(Seligson, 1980; Boucher *et al.*, 1983; Baudoin *et al.*, in press)

In general, the soils of the Central Valley are known for being highly fertile. According to the preliminary soil map of Costa Rica (Pérez *et al.*, 1978), there are eleven soil associations belonging to nine main soil types in the study area. Most soil types have been affected by volcanic activity in the Cordillera Central and typically have developed from volcanic ash deposits or other volcanic tuffs. Most soils can be described as deep, rich in organic matter, and well drained, although some soils are poorly drained. The variation in soil types reflects closely the diversity in topography, climate and geological histories that characterize this area.

As far as climate is concerned, great variation in the micro-geographical distribution of rainfall results from the orientation of the mountain ranges and the location of wind passes. Rainfall is seasonal, with a well-defined dry season during December-April. The dry season in the south western part of the Central Valley is not as severe as in the rest of the valley. This is because these areas do not experience the strong winds that affect the rest of the valley during this time of the year (Fournier *et al.*, 1985). The rainy season also varies in intensity, and there is less rain in the middle of the year (typically in July) than during the months just before and after. This period of less rain is called "veranillo", which means little summer (Coen, 1983). Typically, March and September are the months with the lowest rainfall is lower in the eastern valley than in the western valley.

Because of its geographical location, temperature is not particularly variable in the Central Valley (Protti *et al.*, 1983; Fournier *et al.*, 1985). The mean annual temperature ranges from 15°C at the top of the Cordillera Central and the Cordillera de Talamanca, to 25°C in the south-eastern part of the study area (near the city of Atenas).

The Central Valley of Costa Rica is very diverse biologically. Two distinct approaches have been used to describe the interactions of its physical environment with biological diversity. These are the ecological maps of Costa Rica, which is based on the Holdridge Life Zone system (Holdridge 1966), and the map of Biotic Units, which is based on the structure and floristic composition of the plant communities (Gómez, 1986).

Distribution and ecogeography of wild P. lunatus in the valley

Wild populations of Lima bean can be found throughout the Central Valley of Costa Rica (Standley, 1937; Rocha *et al.*, 1997; Baudoin *et al.*, 1998; Rocha *et al.*, 2002). The populations are usually found in open and disturbed areas with grasses and scattered trees or bushy thickets; they also colonize the coffee plantations from perennial fence (usually *Erythrina* and euphorbs) bordering the plots (Standley, 1937; Debouck, 1987). They are particularly found where coffee is grown under shade (traditional coffee plantations); as well as in the waste lands around these plantations.

bananas. Typically, agricultural activities are less intense in this agro-ecosystem, and do not rely on heavy use of herbicides for the elimination of weeds (Rocha *et al.*, 1997). However, it has been demonstrated that because of changes in agricultural practices and in land use due to urban development, the populations of Lima bean in the Central Valley are fragmented and undergo local extinction and re-colonization (Rocha *et al.*, 1997).

The geographic location of some 450 populations (defined as groups of Lima bean individuals isolated at least 500 m from any other) was determined during 1992-1994. Further surveys were carried out in subsequent years, which found new populations as well as recorded the disappearance of old ones. In order to analyze the physical and ecological attributes of all locations where *P. lunatus* was found during the course of the project (565 populations in total) a detailed classification of each site was conducted using geographical information system (GIS). This work was carried out in collaboration with Centro de Investagaciones en Desarrollo Sostenible (CIEDES) of the Universidad de Costa Rica. The results may be summarized as follows (Baudoin *et al.*, in press).

P. lunatus is found at sites located between 800 and 1,800 masl, but most populations are found between 1,100 and 1,600 masl. The wild populations are more likely to be found in locations with annual precipitation between 1,900 and 2,400 mm and with mean annual temperature between 19 and 22°C. Lima beans are found in large numbers in all relative humidity categories of the valley, not showing a clear association with population abundance.

The sites where the plants are present occupy 30 different soil types. However, 46% of the populations (260) are found in deep inceptisol, well drained and permeable with low fertility.

According to Holdridge (1966) classification, Lima beans are found in seven different life zones, being most abundant in the humid premontane (38% of populations) and the very humid premontane forest (54%). Similarly, the species is observed in 15 different biotic units. However, 72% of the populations are found in only three of these, i.e., humid, temperate and subtropical areas with a marked dry season that lasts 3-6 months.

Overall, the project's findings indicate that Lima beans are not randomly distributed in the study area, and that their location may in fact be influenced by environmental factors. This information can be used to make predictions about additional locations where Lima beans could be found, both within and outside of the Central Valley. The relationship between Lima bean distribution and the physical factors examined explain partly the genetic structure of the species revealed by morphological or physiological traits as well as isozyme and molecular markers (Maquet *et al.*, 1996; Rocha *et al.*, 1997; Zoro Bi, 1999; Ouédraogo, 2003).

