

Germplasm exploration for *Phaseolus* beans (Fabaceae, Phaseolinae) in
Costa Rica.

Collecting Mission supported by the Universidad de Costa Rica, Central
American Bean Network PROFRIJOL and the Centro Internacional de
Agricultura Tropical

Final report prepared by

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February 1998

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SUMMARY:

Interest in plant genetic resources in Central America has resumed because of disease pressures (e.g. web blight, BGMV) as well as limits of current bean varieties. As most of the diversity in landraces has been explored, focus is now on wild forms of primary gene pool and wild species of secondary gene pool.

This exploration results in the disclosing of 29 wild populations for six species. Nine more populations were found for *P. costaricensis*, 10 for wild *P. lunatus*, one for *P. oligospermus*, one for *P. tuerckheimii*, four for wild *P. vulgaris* and four for *P. xanthotrichus*. Ninety-three herbarium voucher specimens were collected for 19 populations of the six species (left at CR). These results confirm the presence of wild *P. vulgaris* on both slopes of the central valley of Costa Rica, namely in the life zones bh-MB and bmh-P, and of *P. costaricensis* in the life zone bmh-MB. These life zones of limited range in Costa Rica have been heavily cut down, thus fully justifying the germplasm collection. For both species the range of distribution has been almost completely sampled. *P. costaricensis* is likely absent in Cordillera de Tilarán, and the probability to find it in the Coto Brus mountain is low.

The availability of germplasm will allow progress in evaluation and wide crossing. It will also allow to address pending questions about the origin of Central American small seeded common and Lima bean groups of cultivars.

RESUMEN:

El recién aumento de presión de enfermedades (p.ej. mosaico dorado, mustia) y las limitaciones de las actuales variedades de frijol en Centroamérica han vuelto a despertar interés en los recursos genéticos. El fitomejorador se fijará primero en el acervo genético primario y luego considerará a los acervos secundarios y otras especies afines. El interés para buscar nuevos genes se enfoca ahora en el germoplasma del pariente silvestre del frijol común y las especies silvestres directamente relacionadas. A continuación de una exploración hecha en Costa Rica en 1987, se trató de ampliar el germoplasma existente, especialmente 2 poblaciones de *Phaseolus vulgaris* silvestre y 11 poblaciones de *P. costaricensis*, con el descubrimiento de nuevas poblaciones en nuevos sitios ecológicos.

Esta exploración permitió descubrir 29 nuevas poblaciones para 6 especies, así: *P. costaricensis* (9), *P. lunatus* (10), *P. oligospermus* (1), *P. tuerckheimii* (1), *P. vulgaris* (4) y *P. xanthotrichus* (4). Se colectaron además 93 muestras de herbario (depositadas en CR). Estos resultados nos confirman la presencia de *P. vulgaris* en las dos vertientes del Valle Central de Costa Rica (especialmente en las zonas de vida bh-MB y bmh-P), y la de *P. costaricensis* en la zona de vida bmh-MB. Esta zona de vida de escasa extensión en Costa Rica ya vienen muy intervenidas, confirmando la importancia de la colecta. Para ambas especies se tiene actualmente el rango de distribución natural prácticamente muestreado (*P. costaricensis* está ausente en la Cordillera de Tilarán; queda una baja probabilidad de encontrarlo en la Cordillera de Coto Brus).

La disponibilidad de germoplasma permitirá de avanzar en la identificación de características útiles; además nos permitirá de repente contestar la vieja pregunta del origen de las variedades centroamericanas.

INTRODUCTION

Increased disease pressure particularly of web blight (Gálvez *et al.*, 1989) and bean golden mosaic virus (Beebe and Pastor Corrales, 1991), and the need for drought tolerance and higher yield (Boucher, 1983) has renewed interest in screening more bean germplasm of Central American origin in Central American countries. Such germplasm collected in the 1950-1960s and conserved namely in USDA, CATIE, Chapingo, El Zamorano and CIAT gene banks has been screened to a large extent so far, and has resulted in the production and diffusion of many popular varieties (Voyses, 1983; Voyses *et al.*, 1994). Sources of

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resistance have been broken in some cases, new constraints (e.g. drought because of climatic alterations such as "El Niño") appear in other cases; there was thus an interest in screening novel germplasm, and so first in looking for it.

Searching novel germplasm once landraces have been mostly explored means exploring further the primary gene pool, that is the wild ancestral forms and weedy races, and at a later stage the secondary gene pool (Harlan, 1992; Harlan and de Wet, 1971). So, if the interest by bean breeders is primarily focused along those lines (Singh, 1992), the focus should be on wild forms of *Phaseolus vulgaris* L. and on species such as *P. polyanthus* Greenman, that have been known for long as belonging to the secondary gene pool (Smart, 1985; Smart, 1990). A species recently discovered *P. costaricensis* Freytag & Debouck (Freytag and Debouck, 1996) has been shown to belong to the secondary gene pool of common bean as well (Schmit *et al.*, 1993; Singh *et al.*, 1997a).

Few germplasm explorations have been carried out recently in Costa Rica for *Phaseolus* bean germplasm. Worth mentioning is the exploration by Hazlett (Hazlett, 1986): this exploration was carried out in Indian reservations of Southeast Costa Rica, looking for traditional landraces but did not include the search for wild germplasm. The search for wild germplasm implies an in-depth knowledge of the different species to be looked for, particularly their taxonomy, ecology and genetic relationships; a particular aspect here includes possibilities of wide crossing.

