yamparaez (3,010 m) - Tarabuco (3,210 m) - Villa villa (2,900 m) - Cororo (2,800 m) - Morado Khasa (2,780 m) - Mollemayu (2,720 m) - Presto (2,420 m) - Sucre; 242 Km.

13 May: Sucre - Tarabuco - Zudañez (2,400 m); 114 Km.

14 May: Zudañez - Patas Tejas (3,200 m) - Corso (1,940 m) - Villa Tomina - (2,000 m) - Sobosobo (2,150 m) - Padilla (2,060 m) - La Cienaga (2,160 m) - Huaca Wasi (2,030 m) - Villa Serrano (2,060 m) - Padilla; 132 Km. Collections: # 3002 to 3007.

15 May: Padilla - Campo Redondo (2,060 m) - Sillani (2,140 m) - Tarabuquillo (2,200 m) - Pairimayo (2,200 m) - Sopachuy (2,060 m) - Amancaya (1,920 m) - San Pedro (1,880 m) - Padilla; 157 Km. Collections: # 3008 to 3014; # 3029 to 3045 (classified later on).

16 May: Padilla - Lampacillo (2,340 m) - El Rosal (2,150 m) - Astillero (1,740 m) - El Duraznal (1,250 m) - Thiumayu (1,200 m) - Puente Azero (1,090 m) - Bartolo (1,200 m) - Bojorges (1,340 m) - Heredia (1,240 m) - Monteagudo (1,160 m); 127 Km. Collections: # 3015 to 3018.

17 May: Monteagudo - Timboypampa (1,210 m) - Tapera Cumandayti (1,120 m) - Cruz Pampa (1,160 m) - Vallecitos Pampa (1,180 m) - Muyu Pampa (1,180 m) - Peña Redonda (1,040 m) - Ipati (1,100 m) - Camiri (870 m) - Boyuibe (860 m) - Comatindi (660 m) - Villa Montes (440 m); 313 Km. Collection: # 3019.

18 May: Dept. of Tarija: Villa Montes - Palos Blancos (770 m) - Lagunita (1,270 m) - Cañadas (990 m) - Estancia Berety (1,140 m) - Entre Ríos (1,260 m) - San Diego (1,640 m) - Junacas (2,280 m) - Tarija (1,880 m); Km 268. Collections: # 3020 to 3022.

19 May: Tarija - Tabladita (1,890 m) - Tarija - Rincón de la Victoria (2,180 m) - Tarija; 89 Km. Collections: # 3023; # 2501, 2502.

20 May: Tarija - Padcaya (1,960 m) - La Merced (1,560 m) - La Mamora (1,220 m) - Padcaya - Tarija; 221 Km. Collection: # 3024.

21 May: Tarija - San Lorenzo (1,980 m) - Cañas Moro (2,040 m) - Tomatas Grande (2,090 m) - Trancas (2,190 m) - San Lorenzo - Iscayachi (3,400 m) - Cieneguillas (3,230 m) - Estancia Chaipi Unu (2,630 m) - El Puente (2,330 m) - Las Carreras (2,320 m) - Aguada Grande (2,420 m) - Villa Abecia (2,300 m) - Camblaya (2,240 m) - Camargo (2,370 m); 264 Km. Collections: # 3025 to 3026.

22 May: Dept. of Chuquisaca: Camargo - Uturungo (2,920 m) - Culpina (2,910 m) - Incahuasi (2,880 m) - Jolencia Alta (2,920 m) - San José de Chunchuli Bajo (2,940 m) - Pucarita (2,950 m) - Santa Elena (2,160 m) - Pukara (3,020 m) - Incahuasi - Camargo: 218 Km. Collections: # 3027 to 3028; # 3046 to 3056 (classified later).

23 May: Dept. of Potosi and Oruro: Camargo - Padcoyo (2,350 m) - Tres Cruces Alava (3,370 m) - Potosi (4,000 m) - Uncia (3,750 m) - Challapata (3,650 m) - Pazna (3,640 m) - Oruro (3,630 m); 506 Km.

24 May: Dept. of Oruro and Cochabamba: Oruro - Caracollo (3,650 m) - Caihuasi (3,740 m) - Lequepalca (3,870 m) - Confital (4,190 m) - Parotani (2,430 m) - Charanoco (2,400 m) - Capinota (2,340 m) - Playa Ancha (2,380 m) - Alciranco (2,400 m) - Santibañez (2,520 m) - Sipe sipe (2,550 m) - Capillani (3,080 m) - Cochabamba (2,550 m); 308 Km. Grand total: 3,516 Km.

25-27 May: classification and documentation of samples at Pairumani Experimental Station; visit to herbarium of U. Cochabamba.

28 May: travel Cochabamba - Lima - Bogota.

So, the area of study this year could be defined as a rectangle covering the interandean valleys and foothills of South central Bolivia, $17^{\circ}19' S$ (latitude of Cochabamba) to $22^{\circ}14' S$ (latitude of site in the valley of Río Bermejo), $66^{\circ}19' W$ (longitude of site close to Quillacollo, in the Cochabamba valley) to $63^{\circ}48' W$ (longitude of site east of Monteagudo, entering the Bolivian Chaco). Westward lies the Altiplano, a flat highland topping at 3,800 masl with salty lands (e.g. Salar de Uyuni) and lakes (e.g. Lake Poopo). Eastward lies the Chaco at 400 masl with dense dry thickets. The study area includes the drainages of Río Grande, Río Pilcomayo and Río Bermejo. It is a rough country with mountainous ranges oriented north-south from the border with Argentina to Sucre, and NW- SE from Sucre to Cochabamba, and thus with very few roads crossing W-E. Vegetation types are basically of three sorts (see Map 2): 'Valles Secos Interandinos' or dry forests and shrubs in the range of 500- 3,000 masl, 'Bosque Tucumano-Boliviano' or subhumid montane forests 800- 3,000

masl (extending from Valle Grande, Santa Cruz down to Tucumán, Argentina), and 'Bosque Serrano Chaqueño' or subtropical dry forest typically colonizing the Andean foothills 500-1,500 masl from the Argentinean border up to Santa Cruz (Beck et al., 1993). These three zones would correspond to climates BSwh, Cwa and BSwh' according to Montes de Oca (1989), following the Köppen classification, or approximately steppe with dry warm winter, mesothermic with dry cool winter, and steppe with dry very warm winter, respectively. Rainfalls would vary 250 to 1,100 mm/ year with dry months from May to September (driest months: June, July) (Johnson, 1976; Montes de Oca, 1989). In the study area, climate could be classified as temperate, with isotherms between 12- 18°C and a few days of frost in the period June- July (increasing with altitude and as one goes westward to the Altiplano). Geology is the most complex in this region with many folds of Ordovician, Devonian, Carboniferous and Triassic in the interandean valleys, and Tertiary and Quaternary sediments to the Chaco (Montes de Oca, 1989). Erosion is intense, and accelerated by overgrazing and deforestation.

4. RESULTS and DISCUSSION

Seed samples, as reported below, were left to the Centro de Investigaciones Fitogenéticas, Pairumani, Bolivia, and to the UC-Davis, for multiplication and future safe duplication. When not enough germplasm could be shared between both institutions, seed were left to CIF, Pairumani, for prior multiplication. As indicated in Annex 1 herbarium voucher specimens were collected during this field exploration and were deposited in La Paz (LPB), Cochabamba (BOLV), Ann Arbor (MICH), St. Louis (MO), New York (NY), and Berkeley (UC). A sample of herbarium voucher label is presented in Annex 3. These labels were added to each voucher herbarium specimen. A copy of the collecting forms was filled and left at CIF, Pairumani. This report has been distributed to CIF, Pairumani, UC-Davis, California, CIAT and IPGRI. The following is an extended information under DGD responsibility.

For *Capsicum* spp.

Cultivated *C. annuum* L.

A single collection (# 3026) of that species was made in the province of Sud Cinti, Chuquisaca, on the side of the Valle Cinteño. It happened by accident, when looking for "ulupica" on the eastern slope of the "Filo de las Ulupicas". It resulted that the name was given to the mountainous edge, but that wild *C. eximium* does not thrive there (but further north, around Santa Elena - our planned next stop - according to local informants). This material was called "aji verde", and was used as hot sauce once grounded between stones. It is a bush type (plant height 0.40 m) with white flowers, usually planted in rows on side of corn around November and harvested in May. Although some peppers were relatively small, they were not as small as the bird pepper, the range of which seemed stopped in the Valle del Cauca, Colombia (personal observations and Heiser, 1964). It might be morphologically closer to any *frutescens* (name used for *annuum* types raised in the

Amazonian Basin) than to current traditional Mesoamerican varieties (Andrews, 1984). Although it might well be the result of a germplasm introduction into Bolivia, it was novel for that part of the country, and therefore included in the Bolivia national collection.



Figure 2 - Variation found in one collection of *Capsicum annuum* # 3026, at Camblaya, Chuquisaca, 2,240 masl, 21 May 1994. The lighter types mature yellow, while the others mature bright red.

Cultivated *C. baccatum* L.