Genetic diversity of wild Lima beans in the valley

A major component of this project was to evaluate the genetic diversity represented by the wild Lima bean populations found in the Central Valley of Costa Rica. This diversity was studied at both the intra- and inter-population levels, and results served as a guide to understand and maintain the genetic structure of the species in the area. Once biochemical (protein, isozyme) and molecular (microsatellite) markers had been developed, the genetic diversity was assessed between and within populations, and a study was conducted to determine factors responsible for the genetic organization and micro-geographical patterns of the wild Lima beans.

Despite the relatively small size of the area considered in this study and the small sample size taken from each population (5 seeds from a bulked sample), there was significant phaseolin variation among the wild populations studied, all belonging to the Meso-American gene pool (Vargas *et al.*, 2000, 2001).

Using phaseolins, populations could be arranged in groups according to their proximity and phenology. This could be explained, at least in part, by climatic factors, such as dry season. Using isozyme markers on 95 populations well distributed in the valley, results showed a very heterogeneous allelic distribution through all the polymorphic loci (Zoro Bi, 1999). Alleles were present in either very few or numerous populations. Geographical distribution of the alleles was very irregular, with some alleles being only found in specific parts of the Central Valley. This non-random spatial distribution of alleles might result from limited gene flow between populations, and or very much localized selection pressures caused by biotic or abiotic stresses.

the populations as well as environmental conditions in the Central Valley. For example, wild populations of Lima beans might undergo repeated bottlenecks, as weeding and other agricultural practices only allow a few plants to survive and reproduce. These processes lead to significant reduction in effective population size, and to high levels of inbreeding, favoring the decrease of heterozygotes in the populations. The recurrent reduction in population size will also favor genetic differentiation among populations. The discontinuity of the habitats where wild Lima beans are most likely to be found in the valley also promotes genetic differentiation among populations. Such fragmentation is mainly the result of replacement of traditional coffee plantations by modern, intensive plantations and accelerated urban development. Differences in abiotic (climate and soil) and biotic factors will also have affected levels and patterns of genetic variation in the Valley (Rocha *et al.* 1997; Ouédraogo, 2003; Baudoin *et al.*, in press)

Environment of Lima Bean: Ecology and Farming System

According to the natural area of distribution of the wild form, the cultigen *P. lunatus* is adapted to the savannah climate of the lowland tropics. During domestication, it has diffused to various ecologies: humid, dry or semi-arid tropics and hot temperate regions. Lima bean tolerates wide-ranging ecological conditions. In its extension zone, it can be found from sea level up to altitudes

It requires a frost-free growing season and a fairly dry period when the pods are ripening. Normal annual rainfall required is 900-1,500 mm, but the crop tolerates as little as 500-600 mm once established. Indeed, like groundnut and pigeon pea, Lima bean is considered to be very drought resistant, thanks in particular to its deep, well-developed root system. *P. lunatus* is much more tolerant of rain during its vegetative development than *P. vulgaris* and is therefore better suited than the latter to the low-altitude humid tropical conditions. The plant will thrive if the average monthly temperature during the growing season lies between 16° and 27°C. Below 13°C, its growth is considerably retarded. The small-seeded forms (cultigroups Sieva and Potato) withstand high temperatures better than the large-seeded ones (cultigroup Big Lima). *P. lunatus* is best cultivated on well-aerated, adequately drained soils with a pH of 6.0-6.8.

The area devoted to Lima beans in the tropics is small compared with that planted to starchy staple and export crops. Farming systems where the species is integrated vary from monocrop systems under intensive agricultural conditions or in drier environment to traditional mixed cropping systems of the rainforest or savannah zones. The bushy determinate varieties are better suited to the intensive cropping system or the drier areas, while the climbing indeterminate types predominate in the traditional (shifting or permanent) system of cultivation or in more humid tropical areas. Climbing plants are very often intercropped with other species, like sorghum, pearl millet, yams, cassava, cotton, banana; they are also grown in household gardens. In the Yucatan Peninsula of Mexico, Lima beans have always been associated with maize in the ancient system of shifting cultivation known colloquially as 'milpa'. In the desertic coastal region of Peru, where the cv-gr Big Lima predominates, the landraces are characterized by a prostrate indeterminate habit and are usually grown as a sole crop or intercropped principally with maize or cotton. In this environment, plants are irrigated with approximately 3,500 m^3 water ha^{-1} during the initial period of vegetative growth.

Conclusions

In order to promote the potential of *P. lunatus*, an in-depth survey of the wild form and landraces is essential, particularly in some countries of Latin America underrepresented in the national and international germplasm collections, such as Belize, Salvador, Honduras, Nicaragua, Panama, Colombia, Venezuela, Argentina, Brazil and some Carribean Islands (Maquet and Baudoin, 1997). It is also recommended to better understand the phytogeography of the wild and cultivated forms, particularly in some countries where collecting missions were carried out on a fragmentary level: this is the case in some regions of Bolivia (Cochabamba, Chuquisaca and Santa Cruz), in the south of Peru, in the Cordillera between Colombia and Venezuela, on the Atlantic Coast of Mexico (particularly in Veracruz and Tamaulipas), in the eastern part of Guatemala and in both the north and the south of Costa Rica.

To preserve the landraces of the Lima bean, it will be useful to identify people