The genus *Phaseolus* for Costa Rica still needs full revision: no recent review has been carried out although the work of (Delgado Salinas, 1985) indeed covers Central America. From the 13 species reported by (Standley, 1937), not all of them are presently accepted as belonging to the genus *Phaseolus sensu stricto* as widely understood today (Delgado Salinas, 1985; Lackey, 1983; Maréchal *et al.*, 1978). Table 1 sums up the most recent synonymy.

Table 1 – *Phaseolus* species once reported for the Flora of Costa Rica and revised synonymy.

Names as per Flora of Costa Rica (1937)	Names currently accepted	Authority
<i>Phaseolus adenanthus</i> Meyer	<i>Vigna adenantha</i> (Meyer) M.M.S.	1
<i>P. anisotrichos</i> Schlecht.	<i>Phaseolus leptostachyus</i> Benthham	2
<i>P. atropurpureus</i> DC.	<i>Macroptilium atropurpureum</i> (DC) Urban	3
<i>P. coccineus</i> L.	<i>P. coccineus</i> L. (see Comments below)	
<i>P. gracilis</i> Poepp.	<i>Macroptilium gracile</i> (Poepp.) Urban	3
<i>P. lunatus</i> L.	<i>P. lunatus</i> L.	
<i>P. obvallatus</i> Schlecht.	<i>P. costaricensis</i> Freytag & Debouck	4
<i>P. oligospermus</i> Piper	<i>P. oligospermus</i> Piper	
<i>P. peduncularis</i> HBK	<i>Vigna peduncularis</i> (HBK) Fawcett & Rendle	5
<i>P. pilosus</i> HBK	<i>Vigna lasiocarpa</i> (Benthham) Verdcourt	6
<i>P. speciosus</i> HBK	<i>Vigna speciosa</i> (HBK) Verdcourt	6
<i>P. vulgaris</i> L.	<i>P. vulgaris</i> L.	
<i>P. xanthotrichus</i> Piper	<i>P. xanthotrichus</i> Piper	

Sources:

- 1: (Maréchal *et al.*, 1978)
- 2: (Delgado Salinas, 1985)
- 3: (Urban, 1928)
- 4: (Freytag and Debouck, 1996)
- 5: (Fawcett and Rendle, 1920)
- 6: (Verdcourt, 1970)

Apart from the straightforward re-classification of taxa within the genera *Macroptilium* and *Vigna*, Table 1 also suggests the following. One should note that in *Flora of Costa Rica* *P. vulgaris* is reported as cultivated ("A plant of American origin, but unknown in a wild state", wrote Paul C. Standley in 1937). Common bean as wild was reported for the first time for Costa Rica after our exploration of 1987 (Debouck *et al.*, 1989). By then two populations were known from the province of San José (one around Aserri and

one around Tarbaca), and we were interested in checking the range of wild *P. vulgaris* in Costa Rica. *P. lunatus* was reported as wild plant, from "Meseta Central", and indeed several populations were found in 1987 (Debouck *et al.*, 1989). Additional surveys were also carried out recently in order to understand genetics and demography aspects of such populations (Degreef *et al.*, 1997; Maquet *et al.*, 1996).

As discussed elsewhere (Freitag and Debouck, 1996), *P. obvallatus*, a species with hypogeal germination and scarlet flowers, long included within *P. coccineus* and its allies (Piper, 1926), probably does not exist east of Sierra de Miramundo in Jalapa, Guatemala. It actually corresponds to *P. costaricensis*, a species with epigeal germination and crese flowers.

It seems that there is some confusion about *P. coccineus* too: Standley (op cit.) wrote: "Cubá. Common in forests and thickets of the central region, also cultivated. ... flowers large, white, purple, or reddish, in very long racemes". From our extensive field work in Central America and Costa Rica, it seems that Standley (op. cit.) refers to cultivated *P. polyanthus* Greenman (called 'cuba' in Costa Rica), or to feral forms of the same species. Such forms are often observed in secondary rain forest with *Cecropia* (both being white-flowered), and to *P. costaricensis* (specimens from F herbarium seen by us; but with flowers not reddish nor purple). There is still a possibility that Standley could refer to cultivated and feral forms of *P. coccineus*, although this taxon is very rare in Costa Rica. In our view, it was probably introduced recently by European immigrants as ornamental (a viewpoint also shared by (Pittier, 1978); it is also frequently introgressed with *P. polyanthus* and does not look pure (so the typical true scarlet colour in flower is almost never seen).

P. leptostachyus is indeed present in Costa Rica, thus extending the range known so far (up to Nicaragua: Delgado Salinas, 1985), as revealed by our exploration (Debouck *et al.*, 1989). *P. oligospermus* was known only by the type collection prior to our activities in Costa Rica, and *P. tuerckheimii* was not reported for this country (Delgado Salinas, 1985).

The exploration carried out in 1987 the results of which are presented in Table 2 served much as a background to this one.

Table 2. Results of 1987 University of Costa Rica- CIAT-IBPGR exploration

Species	Populations sampled
<i>P. costaricensis</i>	11
<i>P. leptostachyus</i>	2
<i>P. lunatus</i>	14
<i>P. oligospermus</i>	1
<i>P. polyanthus</i> (escaped)	1
<i>P. polyanthus</i> (crossed)	1
<i>P. talamancensis</i>	1
<i>P. tuerckheimii</i>	6
<i>P. vulgaris</i> (wild)	2
<i>P. vulgaris</i> (weedy)	2
<i>P. xanthotrichus</i>	5
Total: 11	46

As revealed by our previous exploration, *P. leptostachyus* and *P. talamancensis* are early materials, maturing in November-December, and therefore beyond reach if we look for wild *P. vulgaris* and other related taxa which mature in January-March. The problem is not that serious for *P. leptostachyus*, as this species is with $2n = 2x = 20$ (Delgado Salinas, 1985), and therefore likely quite remote for wide crossing possibilities with the common bean (Sullivan and Freitag, 1986). Too little is known about *P. talamancensis* and every attempt should be made to increase knowledge about it. Explorations at this time of the year are likely to not allow the finding of *P. talamancensis*.