Six collections were added to the Bolivia national collection for places that were not sampled before (see Annex 2). This type of pepper is (and has been) very common in that part of Chuquisaca, where climate and soil conditions help to produce a good pepper for drying. Planted in October- November in plots less than 1 Ha when as monocrop, or in a few rows when intercropped with maize, amaranth, beans and squashes, they are harvested in April- May. In May in western Chuquisaca it is very common to see from the distance red and yellow squarish plots in the landscape with all the peppers spread on the ground for drying; even up to roofs are used if space is lacking (Figure 3)! According to De Lucca D. and Zalles A. (1992), these peppers are usually commercialized dried. Peppers can then be easily sold out without decay; once grounded they will be used for the "picantes", very common dishes in the departments of Chuquisaca and Cochabamba (Cárdenas, 1989). So, germplasm can be easily circulated, for instance to eastern Chuquisaca, where new settlers are clearing land very rapidly. Looking for genuinely native landraces should thus be focused on the interandean valleys of western Chuquisaca. Most of the materials were called "aji", "aji colorado" (a name lacking specificity); # 3014 was called "tioc'uchu", perhaps

better reflecting a native growing out (close to San Pedro on road to Azurduy). According to Cárdenas (1989), *uchu* is the Quechuan name for (this!?) cultivated pepper. Usually, each of our collections would contain 1-3 variants in pepper size, and two variants in pepper colour (intense red and orange yellow at full maturity). Plants are usually bushes up to 80 cm high, with branching regularly developed along main stem, as observed in Campo Redondo, Villa Padilla, Chuquisaca.

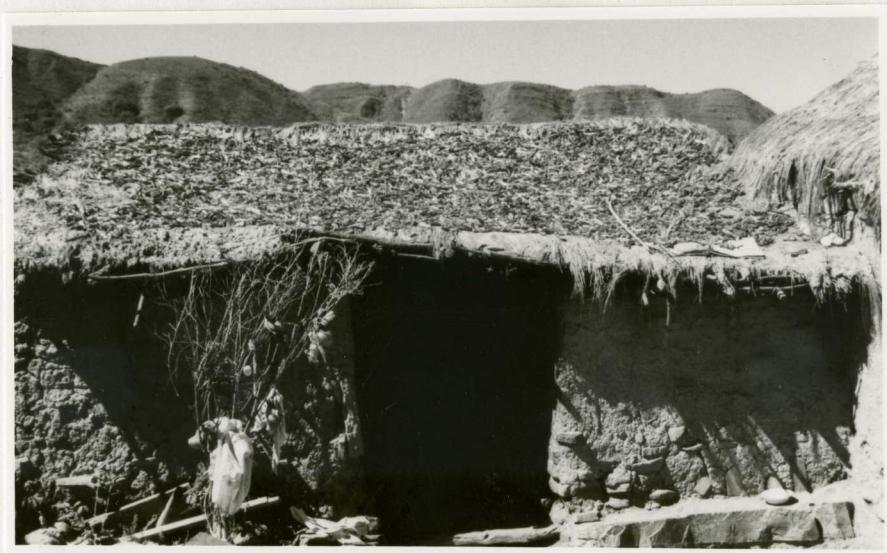


Figure 3 - "Aji colorado", # 3004, drying up on roof in Sobosobo, Chuquisaca, 2,150 m, 14 May 1994.

Wild *C. chacoense* A.T. Hunziker

Three collections (# 3016, 3019, 3028) of this wild species were made in eastern Chuquisaca, already at lower altitude, under thickets in the semideciduous subtropical forest. It seems that this species replaces *C. eximium* in the Bosque Seco Chaqueño (Beck et al., 1993), and extends to Paraguay and Argentina (Hunziker, 1950); one of our collections (# 3016) could be seen as one coming close to the extreme northern part of the range. The altitude of the collection # 3028 should not be considered as representative, since it was obtained from a farmer's seed stock in Santa Elena, Nor Cinti. This collection was obtained by gathering red berries in bushes in the higher Pilcomayo valley northeast of Santa Elena. Fruits were then ground and added to the food. Perhaps because of difficulties in getting seeds germinated, rural inhabitants prefer to bring young seedlings into their kitchen-gardens instead of planting them straight. This is what they reported to us in Thiumayu (# 3016) and Cruz Pampa (# 3019). The fruits are mainly collected in March, when plants are in full production. Berries are also eaten by parrots according to local informants (it seems the

case for ancestral forms of *C. annuum* and *C. baccatum*, (Heiser and Pickersgill, 1975 and Heiser, 1985, respectively). The three collections were reported without hesitation under the local name "aribibi" (spelled "arivivi" and identified as *C. microcarpum* Cav. by Cárdenas, 1989). According to De Lucca D. and Zalles A. (1992), *aribibi* is a guarayo word; the Guarayo culture is aboriginal and spread in Cochabamba and northern Chuquisaca up to western Santa Cruz (in central Santa Cruz according to Montes de Oca, 1989). This information seems confirmed from an earlier exploration carried out by P.G. Smith and M. Cárdenas (Cárdenas, 1972). Another name in Santa Elena was "coincchu"; interestingly enough, Eshbaugh (1980) reported the commercial exploitation of *C. chacoense*, "covincho", in the Tarija area. In the wild, plants generally grow where cattle have no access, in thickets, on river slopes, as subperennial bushes up to 1 m high, heavily branched. Soils are sandy to loamy. Finally, one could foresee that some populations will become extinct as the exploitation of the Chaco becomes more intense (native vegetation replaced for growing out monocrops of maize, sunflower, etc; increasing pressure of grazing). Local use of berries as spice favors certain kind of on-farm keeping, and hence conservation of certain genotypes.

Wild *C. eximium* A.T. Hunziker

Two collections (# 3003, 3027) were made of this taxon, always referred as "ulupicas" by farmers and rural inhabitants, thus confirming their belonging to native flora (Cárdenas, 1989). According to De Lucca D. and Zalles A. (1992), *ulupica* is both a Quechua and an Aymara word, being both aboriginal cultures spread in southern La Paz, Oruro, Potosí, southwestern Cochabamba and western Chuquisaca, generally above 2,000 masl. In contrast with *C. chacoense*, it thrives in the 'Valles Secos Interandinos' (Beck et al., 1993) rich in Cactaceae and thorny Leguminosae (*Acacia*, *Prosopis*), generally on stony or sandy soils. Our ecological observations confirm those by Eshbaugh (Eshbaugh, 1982). As for *C. chacoense*, and perhaps for the same reasons, people use to bring seedlings from the thickets to plant them in the kitchen-gardens (info: Tejas Patas, Zudañez, Chuquisaca). Berries are also harvested from the wild around March, and then dried, for consumption as a powder. In Santa Elena, Norcinti, where both species *C. chacoense* and *C. eximium* were gathered by native people, identification by them was sharply done: while the *ulupica* was reported as a tall plant with almost spherical berries, the *aribibi* was mentioned as a smaller one with more elongate conical berries (the plants we have seen in the field in eastern Hernando Siles hardly reach 1 m high). These folk distinctions match those by formal taxonomists (Eshbaugh, 1979; Eshbaugh, 1982; Hunziker, 1950). As for *C. chacoense*, the interest of local people for berries favors some kind of *in situ* conservation; the long-term threat is overgrazing, namely by goats roaming freely without any restriction of any kind (also valid for the whole flora of Chuquisaca).



Figure 4 - "Ulupica", # 3003, growing among grapevine in a kitchen-garden in Patas Tejas, 2290 masl, 14 May 1994.

A collection, # 3002, has been left identified because it was too dried in the field to make a final botanical identification (almost defoliate, no flowers, and berries overdried because of drought). It looked quite like a wild *Capsicum* although with diminute, non-pungent berries. This last fact should exclude it as a *Capsicum*; however, Eshbaugh (1980) has reported about the absence of pungency in wild species found in Bolivia. Pending on the possibility to see it at full bloom, the author is not discarding the possibility of this collection being a *Witheringia* L'Heritier; in such a case, it could help to 'root' any taxonomical tree in studies on phylogenies of Bolivian species of *Capsicum*.

We did not find growings of "locoto", *Capsicum pubescens* Ruiz & Pavón, in Chuquisaca nor in Tarija, although these peppers were frequent on markets in these two departments. It seems that the growing out of varieties of this species is concentrated north of the area studied this time. According to Cárdenas (1989), it is particularly concentrated around El Locotal, Prov. Chapare, Dept. Cochabamba, in the 'Ceja de Monte Yungueña' (Beck et al., 1993). If the ecology of the cultigen is so different from the one of the putative ancestor, how could one derive from the other? Indeed, on the basis of hybridology experiments and genetic distances calculated from electrophoretic studies (McLeod et al.,

1979), there might be little background to claim that *C. eximium* is the direct ancestor of *C. pubescens*.

For *Manihot* spp.

In eastern Chuquisaca, at the limit of the 'Bosque Serrano Chaqueño' (Beck et al., 1993), we found a wild cassava species, # 3018, tentatively identified as of the sect. *Anisophyllae* (Rogers and Appan, 1973). Flowers were lacking in order to come up with a final identification. Single capsules with smooth epidermis, of diameter 2-3 cm were borne on 2-4 cm racemes. They were 2-3 m high, erect caulescent, self-supporting shrubs with 5-deeply lobed, glabrous, widely spaced leaves and cylindrical stems with smooth and green bark. The natural vegetation, a subtropical semi deciduous forest with *Cesalpinoideae*, *Bignoniaceae* and epiphytic *Tillandsia*, was cleared for *Citrus* plantations. It thrives on organic rich, clayish soils, in the range 1,160- 1,090 masl. Because the distribution of wild *Manihot* in Bolivia is so poorly known, it was decided to collect it.



Figure 5 - Fertile stems of *Manihot* sp., # 3018, 8 Km NW of Puente Azero, Chuquisaca, 1,160 masl, 16 May 1994.

For *Phaseolus* spp.