So, the objectives of this field exploration were to:

- + Confirm the presence of wild *P. vulgaris* in Costa Rica and expand knowledge about its range of distribution,
- + Sample further species of the secondary gene pool, namely *P. costaricensis*,
- + Increase germplasm availability of other species,
- + Generate knowledge about conservation status of those species.

RESULTS

1. General:

A total of 29 populations were found for 6 species, as shown in Table 3, Annexes 1 and 2.

Table 3. Number of species and samples per species found during this exploration (each population is indicated by the collection number).

Species	Populations	Total
Costaricensis	3111, 3112, 3113, 3115, 3118 3120, 3122, 3127, 3128	9
Lunatus	3103, 3105, 3108, 3114, 3117 3119, 3123, 3124, 3129, 3130	10
Oligospermus	3107	1
Tuerckheimii	3110	1
Vulgaris	3106, 3121, 3126, 3131	4
Xanthotrichus	3104, 3109, 3116, 3125	4
Total: 6	29	29

Itinerary

The following itinerary was followed:

Tuesday 3 February 1998: Heredia- Barba- San José de la Montaña- Porrosati- Birrí- Chagüites- Poasito- Alajuela. Collections around Barba (# 3103), San José de la Montaña (# 3104), Birrí (# 3105) and Chagüites (# 3106).

Wednesday 4 February: Cartago- Tejar- San Cristobal Norte- Llano Los Angeles- Santa Elena- Frailes- San Cristobal Sur- Empalme- División- San Isidro El General. Collections around San Cristobal Norte (# 3107, 3108), Frailes (# 3109) and Jardín de Paramó (# 3110).

Thursday 5 February: San Isidro- Rivas- Chimirol- Canaán- Herradura- Pueblo Nuevo de Ríos- Palmital- Buena Vista- La Piedra- Piedra Alta- División- San Isidro. Collections around Herradura (# 3111) and La Piedra (# 3112 and 3113).

Friday 6 February: San Vito- La Unión- La Lucha- Las Mellizas- Fca. La Caprosa- Beneficio Rio Negro- Alturas de Coton- San Vito. Collection around La Lucha (# 3114).

Saturday 7 February: San Vito- San Isidro- Cartago- Cot- Paso Ancho- Cipreses- Pacayas- Cartago- San José. Collections around Cot (# 3115, 3116 and 3117) and Pacayas (# 3118).

Sunday 8 February: Heredia- Alajuela- Grecia- Sarchi Sur- La Luisa- Bajos del Toro- Pueblo Nuevo- Palmira- Zarcero- Laguna- La Peña- Tapezco- Zapote-Zarcero- San Juanillo- Naranjo-Heredia. Collections around La Luisa (# 3119), Tapezco (# 3120) and Zarcero (# 3121).

Monday 9 February: Heredia- Guacimal- San Luis- Los Cerros- Los Llanos- Santa Elena- Monte Verde- Las Nubes- Cebadilla- San Rafael de Abangares- Candelaria- Las Juntas- San José. Collections around Los Llanos (# 3123) and Cebadilla (# 3124).

Tuesday 10 February: Cartago- Quircot- Pacayas- Capellades- Santa Teresa- Valle Río Coliblanco- Valle Río Birris- Pacayas- Cartago- Tobosí. Collections around Quircot (# 3125, 3126, 3127), Capellades (# 3128) and Tobosí (# 3129).

Wednesday 11 February: San José- Tobosí- Tablón- Coralillo- Alumbre- San Juan Norte- Jericó- El Llano de Desemparados- Desemparados- San José. Collections around San Juan Norte (# 3130) and Jericó (# 3131).

Total: 1,977 Km.

Seed Samples

Germplasm has been collected for all populations with the exception of # 3110, 3111, 3117, and 3128, which were to be visited at a later date (March), given the fact they were found at the pod filling stage (see Annex 1). Original seeds were left with the University of Costa Rica, asking for a sample to be deposited at CIAT for safe conservation.

Herbarium Samples

Voucher specimens have been collected for 19 populations, resulting in 93 samples (see Annex 1). All samples were given to the Herbario Nacional de Costa Rica (CR) at the Museo Nacional, San José for their safe keeping and distribution. The low number or lack of voucher specimens is due to the maturity of the populations in the field, or lack of significant variation for making voucher specimens.

2. Per Species

Phaseolus costaricensis Freytag & Debouck

During this exploration, we are able to find nine (9) novel populations, thus extending the number of known populations sampled to 20 (11 were found in 1987).

As we found this species to be particularly distributed in the life zone bnh-MB, we were interested in checking two other zones with the same characteristics as per the ecological maps (Bolaños M. and Watson C., 1993; Tosi, 1969): the Cordillera de Tilarán and the Sierra of Coto Brus. No populations were found in either places. In the national park of Monte Verde in the Cordillera de Tilarán, we quickly topped against a bp-MB, that is, a montane rain forest too humid for *P. costaricensis* to thrive or to disperse seed. A similar situation was found in the Sierra of Coto Brus, close to the border with Panama; we were locally informed however that this life zone exists in that region but further to the north- northeast. Two pending questions thus are: why it is not reported on the map?; could that life zone exist in spite of a high altitude?

From the present results and those of 1987, it seems that the range of distribution of *P. costaricensis* in Costa Rica is basically restricted to the southern slope of the Cordillera Volcánica (volcanoes Platanar, Poas, Barba, Irazú and Turrialba), the northern slope of Fila de Cedral (Cerros de Escazú) and the upper valleys of rivers Pirris, Savegre and Chirripó. The collections # 3120 (close to Tapezco) and # 3128 (Río Birris) mark the extremes of the range along Cordillera Volcánica, to the west and east, respectively. We collected in 1987 two populations (# 2102, 2116) in the Cerros de Escazú- Altos de Alajuelita region. The collection # 2132 represents the sampling in the upper Río Savegre. The collection # 2122 was from the upper Río Pirris. The collections # 2128, 3111, 3112, 3113 represent the sampling in the upper valley of Río Chirripó. The populations not sampled yet in Costa Rica would be few.

Populations were found in the pod filling stage, some already with mature seeds, many still with blooming inflorescences, indicating that end of February is adequate for picking up germplasm. As noticed already in 1987, vines are of great size, some reaching 6 m high. Habitat corresponds to natural openings (e.g. river banks) of primary low montane moist forest and old secondary growth forest in the bnh-MB zone, generally between 1,500- 1,880 masl. Frequent trees were of the genera *Cedrela*, *Inga*, *Cecropia*, *Quercus*, *Heliocarpus*, *Alnus*. Vines which are abundant in this forest include species of *Ipomoea*, *Passiflora* and *Sicyos*; *P. polyanthus* has been found as a companion vine species with the following populations # 3115, 3118, 3120, and 3127. Tree ferns, palms and small bamboos are also seen. The understory is rich in Melastomataceae, Compositae (*Ageratum*, *Dahlia*), Balsaminaceae (*Impatiens*), Piperaceae, Solanaceae, Malvaceae (*Hibiscus*). Plants thrive well in the shade and mists can be frequent. Soils are generally deep, moist, mulchy, rich in organic matter, derived from volcanic ashes, andesites, and other igneous rocks (diorites, gabros). When known locally (# 3112), it is called "cuba de venado", but apparently not eaten. Pollination is by bumble bees and hummingbirds (# 3120). If undisturbed, it can be locally abundant (more than 30 plants per 100 m²). Population # 3120 has been found affected by rust.

Phaseolus lunatus L.

This species was mentioned as wild by (Pittier, 1978), (Piper, 1926) and (Standley, 1937); it is common in the Central Valley. We added ten (10) populations to the sampling.

As expected, we found it in the Valle Central, on the slopes of the Cordillera Volcánica Central, but also on the foothills of the Cordillera de Tilarán (# 3123, 3124) and the Coto Brus mountain (# 3114), which are novel additions to the Flora of Costa Rica. It is common in secondary thickets of the life zones bh-P, bnh-P (variants of the premontane forest), bh-MB (variants of the lower montane forest) (Hartshorn, 1983). These vegetations have now been largely replaced by coffee plantations (e.g. Valle of Río Jérico, # 3130), commercial plantings of ornamentals (e.g. valley Southwest of Cartago, # 3129), and sugarcane (surroundings of Sarchi, # 3119). Under low grazing and low fire pressure, in abandoned fallow spots, wild Lima bean populations often endure. Most populations were found at the end of the pod filling – mature dry pod stage, indicating that February is the right period for finding seed germplasm. It is found in groups of 5-20 plants 2-5 m high climbing on shrubs and small trees. Currently associated vegetation includes: trees of *Cassia*, *Gliricidia sepium*, *Cecropia*, *Erythrina*, *Inga vera*, *Trema micrantha*, shrubs of *Lantana*, *Solanum*, *Sida*, *Ageratum*, *Verbesina*, grasses such as *Gynerium sagittatum* and a lot of thin-stemmed woody vines such as *Cayaponia attenuata* (Janzen, 1983). Being relatively abundant, it is not surprising to find it associated with other *Phaseolus* species; so, we have found it with *P. costaricensis* (# 3115), *P. oligospermus* (# 3107), *P. vulgaris* (# 3131), *P. xanthotrichus* (# 3109, 3116). This species is a heliophytic one, often climbing in open, sunny spots. Soils on which populations were found were quite heterogeneous, although often derived from volcanic ashes and igneous rocks, in most cases of Quaternary origin (Tournon and Alvarado I., 1997). We have seen damage of *Apion* in # 3114 and 3129.

Phaseolus oligospermus Piper

We found one additional population (# 3107) of this species, bringing the number of populations known for Costa Rica to two (2) populations. This finding is particularly useful as it confirms the presence of this species in this country. In 1987 we found it (# 2091) at the type locality just north of Cartago. This time we found it close to San Cristobal Norte in the province of San José, at 1,400 masl. The material was found in full dry maturity, indicating seed dispersal in February. Its habitat seems restricted to the bh-P (bosque húmedo premontano), a humid premontane forest, where a lot of human settlements, as recognized by (Bolaños M. and Watson C., 1993), and numerous coffee plantations have been established. Only four zones with that vegetation type apparently exist in Costa Rica (Tosi, 1969): the valley of Cartago (where # 2091 was found), the valley of Río Grande de Candelaria (where # 3107), the valley of Río Virilla (where the cities of San José, Heredia and Alajuela have been established), and the region between San Ramón and Zarcero. More field work should be done in the later where changes in land use are also noticeable (coffee plantations, sugarcane, ornamental plants).