Wild *P. augusti* Harms

Because we were interested in checking possible places for additional populations of wild *P. vulgaris*, given the indications of H. Brücher about Quillacollo, Liriuni and Taquiña

(mentioned above), we visited these places surrounding the valley of the town of Cochabamba. Given the fact that the expanding city already occupies most of the valley (and is now expanding east towards Sacaba), a visit to these places should not be delayed any further. All places are located in the foothills of the Cordillera de Cochabamba (just north of the city) and the Cordillera del Tunari (west of Cochabamba). An additional justification was in looking for the type of *P. boliviensis* Piper ("... collected at Cochabamba, Bolivia, March 14, 1920, by E.W.D. and Mary M. Holway (no. 411)", (Piper, 1926) for further taxonomical studies.

These visits lead to the discovery of two additional populations of wild *P. augusti* in the valley of Cochabamba: # 3000 (north of Pairumani experimental station, say north-west of Quillacollo), and # 3001 (just on the side of the ex German brewery at Taquiña). The number # 2506 (on the way to Liriuni) was another population of wild *P. augusti* disclosed in 1988 (marked as stars on Figure). Searches for additional populations on road to Sacaba, Villa Copacabana, Santibañez, Parotani, Sipe Sipe and Chacapaya were unsuccessful. The three populations can be considered as endangered in 20-25 years time, because of overgrazing (# 3001) and recent expanding urbanization, if no protection measures are taken. Unfortunately, geographical data about *P. boliviensis* (one can assume that it is either # 3000 or # 3001) are not accurate enough in order to allow us a monitoring over a longer period of time. The population # 3001 is benefitting indirectly from some access restriction measures taken recently by the brewery in order to protect its water sources. No signs of presence of wild *P. vulgaris* were observed.

It is thus doubtful that wild *P. vulgaris* was present in the places reported by the Brüchers for the valley of Cochabamba. No seed samples nor herbarium specimens were left by the Brüchers. In author's view, there was a confusion with wild *P. augusti*. If wild *P. vulgaris* has been ever present in the valley of Cochabamba (2,500 masl), although altitude might be slightly too high for this species at that latitude, it could have been in more humid places (river beds of Río Rocha, Estancia Alba, Rancho Champa), all nowadays occupied by the city and suburbs.

In addition, two more populations (# 3006, # 3010) were disclosed in Chuquisaca, resulting in eleven populations sampled throughout the country, when adding the seven populations sampled in 1988 (Debouck, 1988) (Map 3). Their distribution corresponds to the montane moist and subhumid forests in the subtropical and temperate zones (included into the 'Valles Secos Interandinos' according to Beck et al. (1993), between 1,900 and 2,900 masl (Debouck, 1988, and present results). For all of them, enough seed germplasm was collected, since it can be considered as threatened because of overgrazing. While # 3006 might be seen as an extension of population # 2496 but further SE in the canyon Sillani, population # 3010 has been found in a sector not explored so far: the upper valley of Río Milanis. Both were found in heavily disturbed forests of *Podocarpus* with *Schinus* and *Caesalpinia*. Population # 2496 was re-visited, and as a possible result of severe drought this year, only two vegetative stems were found. Plants were damaged by lace-bug (*Gargaphia* sp., Hemiptera) in # 3000 and 3006. The collection # 3000 was known as "algo

chui" or dog bean, and used as play by children.

Cultivated *P. lunatus* L.

Two collections of this taxon were made (# 3017, 3046). Both belong to the large-seeded type of lima bean or Big Lima (Baudet, 1977). The material # 3017 is with a white background and a large dark yellow tan spot from the micropyle side of the seed; it was found in a dooryard garden in eastern Tomina, Dept. of Chuquisaca, at a somewhat unexpected altitude for such a cultigroup (1,200 m). Its name "poroto" may well indicate an origin outside this area; this might be reinforced by the fact that farmers there were recently arrived settlers coming from the highlands. It was new to the Bolivian collection however (pattern different from # 2499 of 1988), and therefore collected. The other material # 3046 is with a white background and large black spots irradiating from the hilum. Pattern is quite similar to that of # 2500 of 1988, but the color is black instead of wine red. It was found in Santa Elena, east of Camargo, Chuquisaca, at 2,160 m and called "chorca" or "pallar" as other types disclosed in the Valle Cinteño in 1988 (# 2488, 2494, 2499, 2505)(Debouck, 1988). Seeds were used green in soups, much less as dry bean because reportedly heavily damaged by weevils, also used as play by children. As mentioned in 1988 (Debouck, 1988), we believe this crop has been introduced in Bolivia in pre-Columbian times from Peru where it was domesticated (Gutierrez Salgado et al., 1994), and as such worth collecting. As for many traditional landraces of Andean crops, this kind of germplasm is suffering from neglect, and on the long term disappearing. *Ex situ* conservation looks as a safe back-up for the time being.



Figure 6 - "Poroto", # 3017, grown in kitchen-garden in Thiumayu, Chuquisaca, 1,200 masl, 16 May 1995.

Cultivated *P. vulgaris* L.

Two mixtures were collected: one in Sillani, Tomina, Dept. of Chuquisaca, at 2,140 m and another one in Santa Elena, Nor Cinti, Dept. of Chuquisaca, at 2,160 m. The first mixture was made of "k'opusus" or beans consumed after toasting (Tohme et al., 1995). It included the 27 following morphotypes: CF-36, CF-41, CF-54, CF-97, CF-110 (of Pairumani collection), # 2517, 2520, 2523, 2535, 2567 (of the 1988 exploration), # 3029 to 3045 (apparently new and not present in the Pairumani collection nor collected in 1988). That would mean an addition of 17 accessions to the Bolivian collection of *k'opusus*. These morphotypes were obtained from a farmer who used to plant them together with "k'anka sara", a tall maize variety (2 m 50 high) also for local consumption as toasted grain (note: *sara* is the Quechuan name for maize, and *k'anka* would refer to the toasting). It might correspond to the "Checchi" race of maize, used almost exclusively for parched corn, although plant height does not correspond to the original description (Ramírez E. et al., 1960). This farmer also had Maíz Blanco, all planted in November and intermixed with *Cucurbita ficifolia* Bouché ("lacayote"), *Cucurbita maxima* Duch. ex Lam. ("angula"), *Lagenaria siceraria* (Mol.) Standl. ("calabaza"), and *Amaranthus caudatus* L. ("coimi", also consumed after toasting). This collection might be the extreme south of the range of toasted beans also called *nuñas* or *reventones* in other parts. According to Dr. Avila (pers. comm., 1994), Quechuan Indians look for similarities in speckled patterns between both crops, using the Checchi with its dotted aleurone as standard for comparison and as criterion for good toasting potential. According to Ramírez E. et al. (1960), *chechii* name refers to a grey colour on a white background. This interesting scenario for selection pressure in both crops faces however some difficulties: corn might have been introduced from Mesoamerica into the Andes during the second half of history of bean in the latter (Pearsall, 1992). The four primitive varieties of Mexico - and all four as pop corns - do not present the dotted aleurone (Wellhausen et al., 1952). Several varieties of common bean with good potential for toasting have uniform colour patterns or very large colour dots not presented in any traditional maize landrace (Tohme et al., 1995). More data are still necessary to test this interesting scenario of joint selection; now, one could think about the reverse way, that is, some maize types have been selected on purpose for toasting on the basis of characteristics already present in the common bean types. In a paper to be published soon (Tohme et al., 1995), a hypothesis about an early selective pressure for toasting in the Andean common bean types is presented. The habit of toasting grains, by then already applied to *k'opusus* and *coimi*, could have been extended to the other grain crop - maize - once introduced from Mesoamerica in pre-Ceramic times.

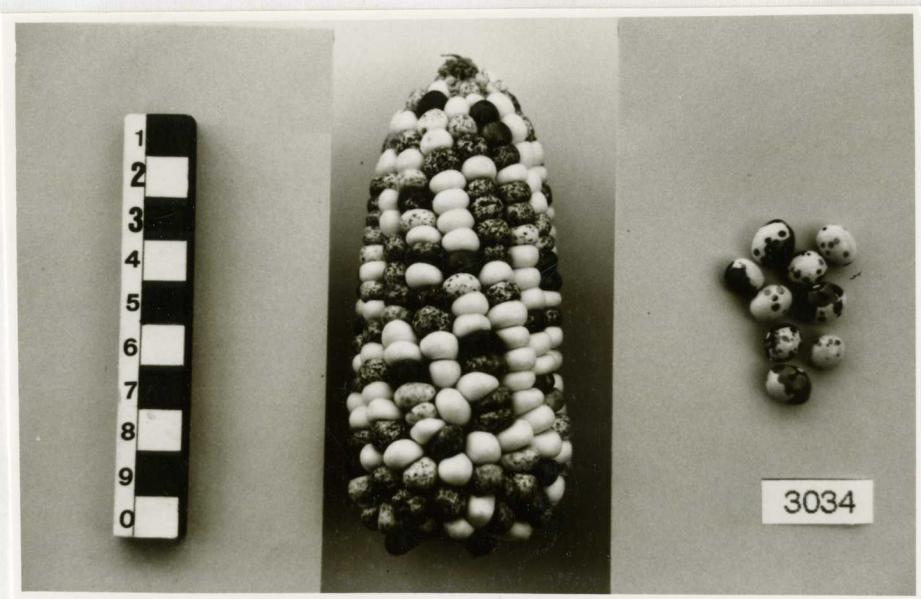


Figure 7 - "K'opuru", # 3034, obtained in Sillani, Chuquisaca, 2,140 masl, 15 May 1994. In center is an ear of "Checchi" maize; note similarities in colour pattern in both crops.