Phaseolus tuerckheimii Donnell Smith

We found one more population # 3110 (which complements collection # 2131 of 1987, 200 m above it), so resulting in seven populations sampled so far in Costa Rica. It was found in the early pod filling period, indicating that March-April is the appropriate period for seed germplasm. It was found in the bp-MB, that is a moist almost evergreen montane forest with frequent mist, rich in *Alnus*, *Dahlia*, *Begonia*, *Macleania*, *Rubus*, Melastomataceae, Orchidaceae, and ferns. Escaped *P. polyanthus* was also found with this population. At that site soil is of rich organic matter, derived from metamorphic schists. A vine of 2-4 m high; it was found at low density of 1-10 plants/ 500 m². In our view it would not survive long the cutting of the original forest.

Phaseolus vulgaris L.

We added four novel populations (# 3106, 3121, 3126 and 3131) to the two ones disclosed in 1987 (# 2097 and 2111). The novel populations were found on the northern slope of the Central Valley (# 3106, 3121 and 3126) and on the southern slope of it (# 3131). All populations were found at dry maturity, indicating that seed dispersal usually takes place around February. They were found in old secondary growth thickets rich in Compositae (*Ageratum*, *Verbesina*, *Dahlia*), Convolvulaceae, Lamiaceae, Solanaceae and Leguminosae (*Desmodium*, *Teramnus*, *Inga*), where they were climbing up to 4 m high on small trees and bushes. Spots are open, sunny; soils are generally derived from old volcanic ashes, basalts, other igneous rocks, well drained, fertile and deep. If the populations are generally numerous (between 30 and 50 seed setting plants

could be counted in each location), they are quite localized in occupying a spot of 100-200 m². The range of wild common bean in Costa Rica corresponds to that of continental, relatively dry variants of the life zones bmh-P, bh-MB and bmh-MB. These are humid forests of the Premontane and Low Montane zones as defined by (Bolaños M. and Watson C., 1993). The range of altitudes was 1,510- 1,610 masl.

Population # 3121 was with shiny, jet-black seed, and found affected by bruchids. Population # 3126 clearly showed signs of introgression with cultivated beans, as evidenced by larger seed sizes, and striped patterns. It was growing in the middle of a corn field planted with beans (including of the species *Phaseolus polyanthus* Greenman), amaranths and *Arracacia xanthorrhiza* Bancr.. Population # 3131 was known locally by rural inhabitants as "frijol de venado" and seasonally consumed as snap bean; rural inhabitants reported regression of the population in recent years. This information somewhat confirms our own feelings that wild *P. vulgaris* L. is endangered in the Valle Central because of habitat destruction (e.g. the surroundings of Quircot, where # 3126 was found, or the planned park in the valley of Río Seco where # 3121 was found) and overgrazing (# 3106 was found only in one corner of the land where cattle would not enter because of the proximity of the cliff).

Phaseolus xanthotrichus Piper

Some four additional populations (# 3104, 3109, 3116, 3125) of this short-living perennial species have been found during this exploration, expanding the number of known populations to nine. Materials were found at full dry maturity, indicating that February is the period of seed dispersal. They were found in the life zones bmh-P and bh-MB, with annual rainfall of 2,000 mm or more (Bolaños M. and Watson C., 1993). Under that amount of rainfall, with tuberous rounded roots, this species can survive only on deep, brown, well-drained soils that are derived from old evolved volcanic ashes. Populations are generally small (less than 20 individuals), growing in the shade of the understory. Vines are generally less than 2 m and thus not noteworthy. It is therefore possible that more populations exist but have been passed along unnoticed so far. Pods have been observed with damages by birds (in # 3104); powdery mildew is often affecting leaves at the end of the growing cycle (in # 3104). The absence of *Apion* weevil is worth noting.

DISCUSSION

Several points emerge from our results, in relation to the geographic distribution of *Phaseolus* species in Costa Rica, their conservation status in the field, and the possibilities for future use. We shall particularly concentrate on species of interest for the near future.

First, wild common beans found during this exploration can be claimed as wild, because of their unique attributes as of wild plants: very small seed size, speckled pattern with grey and black colours, explosive pod dehiscence, strong climbing habit. Such traits have been seen in other populations across the range (Brücher, 1988; Delgado Salinas *et al.*, 1988; Toro Ch. *et al.*, 1990). Wild common bean seems to be more frequent than initially thought in Costa Rica. A working hypothesis is that this legume species was relatively widespread in the Valle Central where precisely human settlements were established. From our results, its range extends almost all across the Valle Central, from around Sarchi to the West to Cartago to the East, across the most densely peopled areas of Costa Rica. Our exploration of 1987 (Debouck *et al.*, 1989) has revealed its presence for the first time in Costa Rica, and on the southern slope of the central valley; this time we know wild common bean is also distributed on the northern slope of such valley. Several authors (Delgado Salinas *et al.*, 1988; Freyre *et al.*, 1996; Gentry, 1969) have noted that the range of wild common bean may have benefited from human disturbance. Yet the replacement of the original vegetation by a short size vegetation or frequently cleared bush e.g. on roadsides is conducive to the extinction of wild beans. As discussed elsewhere (Beebe *et al.*, 1997), the survival of wild *P. vulgaris* seem to be linked to the maintenance of a weedy environment with periodic (say every 10-20 years) disturbances. Higher frequencies of clearing will probably favour a grassland habitat instead of a mixed bush where wild common beans usually thrive.

A third case (after the two ones found in 1987) of wild-weed-crop complex was found during this exploration, above Quircot in Cartago. There wild forms freely intercrossed with landraces resulting in pole types with intermediate seed size and strong dehiscence. This type of gene flow has been documented in other parts of the range of wild *P. vulgaris* (Beebe *et al.*, 1997). It could be indicative of conditions through

which variability can be generated and incorporated into landraces, an indirect or direct incentive for plant domestication. Our results would allow testing whether wild beans were indeed domesticated in Costa Rica or not. The origin of race Mesoamerica (Singh *et al.*, 1991) is not yet fully established, although its origin in Central America is little disputed; this recently collected material could be very useful as to trace the origin of the small seeded Central American black and red types.

Second, about *P. costaricensis*. Perhaps all populations that can be found in Costa Rica have been sampled. As discussed above, it is unlikely that this species exists in the Cordillera de Tilarán (where the last piece of bnh-MB forest to the Northwest has been reported: (Tosi, 1969)). Such mountainous range was visited in vain this year. The inner slope of the Cordillera Volcánica has been extensively sampled, and the extreme populations have been located. Perhaps a few populations could still be sampled on the southern slope of Cordillera de Talamanca (namely the Coto Brus region); they can be accessed only walking and thus require another collecting methodology. As indicated elsewhere (Freytag and Debouck, 1996), many populations of this species could be considered as endangered; indeed we could not locate #2126 disclosed in 1987. We suspect this population has been destroyed as a consequence of landslides after the tornado of 1994. Generally, *P. costaricensis* would not survive long after the cutting of the primary montane moist forest. An important trait for the survival of populations of wild beans (as shown elsewhere on a Lima bean model: (Degreef *et al.*, 1997) is the early and massive seed setting. From our field observations about *P. costaricensis*, it seems that massive seed setting occurs late in the life cycle of the species, i.e. after 3-4 years, not making it fitted to habitats with frequent disturbances, where species such as *P. vulgaris* and *P. lunatus* would better adapt. On the other hand, the availability of germplasm for nine additional populations shall allow to make further progress in germplasm evaluation and wide crossing, where this species has shown great promise (Singh *et al.*, 1997b).

Third, wild Lima bean is perhaps the species with lower risk of extinction at broad level in comparison to the others, even if many populations in the central valley are at risk (Degreef *et al.*, 1997). It is presently colonizing the life zones bh-P, bnh-P and bh-MB, representing in total an extended area in central Costa Rica on the Pacific side (Bolaños M. and Watson C., 1993; Sawyer and Lindsey, 1971; Tosi, 1969). Some management practices such as the non weeding of borders in coffee plantations seem to favour certain populations. On the other hand this germplasm shall also be useful in crop evolution studies as the origin of the small seeded gene pool of *P. lunatus* is still poorly understood (Fofana *et al.*, 1997; Gutiérrez Salgado *et al.*, 1995; Maquet *et al.*, 1993).

CONCLUSIONS

Twenty populations of *P. costaricensis* have been sampled so far in Costa Rica; this is close to the maximum number of possible populations for that country. Several populations could be considered at risk.

Six populations of wild *P. vulgaris* are now known for Costa Rica; they were found on both slopes of the central valley. This germplasm should be considered in evolutionary studies about origin of Central American bean varieties. Several of these populations will probably disappear soon because of the extension of human activities to those areas.

Acknowledgements

This exploration would have been impossible without the efficient, friendly, and enthusiastic collaboration of my colleagues: Rodolfo Araya Villalobos, Fausto Camacho Chacón, Patricia Sánchez Trejos and William González Ugalde. We are particularly grateful to Drs. A.v. Schoonhoven and R. Lepiz for their continuing support and interest. We also would like to deeply acknowledge the financial support of Universidad de Costa Rica, the Central American Bean Network PROFRIJOL, and the Centro Internacional de Agricultura Tropical. The help of Sandra Albarracín in the final setting of the manuscript is appreciated.

LITERATURE CITED

- Beebe, S., O. Toro Ch., A.V. González, M.I. Chácon, D.G. Debouck, 1997 Wild-weed-crop complexes of common bean (*Phaseolus vulgaris* L., Fabaceae) in the Andes of Peru and Colombia, and their implications for conservation and breeding. *Genet. Resources & Crop Evol.* 44: 73-91.
- Beebe, S.E., M. Pastor Corrales, 1991 Breeding for disease resistance. *In: A. van Schoonhoven and O. Voysest (eds.) Common beans: research for crop improvement.* Commonwealth Agricultural Bureaux International, Wallingford, United Kingdom. pp. 561-617.
- Bolaños M., R.A., V. Watson C., 1993 Mapa ecológico de Costa Rica. Centro Científico Tropical. Scale 1:200.000. 9 sheets, San José, Costa Rica.
- Boucher, D.H., 1983 Common beans (Frijoles). *In: D. H. Janzen (ed.) Costa Rican natural history.* The University of Chicago Press, Chicago, Illinois, USA. pp. 79-81.
- Brücher, H., 1988 The wild ancestor of *Phaseolus vulgaris* in South America. *In: P. Gepts (ed.) Genetic resources of Phaseolus beans.* Kluwer Academic Publishers, Dordrecht, Holland. pp. 185-214.
- Debouck, D.G., R. Araya Villalobos, R.A. Ocampo Sanchez, W.G. Gonzalez Ugalde, 1989 Collecting *Phaseolus* in Costa Rica. *FAO/IBPGR Plant Genet. Resources Newsl.* 78/79: 44-46.
- Degreef, J., J.P. Baudoin, O.J. Rocha, 1997 Case studies on breeding systems and its consequences for germplasm conservation. 2. Demography of wild Lima bean populations in the Central Valley of Costa Rica. *Genet. Resources & Crop Evol.* 44: 429-438.
- Delgado Salinas, A., 1985 Systematics of the genus *Phaseolus* (Leguminosae) in North and Central America. PhD Thesis, University of Texas, Austin, Texas, USA, pp. 363.
- Delgado Salinas, A., A. Bonet, P. Gepts, 1988 The wild relative of *Phaseolus vulgaris* in Middle America. *In: P. Gepts (ed.) Genetic resources of Phaseolus beans.* Kluwer Academic Publishers, Dordrecht, Holland. pp. 163-184.
- Fawcett, W., A.B. Rendle, 1920 Flora of Jamaica. *Flora Jamaica.* 4: 1-369.
- Fofana, B., X. Vekemans, P. du Jardin, J.P. Baudoin, 1997 Genetic diversity in Lima bean (*Phaseolus lunatus* L.) as revealed by RAPD markers. *Euphytica.* 95: 157-165.
- Freyre, R., R. Ríos, L. Guzmán, D.G. Debouck, P. Gepts, 1996 Ecogeographic distribution of *Phaseolus* spp. (Fabaceae) in Bolivia. *Econ. Bot.* 50: 195-215.
- Freytag, G.F., D.G. Debouck, 1996 *Phaseolus costaricensis*, a new wild bean species (Phaseolinae, Leguminosae) from Costa Rica and Panama, Central America. *NOVON.* 6: 157-163.
- Gálvez, G.E., B. Mora, M.A. Pastor-Corrales, 1989 Web blight. *In: H. F. Schwartz and M. A. Pastor-Corrales (eds.) Bean production problems in the tropics (second edition).* Centro Internacional de Agricultura Tropical, Cali, Colombia. pp. 195-209.
- Gentry, H.S.,⁴¹ 1969 The ancestor of the common bean and its potential as a breeding resource Dry bean research, 9th Conference, Fort Collins, Colorado, 1968. USDA, Agricultural Research Service, Washington, D.C., USA. pp. 73-78.
- Gutiérrez Salgado, A., P. Gepts, D.G. Debouck, 1995 Evidence for two gene pools of the Lima bean, *Phaseolus lunatus*, in the Americas. *Genet. Resources & Crop Evol.* 42: 15-28.