The second mixture was made of "porotos", regular beans planted in association with maize. It included 18 morphotypes: CF-16, CF-33, CF-49, CF-57, FI-83, FI-109, FI-121 (of Pairumani collection), and # 3047 to 3056 (apparently new and not present in the Pairumani collection nor collected in 1988, resulting in 10 new accessions for the Bolivian national collection). The collections # 3050 and 3055 because of their almost spherical shape could well be "chui", generally used as play (Cárdenas, 1989). Given social changes affecting rural populations (younger generations leaving the countryside), the growing out of this group is likely to be discontinued. If some beans might indeed have been domesticated for leisure (Debouck, 1989), it might be one of the most interesting groups because of wider variability! This obviously needs to be assessed further with biochemical/ molecular markers.

Wild *P. vulgaris* L.

This trip allowed us to triplicate the number of known populations of wild common bean for Bolivia, with seven germplasm collections and the collection numbers # 3007, 3011, 3012, 3020, 3021, 3024, 3025. The collection # 3023 will be discussed below under weedy forms. Although the material was already well dried in some places, it was not too late, since we were still able to make herbarium specimens for most of them (# 3007, 3011, 3012, 3020, 3024 and 3025). Amounts of seeds were normal to abundant (more than 1,000 original seeds).

The twelve populations known for Bolivia (Map 1) give now a better picture and would allow the following comments. First, the range of distribution of wild *P. vulgaris* in Bolivia is restricted to interandean valleys south of parallel 17°30'S, between 65°00'W and 64°00'W, and limited southward to the Río Bermejo valley. That rectangle encompasses the valleys of Río Mizque, Río Grande, Río Pilcomayo, Río Bermejo and tributaries (extreme north: # 2484, 17°47'S; extreme south: # 3024, 22°14'S; extreme east: # 3020, 64°09'W; extreme west: # 2484, 65°10'W). Valleys are generally oriented from north to south, centrally located along an east-west gradient, and organized in a succession of increasing altitude towards the Altiplano to the west. Along that succession, if humidity is still too high, wild bean populations will be found on the western slope of one *cordillera* (as in # 3020, just north of village of Entre Ríos); if humidity is already too low, they will be found on the eastern slope facing humid winds blowing westward from the East (as in # 2501, west of town of Tarija).

Second, populations of wild *P. vulgaris* display a morphological variation along a north to south gradient. The northernmost population # 2484 (found in 1988 south of the place called Totora, in the Cochabamba department) is already close to the Peruvian morphotypes of Cuzco and Apurimac with larger racemes with 2-4 primary bracts, while the southernmost population # 3024 (disclosed this year south of site called La Mamora, in the Río Bermejo valley, department of Tarija) is close to the Argentinean morphotypes of Jujuy, Salta and Tucuman with rhombohedric leaflets and short racemes with 1-2 primary bracts, as described by (Brücher, 1988). The presence of variation for that later trait within # 3024 would preclude however any definitive conclusion before a statistical analysis. Third, has all the range been explored? During this trip, because of lack of roads and bridges, blocked paths, we could not enter the upper Pilcomayo (e.g. we could not reach Azurduy from Sopachuy), that would constitute the only noteworthy missing spot at the level of a first general survey like this one for Bolivia. Another place of potential interest might be the valley of Río Pilaya (surroundings of Pampa Grande, border Depts. Chuquisaca - Tarija, not accessible by road yet).

Fourth, from the present distribution, it seems that wild common bean is a floristic element of both the Tucumano-Bolivian forest and the humid variants of the dry forest of 'Valles Secos Interandinos' described by Beck et al. (1993). The population # 3024, found in a very little disturbed humid temperate forest in the upper Bermejo valley, rich in Bambusoideae, Bignoniaceae (*Tecoma*), Convolvulaceae (*Ipomoea*), Juglandaceae (*Juglans boliviensis*), Lauraceae (*Ocotea*), Melastomataceae, Meliaceae (*Cedrela*) and Myrtaceae, is a clear indication that common bean is wild in Bolivia, and not weedy as once claimed (Gentry, 1969). It also enters into the *Podocarpus* forest, now disturbed in most places (populations # 3011, 3021 of 1994, # 2501 of 1988 re-visited this year), that is a moist temperate forest (Unzueta, 1975) with a winter dry period of approxim. four months. Now, it is quite possible that in places where forests have been cleared to give place to secondary thickets with *Acacia*, *Physalis*, *Schinus*, *Solanum*, *Verbesina*, the range of wild common bean has been extended, provided that cattle has been long kept away (as for population # 3025; Figure 8). In this case, grazing is delayed till corn is harvested, allowing a growing period

of 6-8 months, a duration long enough for the wild bean to set seeds and escape destruction. Giving the presence of goats ranging freely in most southern Chuquisaca and northern Tarija, we considered that many wild bean populations are not presently secured *in situ*, and therefore collected germplasm.



Figure 8 - Collection site of wild *P. vulgaris* # 3025, 1 Km SW Capilla de Trancas, Tarija, 2,180 masl, 21 May 1994. Vegetation on the hill in the back of the picture has been already wiped out; wild common beans have survived so far on thickets of *Acacia* on borders of maize fields where grazing is long delayed.

A certain number of places were visited in vain this year (see list below). Assuming that the ecological conditions were appropriate (or close to the limit, in order to find extreme variants), the author made the stop and looked for wild beans. There are eventually well defined reasons for not finding them; some of them might be: place naturally not suitable, place not suitable this year (drought!), overgrazing, vicariance with other wild legumes such as *Vigna*.

Department	List of places visited in vain	
	Coordinates	Possible reason(s)
1) Cochabamba	66°15'W 17°35'S 2,400	naturally too dry
2) Cochabamba	66°22'W 17°26'S 2,600	overgrazed
3) Cochabamba	65°22'W 17°53'S 2,000	overgrazed, crops
4) Cochabamba	65°14'W 18°06'S 2,150	overgrazed
5) Cochabamba	64°56'W 18°10'S 2,140	overgrazed (goats)

6) Cochabamba	65°15'W 18°18'S 2,280	<i>Vigna</i> sp.
7) Chuquisaca	64°58'W 18°53'S 2,400	too dry this year?
8) Chuquisaca	64°18'W 19°11'S 2,060	overgrazed
9) Chuquisaca	64°29'W 19°20'S 2,250	completely eroded
10) Chuquisaca	64°11'W 19°27'S 1,900	<i>Vigna lasiocarpa</i> (?)
11) Chuquisaca	64°45'W 20°35'S 2,160	too far east?
12) Tarija	64°50'W 21°35'S 2,250	overgrazed, fire
13) Tarija	64°50'W 21°27'S 2,250	overgrazed

Anthracnose was observed in several populations (# 3007, 3011, 3012, 3020, 3024, 3025), with the highest pressure in # 3024. Pod damages caused by birds were observed in populations # 3011, 3012, 3024 and 3025, as it has been seen already in other parts of the range (Debouck et al., 1993). Wild beans were known as "monte chui" (# 3007), "porotito" (# 3011), "campo purutu" (# 3012), "poroto del zorro" (# 3021, 3024) and "porotito" (# 3025); they were locally eaten by rural inhabitants in southern Chuquisaca (# 3011).

The wild-weed-crop complexes

Observations made in 1988 about hybridizations naturally occurring between wild and cultivated beans (Debouck, 1988) were confirmed and extended during this trip. In the Rincón de la Victoria, north-west of Tarija, # 2502 was found again in the same thickets intermixed with remaining spots of *Podocarpus*, as an indication that weedy regressive forms can maintain themselves in the right environment. To author's knowledge, this is relatively rare in *P. vulgaris*, but possible in appropriate ecological conditions (wild *P. vulgaris*, # 2501, was and is still growing there in a radius of 100 m from # 2502). In the suburbs SW of Tarija, in a refuse heap at Tabladita on way to San Jacinto, growing on *Opuntia* and *Schinus*, there was a wild bean (# 3023) mixed with a Bayo type with at least four intermediate, black-striped types with grey-cream background (Figure 9). Introgression was also observed in # 3025, found on borders of maize fields near Trancas approxim. 23 NNW of Tarija, with bayo and brownish black-spotted types larger than the sympatric wild type.

Figure 9 - Wild- weed- crop complex, # 3023, found in the immediate surroundings of town Tarija, Dept. Tarija, 1,890 masl, 19 May 1994. The extreme column at left is close to a pure wild type, while two columns at right are of cultivated varieties. The five middle columns are of weedy races (actual size).

Pending on confirmations with additional morphological and biochemical studies, it seems that crosses occur where cultivated and wild common bean populations are in close contact (say a radius of 100 m or less) in Bolivia, as it has been observed in other parts of the range of wild *P. vulgaris* in Latin America (Acosta Gallegos et al., 1994; Debouck et al., 1989). The case of Tabladita (# 3023) is most interesting: we looked for typical, pure wild

bean and could not find any (rather an expected result given the heavy disturbance of the habitat). It happened as if this wild bean were genetically absorbed into the weedy complex!