- Harlan, J.R., 1992 Crops and Man - Second edition. American Society of Agronomy, Inc. and Crop Science Society of America, Inc., Madison, Wisconsin, USA, pp. 284.
- Harlan, J.R., J.M.J. de Wet, 1971 Toward a rational classification of cultivated plants. *Taxon*. **20**: 509-517.
- Hartshorn, G.S., 1983 Plants - Introduction. *In*: D. H. Janzen (ed.) Costa Rican natural history. The University of Chicago Press, Chicago, Illinois, USA. pp. 118-157.
- Hazlett, D.L., 1986 Ethnobotanical observations from Cabecar and Guaymí settlements in Central America. *Econ. Bot.* **40**: 339-352.
- Janzen, D.H., 1983 *Cayaponia racemosa* (wild bitter melon). *In*: D. H. Janzen (ed.) Costa Rican natural history. The University of Chicago Press, Chicago, Illinois, USA. pp. 211-212.
- Lackey, J.A., 1983 A review of generic concepts in American Phaseolinae (Fabaceae, Faboideae). *Iselya*. **2**: 21-64.
- Maquet, A., B. Wathelet, J.P. Baudoin, 1993 Further studies on the genetic diversity of lima beans (*Phaseolus lunatus* L.) using allozymes. *Annu. Rpt. Bean Improvement Coop.* **36**: 55-56.
- Maquet, A., I. Zoro Bi, O.J. Rocha, J.P. Baudoin, 1996 Case studies on breeding systems and its consequences for germplasm conservation. 1. Isoenzyme diversity in wild Lima bean populations in central Costa Rica. *Genet. Resources & Crop Evol.* **43**: 309-318.
- Maréchal, R., J.-M. Mascherpa, F. Stainier, 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.
- Piper, C.V., 1926 Studies in American Phaseolinae. *Contr. US Nat. Herb.* **22**: 663-701.
- Pittier, H., 1978 Plantas usuales de Costa Rica. Editorial Costa Rica, Biblioteca Patria, San José, Costa Rica, pp. 329.
- Sawyer, J.O., A.A. Lindsey, 1971 Vegetation of the life zones in Costa Rica. *Indiana Academy of Science Monograph No. 2*: 1-214.
- Schmit, V., P. du Jardin, J.P. Baudoin, D.G. Debouck, 1993 Use of chloroplast DNA polymorphisms for the phylogenetic study of seven *Phaseolus* taxa including *P. vulgaris* and *P. coccineus*. *Theor. Appl. Genet.* **87**: 506-516.
- Singh, S.P., 1992 Common bean improvement in the tropics. *Plant Breeding Reviews*. **10**: 199-269.
- Singh, S.P., D.G. Debouck, W.W. Roca, 1997a Successful interspecific hybridization between *Phaseolus vulgaris* L. and *P. costaricensis* Freytag & Debouck. *Annu. Rept. Bean Improvement Coop.* **40**: 40-41.
- Singh, S.P., P.L. Gepts, D.G. Debouck, 1991 Races of common bean (*Phaseolus vulgaris*, Fabaceae). *Econ. Bot.* **45**: 379-396.
- Singh, S.P., W.R. Roca, D.G. Debouck, 1997b Ampliación de la base genética de los cultivares de frijol: hibridación interespecífica en especies de *Phaseolus*. *In*: S. P. Singh and O. Voysest (eds.) Taller de mejoramiento de frijol para el siglo XXI: bases para una estrategia para América Latina. Centro Internacional de Agricultura Tropical, Cali, Colombia. pp. 9-19.
- Smartt, J., 1985 Evolution of grain legumes. IV. Pulses in the genus *Phaseolus*. *Expl. Agric.* **21**: 193-207.