5. CONCLUSIONS

From the above, one could mention as concluding remarks:

- 1) some germplasm of wild peppers has been collected in order to understand domestication and evolution of the cultivated species native to the southern Andes, *C. baccatum* and *C. pubescens*. The wild species, *C. chacoense* and *C. eximium*, are collected from the wild and used by rural inhabitants. Germplasm is not presently at risk as long as these traditional ways of 'handling' germplasm are maintained; some populations are threatened by habitat destruction in the interandean valleys of Chuquisaca and Tarija and Chaco foothills.
- 2) native pepper varieties of *C. baccatum* display relatively low levels of morphological diversity. They are not particularly threatened for now, as long as improved varieties, especially of *C. annuum*, are not introduced, and as long as consumption patterns are not changed.
- 3) commercial bean types are produced and consumed to relatively low level in Bolivian interandean valleys. Instead, relatively important sets of diversity are grown locally for other purposes: grains to be consumed after toasting, grains kept as play. This allows a higher amount of diversity, as inferred from morphological variation. *K'opurus* (types for toasting) are presently not used to the extent possible, and their diversity can be affected by changes in production/ consumption patterns. *Chuies* (types used as play) are definitively at risk in part because of rural exodus. *Ex situ* conservation is for the time being the best back-up available.
- 4) the range of wild common bean in Bolivia has been sampled. With molecular markers, it is now possible to answer the question whether common bean have been specifically domesticated in Bolivia. Although not all locations might be representative of the original range, it is certain that wild common bean is a floristic element of the 'Bosque Tucumano-Boliviano' and drier variants, and not an early escape from cultivation in Bolivia. As deforestation goes on and overgrazing, many populations are becoming endangered.
- 5) as in other parts of the range where wild forms and cultivated common beans come into contact, wild- weed- crop complexes may arise. As habitats of wild common beans are becoming narrower, and as the crop extends outside the original ecological niche, the complexes tend to be rarer. The biological significance of such complexes as well as the role played by farmers in using them is still to be documented.

ACKNOWLEDGEMENTS

This work has been made possible thanks to a grant obtained by Dr. Paul Gepts from the United States Department of Agriculture to the University of California at Davis, that is deeply acknowledged. The author would like to thank warmly the following institutions for support: the Centro de Investigaciones Fitogenéticas de Pairumani (Fundación Pro-Bolivia), Cochabamba, Bolivia; the Centro Internacional de Agricultura Tropical, Palmira, Colombia; and the International Board for Plant Genetic Resources, Rome, Italy (now International Plant Genetic Resources Institute). The author expresses its warm thanks to his colleagues and friends, Ing.MSc. Raul Rios, Biol. Lorena Guzman, and Dr. Paul Gepts, whose help has been decisive to the success of this work. Very special thanks are due to Dr. Gonzalo Avila, Director of CIF, for a very nice welcome and challenging scientific discussions in Pairumani. The author thanks Dr. S. Beck, Curator of the National Herbarium of Bolivia, La Paz, and Biol. Carola Antesana, Curator of Herbario Forestal Nacional "Martin Cárdenas", Cochabamba, for access to the herbarium collections. Thanks are also due to Gloria Restrepo A. for her care in the preparation of the manuscript. Last but not least, the author would like to thank warmly farmers of Cochabamba, Chuquisaca and Tarija for their hospitality and patience to our numerous questions. This report and essay is only a small tribute in comparison to their immense care and skills in selecting and caring for plant germplasm of beans and peppers.

6. LITERATURE CITED

- Acosta Gallegos, J. A., Gepts, P. and Debouck, D. G. 1994. Observations on wild and weedy forms of common bean in Oaxaca, Mexico. *Annu. Rept. Bean Improvement Coop.* 37: 137-138.
- Andrews, J. 1984. Peppers - The domesticated Capsicums. University of Texas Press, Austin, Texas, USA, 170p.
- Baudet, J. C. 1977. The taxonomic status of the cultivated types of lima bean (*Phaseolus lunatus* L.). *Tropical Grain Legume Bull.*, IITA, Ibadan, Nigeria 7: 29-30.
- Beck, S. G., Killeen, T. J. and Garcia E., E. 1993. Vegetación de Bolivia. In: "Guía de arboles de Bolivia", Killeen, T.J., García E., E. and Beck, S.G. (eds.), Quipus S.R.L., La Paz, Bolivia, pp. 6-24.
- Berglund-Brücher, O. 1967. Wildbohnen-Funde in Südamerika. *Naturwiss.* 54 (17): 466-468.
- Berglund-Brücher, O. and Brücher, H. 1976. The south American wild bean (*Phaseolus aborigineus* Burk.) as ancestor of the common bean. *Econ. Bot.* 30: 257-272.
- Brücher, H. 1988. The wild ancestor of *Phaseolus vulgaris* in South America. In: "Genetic resources of *Phaseolus* beans", Gepts, P. (ed.), Kluwer Academic Publishers, Dordrecht, Holland, pp. 185-214.
- Cárdenas, M. 1972. Por las selvas, las montañas y los valles de Bolivia - Memorias de un naturalista. Editorial Don Bosco, La Paz, Bolivia, 442p.
- Cárdenas, M. 1989. Manual de plantas económicas de Bolivia - 2da edición. Editorial Los Amigos del Libro, La Paz, Bolivia, 333p.

- Conicella, C., Errico, A. and Saccardo, F. 1990. Cytogenetic and isozyme studies of wild and cultivated *Capsicum annuum*. *Genome* 33 (3): 279-282.
- D'Arcy, W. G. and Eshbaugh, W. H. 1974. New World peppers (*Capsicum* - Solanaceae) north of Colombia: a résumé. *Baileya* 19: 93-105.
- De Lucca D., M. and Zalles A., J. 1992. Flora medicinal boliviana. Editorial Los Amigos del Libro, La Paz, Bolivia, 498p.
- Debouck, D. G. 1988. Recolección de germoplasma de *Phaseolus* en Bolivia. Centro Internacional de Agricultura Tropical, Cali, Colombia. Mimeographed, 24 p.
- Debouck, D. G. 1989. Early beans (*Phaseolus vulgaris* L. and *P. lunatus* L.) domesticated for their aesthetic value? *Annu. Rept. Bean Improvement Coop.* 32: 62-63.
- Debouck, D. G. 1991. Systematics and morphology. In: "Common beans: research for crop improvement", van Schoonhoven, A. and Voysest Voysest, O. (eds.), Commonwealth Agricultural Bureaux International, Wallingford, United Kingdom, pp. 55-118.
- Debouck, D. G., Gamarra Flores, M., Ortiz Arriola, V. and Tohme, J. 1989. Presence of a wild-weed-crop complex in *Phaseolus vulgaris* L. in Peru? *Annu. Rept Bean Improvement Coop.* 32: 64-65.
- Debouck, D. G., Toro, O., Paredes, O. M., Johnson, W. C. and Gepts, P. 1993. Genetic diversity and ecological distribution of *Phaseolus vulgaris* (Fabaceae) in northwestern South America. *Econ. Bot.* 47 (4): 408-423.
- Delgado Salinas, A. 1985. Systematics of the genus *Phaseolus* (Leguminosae) in North and Central America. Austin, Texas, PhD.
- Eshbaugh, W. H. 1970. A biosystematic and evolutionary study of *Capsicum baccatum* (Solanaceae). *Brittonia* 22: 31-43.
- Eshbaugh, W. H. 1979. Biosystematic and evolutionary study of the *Capsicum pubescens* complex. *Natl. Geogr. Soc. Res. Rpts, 1970 Projects:* 143-162.
- Eshbaugh, W. H. 1980. Chili peppers in Bolivia. *FAO/IBPGR Plant Genet. Resources Newsl.* 43: 17-19.
- Eshbaugh, W. H. 1982. Variation and evolution in *Capsicum eximium* (Solanaceae). *Baileya* 21 (4): 193-198.
- Eshbaugh, W. H. 1993. Peppers: history and exploitation of a serendipitous new crop discovery. In: "New crops", Janick, J. and Simon, J.E. (eds.), John Wiley & Sons, Inc., New York, USA, pp. 132-139.
- Foster, R. C. 1958. A catalogue of the ferns and flowering plants of Bolivia. *Contr. Gray Herb. Harvard Univ.* 184: 1-223.
- Gentry, H. S. 1969. Origin of the common bean, *Phaseolus vulgaris*. *Econ. Bot.* 23 (1): 55-69.
- Gepts, P. 1993. The use of molecular and biochemical markers in crop evolution studies. In: "Evolutionary Biology. Volume 27", Hecht, M.K. (ed.), Plenum Press, New York, USA, pp. 51-94.
- Gutierrez Salgado, A., Gepts, P. and Debouck, D. G. 1994. Evidence for two gene pools of the lima bean, *Phaseolus lunatus*, in the Americas. *Genet. Resources & Crop Evol.: in press.*
- Heiser, C. B. 1964. Los chiles y ajíes de Costa Rica y Ecuador. *Ciencia y Naturaleza* 7 (2): 50-57.