- Smartt, J., 1990 Grain legumes: evolution and genetic resources. Cambridge University Press, Cambridge, United Kingdom, pp. 379.
- Standley, P.C., 1937 Flora of Costa Rica. Field Mus. Nat. Hist. Bot. Ser. 18: 1-1616.
- Sullivan, J.G., G. Freytag, 1986 Predicting interspecific compatibilities in beans (*Phaseolus*) by seed protein electrophoresis. Euphytica. 35: 201-209.
- Toro Ch., O., J. Tohme, D.G. Debouck, 1990 Wild bean (*Phaseolus vulgaris* L.): description and distribution. Centro Internacional de Agricultura Tropical, Cali, Colombia, pp. 106.
- Tosi, J.A., 1969 Mapa ecológico, República de Costa Rica, según la clasificación de zonas de vida del mundo de L.R. Holdridge. Centro Científico Tropical, San José, Costa Rica, pp. 1 hoja.
- Tournon, J., G.E. Alvarado I., 1997 Mapa geológico de Costa Rica. Escala 1:500,000. Folleto explicativo. Instituto Tecnológico de Costa Rica, Cartago, Costa Rica, pp. 79.
- Urban, I., 1928 Plantae cubenses novae vel rariores a clo. Er. L. Ekman lectae. IV. Symbolae Antillanae. 9: 433-568.
- Verdcourt, B., 1970 Studies in the Leguminosae-Papilionoideae for the Flora of Tropical East Africa. IV. Kew Bull. 24: 507-569.
- Voyses, O., 1983 Variedades de frijol en América Latina y su origen. Centro Internacional de Agricultura Tropical, Cali, Colombia, pp. 87.
- Voyses, O., M.C. Valencia, M.C. Amezcúta, 1994 Genetic diversity among Latin American Andean and Mesoamerican common bean cultivars. Crop Sci. 34: 1100-1110.

Annex 1 – List of seed and herbarium numbers per species and per accession

Collection Number	Species Identification	Voucher Specimens	Amount of Seeds
3103	lunatus wild	7	1,412
3104	xanthotrichus	4	over 400
3105	lunatus wild	no	667
3106	vulgaris wild	too late	1,106
3107	oligospermus	2	200
3108	lunatus wild	no	1,420
3109	xanthotrichus	5	over 400
3110	tuerckheimii	8	707 (later)
3111	costaricensis	6	no; green
3112	costaricensis	6	613
3113	costaricensis	5	494
3114	lunatus wild	8	924
3115	costaricensis	6	460
3116	xanthotrichus	too late	878
3117	lunatus wild	2	no; green
3118	costaricensis	7	148
3119	lunatus wild	3	1,074
3120	costaricensis	5	90
3121	vulgaris wild	3	1,519
3122	costaricensis	3	33
3123	lunatus wild	6	940
3124	lunatus wild	no	210
3125	xanthotrichus	too late	463
3126	vulgaris wild	too late	1,450
3127	costaricensis	5	240
3128	costaricensis	2	102 (later)
3129	lunatus wild	no	894
3130	lunatus wild	too late	504
3131	vulgaris wild	too late	1,737
Total: 19 populations	6 different species	93 voucher specimens	

Notes: too late= material too dry for representative herbarium specimens; later= second visit to sites by Ing. R. Araya; no= no significant variation for herbarium specimens.

Annex 2 – List of collection numbers and their geographic location

Collection Number	Species	Province	Longitude	Latitude	Altitude (masl)
3103	Luns	Heredia	84 ° 08' W	10 ° 01' N	1,140
3104	xant	Heredia	84 ° 07' W	10 ° 05' N	1,720
3105	luns	Heredia	84 ° 08' W	10 ° 04' N	1,460
3106	vulgs	Alajuela	84 ° 10' W	10 ° 06' N	1,510
3107	oligo	San José	84 ° 01' W	09 ° 46' N	1,400
3108	luns	San José	84 ° 01' W	09 ° 46' N	1,400
3109	xant	San José	84 ° 02' W	09 ° 45' N	1,700
3110	tuerc	San José	83 ° 43' W	09 ° 29' N	2,180
3111	costar	San José	83 ° 37' W	09 ° 29' N	1,550
3112	costar	San José	83 ° 40' W	09 ° 31' N	1,500
3113	costar	San José	83 ° 41' W	09 ° 31' N	1,880
3114	luns	Puntarenas	82 ° 47' W	08 ° 53' N	1,240
3115	costar	Cartago	83 ° 54' W	09 ° 53' N	1,560
3116	xant	Cartago	83 ° 54' W	09 ° 53' N	1,600
3117	luns	Cartago	83 ° 54' W	09 ° 53' N	1,600
3118	costar	Cartago	83 ° 47' W	09 ° 54' N	1,570
3119	luns	Alajuela	84 ° 20' W	10 ° 09' N	1,280
3120	costar	Alajuela	84 ° 24' W	10 ° 13' N	1,710
3121	vulgs	Alajuela	84 ° 23' W	10 ° 10' N	1,610
3122	costar	Alajuela	84 ° 23' W	10 ° 10' N	1,610
3123	luns	Puntarenas	84 ° 51' W	10 ° 16' N	1,100
3124	luns	Guanacaste	84 ° 51' W	10 ° 19' N	1,180
3125	xant	Cartago	83 ° 56' W	09 ° 54' N	1,500
3126	vulgs	Cartago	83 ° 56' W	09 ° 54' N	1,500
3127	costar	Cartago	83 ° 56' W	09 ° 54' N	1,500
3128	costar	Cartago	83 ° 47' W	09 ° 55' N	1,520
3129	luns	Cartago	84 ° 00' W	09 ° 50' N	1,370
3130	luns	San José	84 ° 05' W	09 ° 48' N	1,380
3131	vulgs	San José	84 ° 03' W	09 ° 49' N	1,540