- Heiser, C. B. 1969. Systematics and the origin of cultivated plants. *Taxon* 18: 36-45.
- Heiser, C. B. 1985. Of plants and people. Univ. Oklahoma Press, Norman, Oklahoma, USA, 237p.
- Heiser, C. B. and Pickersgill, B. 1975. Names for the bird peppers (*Capsicum*, Solanaceae). *Baileya* 19: 151-156.
- Hunziker, A. T. 1950. Estudios sobre Solanaceae. 1. Sinopsis de las especies silvestres de *Capsicum* de Argentina y Paraguay. *Darwiniana* 9 (2): 225-247.
- Johnson, A. M. 1976. The climate of Peru, Bolivia and Ecuador. In: "Climates of Central and South America", Schwerdtfeger, W. (ed.), Elsevier Scientific Publishing Co., Amsterdam, The Netherlands, pp. 147-218.
- Lefebvre, V., Palloix, A. and Rives, M. 1993. Nuclear RFLP between pepper cultivars (*Capsicum annuum* L.). *Euphytica* 71: 189-199.
- Maréchal, R., Mascherpa, J. and Stainier, F. 1978. Etude taxonomique d'un groupe complexe d'espèces des genres *Phaseolus* et *Vigna* (Papilionaceae) sur la base de données morphologiques et polliniques, traitées par l'analyse informatique. *Boissiera* 28: 1-273.
- McLeod, M. J., Eshbaugh, W. H. and Guttman, S. I. 1979. A preliminary biochemical systematic study of the genus *Capsicum* - Solanaceae. In: "The biology and taxonomy of the Solanaceae", Hawkes, J.G., Lester, R.N. and Skelding, A.D. (eds.), Academic Press, London, United Kingdom, pp. 701-713.
- McLeod, M. J., Guttman, S. I. and Eshbaugh, W. H. 1982. Early evolution of chili peppers (*Capsicum*). *Econ. Bot.* 36 (4): 361-368.
- McLeod, M. J., Guttman, S. I., Eshbaugh, W. H. and Rayle, R. E. 1983. An electrophoretic study of evolution in *Capsicum* (Solanaceae). *Evolution* 37 (3): 562-574.
- Montes de Oca, I. 1989. Geografía y recursos naturales de Bolivia. Editorial Educational, Ministerio de Educación y Cultura, La Paz, Bolivia, 574p.
- Naj, A. 1992. Peppers - A story of hot pursuits. Vintage Books, New York, USA, 245p.
- Pearsall, D. M. 1992. The origins of plant cultivation in South America. In: "The origins of agriculture - An international perspective", Cowan, C.W. and Watson, P.J. (eds.), Smithsonian Institution Press, Washington, D.C. USA, pp. 173-205.
- Pickersgill, B. 1971. Relationships between weedy and cultivated forms in some species of chili peppers (genus *Capsicum*). *Evolution* 25: 683-691.
- Pickersgill, B. 1986. Peppers (*Capsicum* spp.). In: "Guidelines for seed exchange and plant introduction in tropical crops", León, J. and Withers, L.A. (eds.), FAO Plant Production and Protection Paper No. 76, FAO, Rome, Italy, pp. 73-78.
- Pickersgill, B. 1989. Cytological and genetical evidence on the domestication and diffusion of crops within the Americas. In: "Foraging and farming - The evolution of plant exploitation", Harris, D.R. and Hillman, G.C. (eds.), Unwin Hyman Ltd, London, United Kingdom, pp. 426-439.
- Piper, C. V. 1926. Studies in American Phaseolinae. *Contr. US Nat. Herb.* 22 (9): 663-701.
- Ramírez E., R., Timothy, D. H., Díaz B., E. and Grant, U. J. 1960. Races of maize in Bolivia. National Academy of Sciences, National Research Council, Publication 747, Washington, D.C., USA, 159p.
- Rogers, D. J. and Appan, S. G. 1973. *Manihot* and *Manihotoides* (Euphorbiaceae) - A computer-assisted study. *Flora Neotropica*, Monograph No. 13: 1-272.

- Tohme, J., Toro, O., Vargas, J. and Debouck, D. G. 1995. Variability studies in Andean *nuña* common beans (*Phaseolus vulgaris*, Fabaceae). *Econ. Bot.* 49 (1): *in press*.
- Toro, O., Tohme, J. and Debouck, D. G. 1990. Wild bean (*Phaseolus vulgaris* L.): description and distribution. Centro Internacional de Agricultura Tropical, Cali, Colombia, 106p.
- Unzueta, O. 1975. Mapa ecológico de Bolivia. Memoria explicativa. Ministerio de Asuntos Campesinos y Agropecuarios. División de Riegos e Ingeniería, La Paz, Bolivia, 320p.
- Wellhausen, E. J., Roberts, L. M. and Hernandez Xolocotzi, E. 1952. Races of maize in Mexico. Their origin, characteristics and distribution. Bussey Institution, Harvard University, Harvard, Massachusetts, USA, 223p.
- Zijlstra, S., Purimahua, C. and Lindhout, P. 1991. Pollen tube growth in interspecific crosses between *Capsicum* species. *HortSci.* 26 (5): 585-586.

7. ANNEXES

Annex 1 - List of germplasm collections by numbers.

<u>Number</u>	<u>Species</u>	<u>Longitude</u>	<u>Latitude</u>	<u>Altitude</u>	<u>Date</u>
3000*	augusti	66°19'W	17°19'S	2650 m	09/V/1994
3001*	augusti	66°11'W	17°19'S	2830 m	09/V/1994
3002*	spp.	64°38'W	19°07'S	3200 m	14/V/1994
3003*	eximum	64°38'W	19°07'S	2290 m	14/V/1994
3004	baccatum	64°24'W	19°16'S	2150 m	14/V/1994
3005	eximum	64°24'W	19°16'S	2150 m	14/V/1994
3006*	augusti	64°21'W	19°17'S	2080 m	14/V/1994
3007*	vulg silv	64°21'W	19°17'S	2080 m	14/V/1994
3008	baccatum	64°20'W	19°17'S	2060 m	15/V/1994
3009	baccatum	64°20'W	19°17'S	2100 m	15/V/1994
3010*	augusti	64°27'W	19°23'S	2200 m	15/V/1994
3011*	vulg silv	64°27'W	19°23'S	2180 m	15/V/1994
3012*	vulg silv	64°27'W	19°32'S	1960 m	15/V/1994
3013	baccatum	64°26'W	19°35'S	1900 m	15/V/1994
3014	baccatum	64°28'W	19°37'S	1870 m	15/V/1994
3015	baccatum	64°11'W	19°28'S	2150 m	16/V/1994
3016*	chacoens	64°06'W	19°34'S	1200 m	16/V/1994
3017	lunatusc	64°06'W	19°34'S	1200 m	16/V/1994
3018*	manihot	64°05'W	19°35'S	1160 m	16/V/1994
3019*	chacoens	63°48'W	19°49'S	1160 m	17/V/1994
3020*	vulg silv	64°09'W	21°30'S	1270 m	18/V/1994
3021	vulg silv	64°16'W	21°25'S	1670 m	18/V/1994
3022	vulg cult	64°16'W	21°25'S	1700 m	18/V/1994
3023	vulg weed	64°45'W	21°32'S	1890 m	19/V/1994
3024*	vulg silv	64°36'W	22°14'S	1130 m	20/V/1994
3025*	vulg silv	64°51'W	21°18'S	2180 m	21/V/1994
3026	annuum	65°11'W	21°00'S	2240 m	21/V/1994
3027	eximum	64°46'W	20°35'S	2160 m	22/V/1994
3028	chacoens	64°46'W	20°35'S	2160 m	22/V/1994
3029	vulg cult	64°20'W	19°17'S	2140 m	15/V/1994
3030	vulg cult	64°20'W	19°17'S	2140 m	15/V/1994
3031	vulg cult	64°20'W	19°17'S	2140 m	15/V/1994
3032	vulg cult	64°20'W	19°17'S	2140 m	15/V/1994
3033	vulg cult	64°20'W	19°17'S	2140 m	15/V/1994
3034	vulg cult	64°20'W	19°17'S	2140 m	15/V/1994
3035	vulg cult	64°20'W	19°17'S	2140 m	15/V/1994
3036	vulg cult	64°20'W	19°17'S	2140 m	15/V/1994
3037	vulg cult	64°20'W	19°17'S	2140 m	15/V/1994

3038	vulgcult	64°20'W	19°17'S	2140 m	15/V/1994
3039	vulgcult	64°20'W	19°17'S	2140 m	15/V/1994
3040	vulgcult	64°20'W	19°17'S	2140 m	15/V/1994
3041	vulgcult	64°20'W	19°17'S	2140 m	15/V/1994
3042	vulgcult	64°20'W	19°17'S	2140 m	15/V/1994
3043	vulgcult	64°20'W	19°17'S	2140 m	15/V/1994
3044	vulgcult	64°20'W	19°17'S	2140 m	15/V/1994
3045	vulgcult	64°20'W	19°17'S	2140 m	15/V/1994
3046	lunatusc	64°46'W	20°35'S	2160 m	22/V/1994
3047	vulgcult	64°46'W	20°35'S	2160 m	22/V/1994
3048	vulgcult	64°46'W	20°35'S	2160 m	22/V/1994
3049	vulgcult	64°46'W	20°35'S	2160 m	22/V/1994
3050	vulgcult	64°46'W	20°35'S	2160 m	22/V/1994
3051	vulgcult	64°46'W	20°35'S	2160 m	22/V/1994
3052	vulgcult	64°46'W	20°35'S	2160 m	22/V/1994
3053	vulgcult	64°46'W	20°35'S	2160 m	22/V/1994
3054	vulgcult	64°46'W	20°35'S	2160 m	22/V/1994
3055	vulgcult	64°46'W	20°35'S	2160 m	22/V/1994
3056	vulgcult	64°46'W	20°35'S	2160 m	22/V/1994

* indicates that herbarium voucher specimens were deposited in La Paz (LPB), Cochabamba (BOLV), Ann Arbor (MICH), St. Louis (MO), New York (NY), and Berkeley (UC).

Annex 2 - List of germplasm collections by species.

<u>Number</u>	<u>Department</u>	<u>Longitude</u>	<u>Latitude</u>	<u>Altitude</u>	<u>Date</u>
---------------	-------------------	------------------	-----------------	-----------------	-------------

***Capsicum* chili peppers**

Capsicum annuum L. cultivated forms

3026	Chuquisaca	65°11'W	21°00'S	2240 m	21/V/1994
------	------------	---------	---------	--------	-----------

Capsicum baccatum L. cultivated forms

3004	Chuquisaca	64°24'W	19°16'S	2150 m	14/V/1994
3008	Chuquisaca	64°20'W	19°17'S	2060 m	15/V/1994
3009	Chuquisaca	64°20'W	19°17'S	2100 m	15/V/1994
3013	Chuquisaca	64°26'W	19°35'S	1900 m	15/V/1994
3014	Chuquisaca	64°28'W	19°37'S	1870 m	15/V/1994
3015	Chuquisaca	64°11'W	19°28'S	2150 m	16/V/1994

Capsicum chacoense A.T. Hunziker

3016	Chuquisaca	64°06'W	19°34'S	1200 m	16/V/1994
3019	Chuquisaca	63°48'W	19°49'S	1160 m	17/V/1994
3028	Chuquisaca	64°46'W	20°35'S	2160 m	22/V/1994

Capsicum eximium A.T. Hunziker

3003	Chuquisaca	64°38'W	19°07'S	2290 m	14/V/1994
3027	Chuquisaca	64°46'W	20°35'S	2160 m	22/V/1994

***Manihot* cassava**

Manihot

3018	Chuquisaca	64°05'W	19°35'S	1160 m	16/V/1994
------	------------	---------	---------	--------	-----------

***Phaseolus* beans**

Phaseolus augusti Harms

3000	Cochabamba	66°19'W	17°19'S	2650 m	09/V/1994
3001	Cochabamba	66°11'W	17°19'S	2830 m	09/V/1994
3006	Chuquisaca	64°21'W	19°17'S	2080 m	14/V/1994
3010	Chuquisaca	64°27'W	19°23'S	2200 m	15/V/1994

Phaseolus lunatus L. cultivated form

3017	Chuquisaca	64°06'W	19°34'S	1200 m	16/V/1994
3046	Chuquisaca	64°46'W	20°35'S	2160 m	22/V/1994

Phaseolus vulgaris L. cultivated forms

3029	Chuquisaca	64°20'W	19°17'S	2140 m	15/V/1994
3030	Chuquisaca	64°20'W	19°17'S	2140 m	15/V/1994
3031	Chuquisaca	64°20'W	19°17'S	2140 m	15/V/1994
3032	Chuquisaca	64°20'W	19°17'S	2140 m	15/V/1994
3033	Chuquisaca	64°20'W	19°17'S	2140 m	15/V/1994
3034	Chuquisaca	64°20'W	19°17'S	2140 m	15/V/1994
3035	Chuquisaca	64°20'W	19°17'S	2140 m	15/V/1994
3036	Chuquisaca	64°20'W	19°17'S	2140 m	15/V/1994
3037	Chuquisaca	64°20'W	19°17'S	2140 m	15/V/1994
3038	Chuquisaca	64°20'W	19°17'S	2140 m	15/V/1994
3039	Chuquisaca	64°20'W	19°17'S	2140 m	15/V/1994
3040	Chuquisaca	64°20'W	19°17'S	2140 m	15/V/1994
3041	Chuquisaca	64°20'W	19°17'S	2140 m	15/V/1994
3042	Chuquisaca	64°20'W	19°17'S	2140 m	15/V/1994
3043	Chuquisaca	64°20'W	19°17'S	2140 m	15/V/1994
3044	Chuquisaca	64°20'W	19°17'S	2140 m	15/V/1994
3045	Chuquisaca	64°20'W	19°17'S	2140 m	15/V/1994
3047	Chuquisaca	64°46'W	20°35'S	2160 m	22/V/1994
3048	Chuquisaca	64°46'W	20°35'S	2160 m	22/V/1994
3049	Chuquisaca	64°46'W	20°35'S	2160 m	22/V/1994
3050	Chuquisaca	64°46'W	20°35'S	2160 m	22/V/1994
3051	Chuquisaca	64°46'W	20°35'S	2160 m	22/V/1994
3052	Chuquisaca	64°46'W	20°35'S	2160 m	22/V/1994
3053	Chuquisaca	64°46'W	20°35'S	2160 m	22/V/1994
3054	Chuquisaca	64°46'W	20°35'S	2160 m	22/V/1994
3055	Chuquisaca	64°46'W	20°35'S	2160 m	22/V/1994
3056	Chuquisaca	64°46'W	20°35'S	2160 m	22/V/1994

Phaseolus vulgaris L. wild forms

3007	Chuquisaca	64°21'W	19°17'S	2080 m	14/V/1994
3011	Chuquisaca	64°27'W	19°23'S	2180 m	15/V/1994
3012	Chuquisaca	64°27'W	19°32'S	1960 m	15/V/1994
3020	Tarija	64°09'W	21°30'S	1270 m	18/V/1994
3021	Tarija	64°16'W	21°25'S	1670 m	18/V/1994
3024	Tarija	64°36'W	22°14'S	1130 m	20/V/1994
3025	Tarija	64°51'W	21°18'S	2180 m	21/V/1994

Phaseolus vulgaris L. weedy form

3023	Tarija	64°45'W	21°32'S	1890 m	19/V/1994
------	--------	---------	---------	--------	-----------

Annex 3

Trabajo de Recolección de Germoplasma de *Phaseolus* patrocinado por el Consejo Internacional de Recursos Fitogenéticos

Misión colaborativa entre el Centro Internacional de Agricultura Tropical (Cali, Colombia) y el Centro de Investigaciones Fitogenéticas de Pairumani - Cochabamba, la Universidad de California - Davis, con el apoyo del USDA.

HERBARIO

Nombre científico: Capsicum chacoense A. T. Hunziker
Determinavit: D.G. Debouck Fecha: 27/ V/ 1994
Nombre vulgar: aribibi
País/Estado/Municipio/Localidad: BOLIVIA, CHUQUISACA, Hernando Siles, 34 Km E de Monteagudo, en Cruz Pampa.

Longitud: 63° 48' W Latitud: 19° 49' S Altitud: 1160 m

Fecha de Recolección: 17/ V/ 1994

Observaciones: en bordes de arroyos en bosque semideciduo de Acacia, Bignoniacae, Compositae, Crotalaria. También en solares de casas y orillas de campos de maiz y mani. Suelo organico franco pardo arenoso. Semi soleado. Abundancia intermedia, donde no hay ganado. Traido en plantas por la gente. Consumido, en plena cosecha en marzo. Arbusto 1-1 m 50.

Colectores: D.G. Debouck, R. Rios, L. Guzman & P. Gepts
Nº: 3019 Se colectaron semillas bajo el Nº: 3019

Trabajo de Recolección de Germoplasma de *Phaseolus* patrocinado por el Consejo Internacional de Recursos Fitogenéticos

Misión colaborativa entre el Centro Internacional de Agricultura Tropical (Cali, Colombia) y el Centro de Investigaciones Fitogenéticas de Pairumani - Cochabamba, la Universidad de California - Davis, con el apoyo del USDA.

HERBARIO

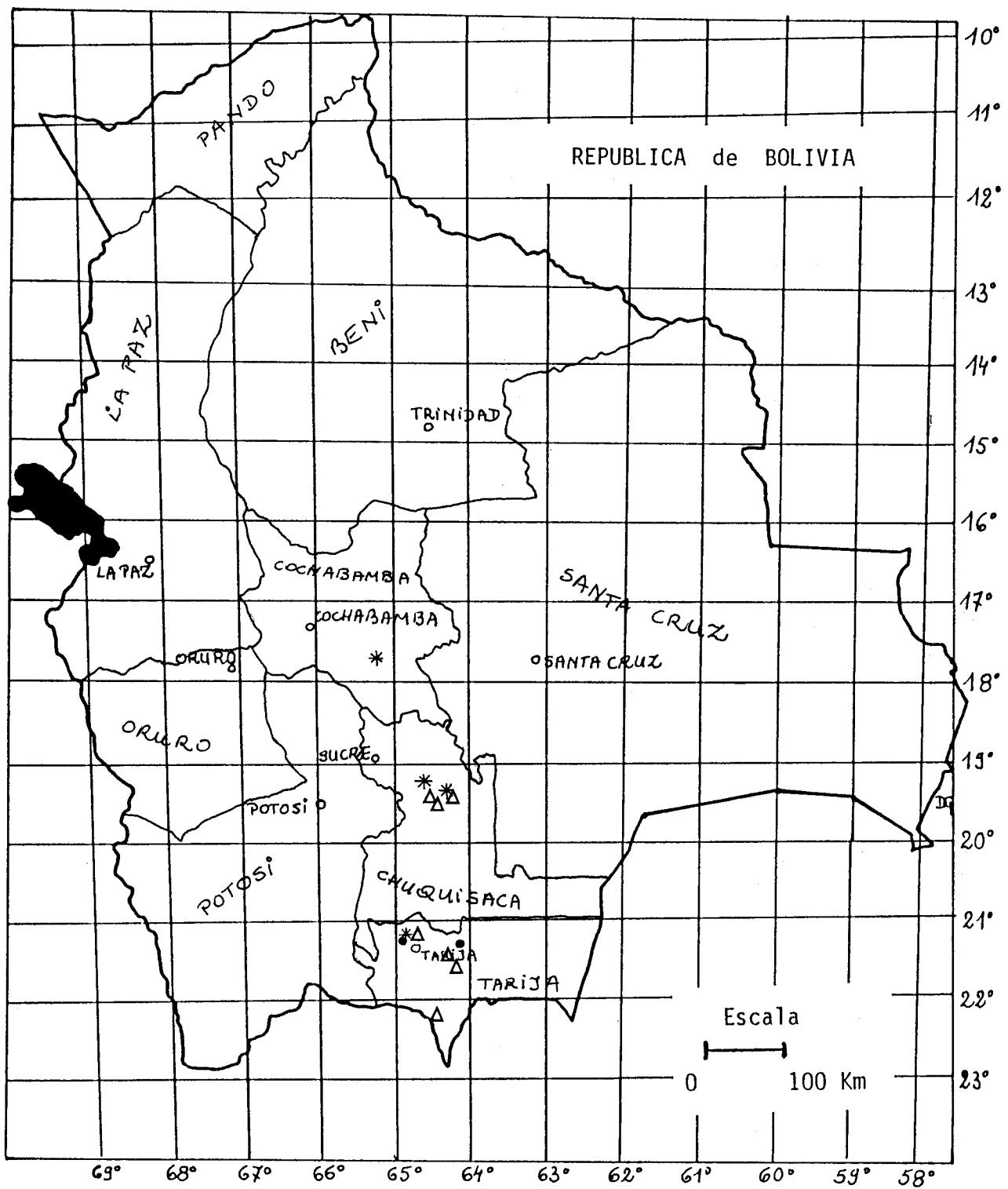
Nombre científico: Phaseolus vulgaris L. Forma silvestre
Determinavit: D.G. Debouck Fecha: 27/ V/ 1994
Nombre vulgar: porotito
País/Estado/Municipio/Localidad: BOLIVIA, TARIJA, Mendez, Trancas, 1 Km SW de la capilla de Trancas.

Longitud: 64° 51' W Latitud: 21° 18' S Altitud: 2180 m

Fecha de Recolección: 21/ V/ 1994

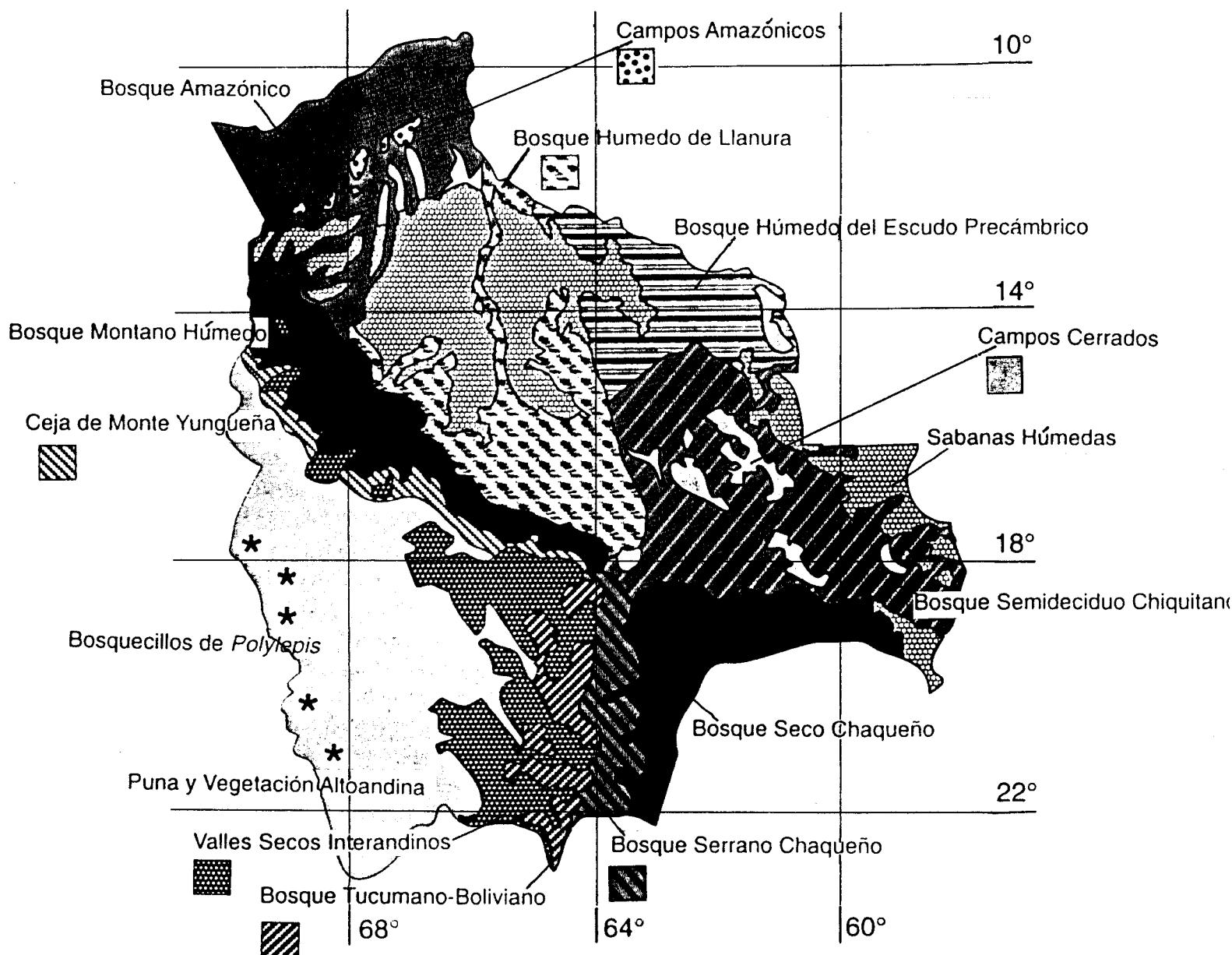
Observaciones: en matorrales al borde de los cultivos de maíz y porotos, con Compositae, Bidens, Solanaceae, Physalis, Ipomoea, Desmodium, Teramnus. Soleado abierto. Suelo franco organico pardo derivado de esquisitos duros. En madurez seca. Abundante pero muy localizado, donde no entra el ganado. Daños de pajaros, antracnosis. No lo comen.

Colectores: D.G. Debouck, R. Rios, L. Guzman & P. Gepts
Nº: 3025 Se colectaron semillas bajo el Nº: 3025

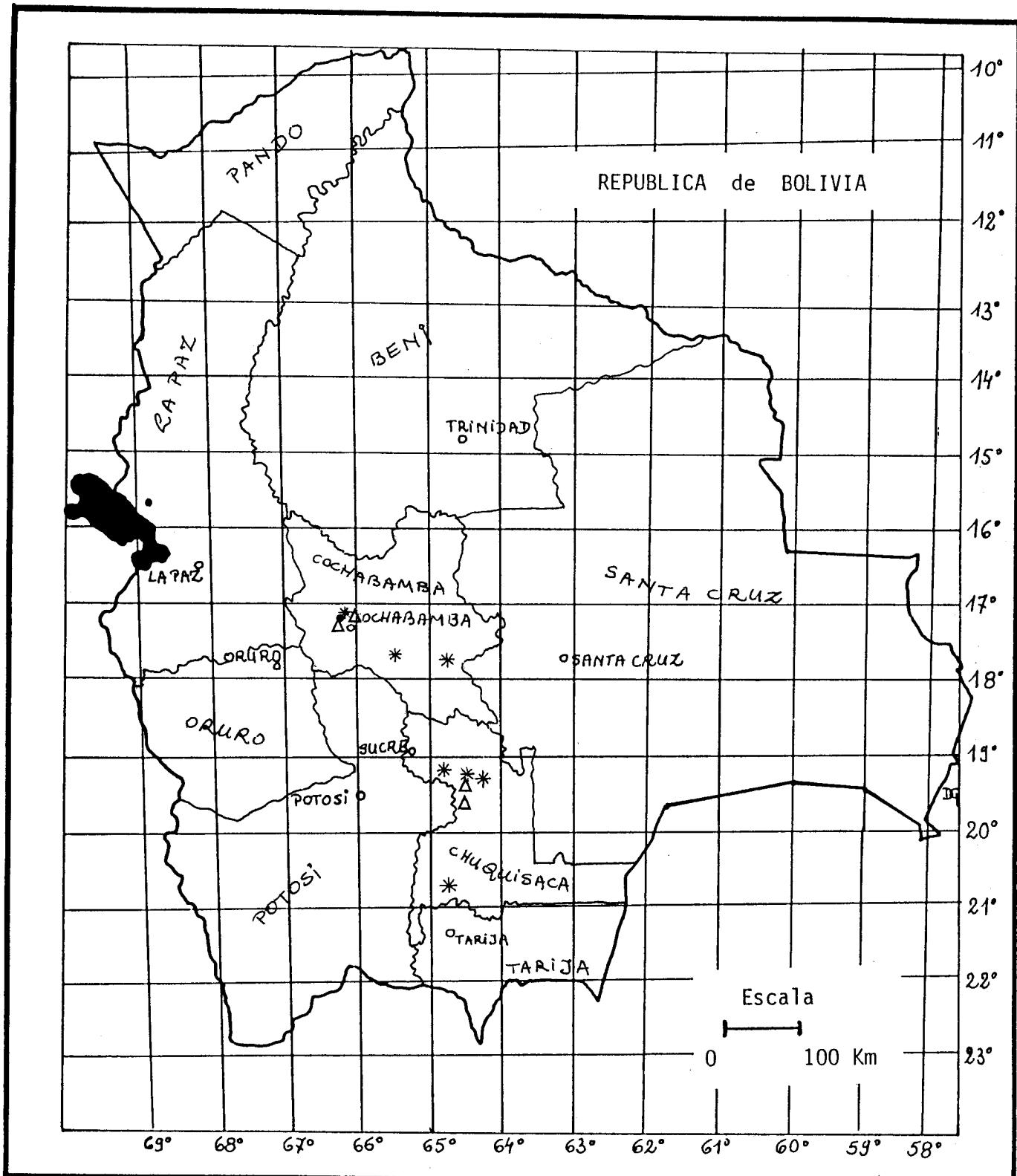


Map 1

- Distribution of wild *Phaseolus vulgaris* L. in Bolivia. Solid circles refer to past herbarium collections, stars refer to germplasm collections made in 1988, open triangles refer to germplasm collections done in 1994.



Map 2 - Distribution of vegetation types in Bolivia. Source: Beck et al., 1993.



Map 3

- Distribution of wild *Phaseolus augusti* Harms in Bolivia. Solid circles refer to past herbarium collections, stars refer to germplasm collections made in 1988, open triangles refer to germplasm collections done in 1994.