Variation in the primitive landraces of common bean (*Phaseolus vulgaris* L.) from Argentina

Antonio M. De Ron [1], Maria C. Menéndez-Sevillano [2] & Marta Santalla [1]

[1] Legumes Breeding Group CSIC-USC. Misión Biológica de Galicia. P. O. Box 28. 36080 Pontevedra, Spain

[2] Faculty of Agronomy. University of Buenos Aires. Av. San Martín 4453. 1417 Buenos Aires, Argentina

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Abstract

We describe the phenotypic variation found in four common bean (*Phaseolus vulgaris* L.) complex primitive landraces, among a group of 83, from Northwestern Argentina with particular attention to the wide diversity found in some small areas. We also hypothesized how this diversity is maintained and the situation of mixtures or primitive complex landraces that grow close to their wild ancestor. Wide diversity regarding seed type and plant characteristics was displayed by the landraces MCM-SV (composed of 11 lines), MCM-292 (14 lines), MCM-298 (5 lines) and VAV-3716 (14 lines). Food uses of dry seed and fresh pod seemed to be more relevant that the aesthetic traits although all of them were presumably selected by humans for centuries resulting in the current phenotype of these complex primitive landraces. Additionally some weedy types (intermediate between wild and domesticated types) were detected in the landraces MCM-292 and MCM-298. The four complex landraces described consisted of highly diverse mixtures and could play a role in breeding to enlarge the genetic basis of domesticated varieties belonging to the Andean bean gene pool.

Introduction

The provinces of the Argentinean northwest (“NOA”, in Spanish “Noroeste Argentino”) represent together with Bolivia the Southern limit of the Andean Center of distribution of wild common bean (*Phaseolus vulgaris* L.) and possibly an area of domestication together with the Northern Andes (Beebe et al., 2001; Gepts et al., 1986; Gepts and Debouck, 1991; Islam et al., 2002; Koenig and Gepts, 1989; Singh et al., 1991a). In this area, traditional agriculture in small farms is still practised in isolated valleys that includes the use of primitive or unimproved landraces of “porotos” or beans often intercropped with maize (Parodi, 1953). The wild forms grow in Argentina through the provinces of Salta, Jujuy and Tucumán, along the valleys of the Eastern Andean Mountain Range (altitude 700 - 3000 masl, latitude 22° - 27° S, longitude 63° - 66° W).

Different collecting missions involving common bean primitive landraces and wild populations were carried out in the NOA since the 70's (Menéndez-Sevillano, 2002) in order to increase the availability of regional genetic diversity that could be used as a source of genes to introduce in current cultivars (Singh et al., 1995). This regional diversity is one of the characteristics of common bean populations in Meso and South America. Because common bean is a self-pollinated crop, these populations consist of mixtures of pure lines.

From the information gathered in the collecting missions, as well as from historical sources (Acosta, 1590), it is well known that the above mentioned primitive germplasm mixtures have been cultivated for centuries and show significant differences with the current improved varieties in North America and

Europe. These mixed populations, therefore, represent a form of "in situ" germplasm conservation. For agricultural crops, "in situ" conservation refers to the habitat where crops developed their distinctive properties, predominantly in farmers' fields.

The diversity displayed by the primitive Argentinean bean landraces (Menéndez-Sevillano, 2002; De Ron et al., 1999) is a consequence of the evolution of the species after domestication and its coexistence with wild ancestral forms. Debouck (1989) suggested that the current diversity observed in the bean landraces in the NOA - but ñuñas - is derived from non-food uses since this species was domesticated before the existence of ceramic devices for boiling the dry seeds; so, "aesthetic" selection could have been the principal force for bean evolution is this area. This aesthetic selection would have lasted for several milennia and could have resulted in cultivars with a high level of antinutritional factors and wide variation in seed colours and colour patterns perhaps unmatched in any other crop. Previously, Burkart (1955) also reported this use of beans since the use of vividly coloured seeds called "chuis" as a toy by children was observed in Bolivia.

In addition to selection for aesthetic or ornamental reasons, selection for food purposes must also be considered as a relevant evolutionary factor of the species in this area. Bean is a component of traditional Argentinean food such as the "locro", a high nutritive local recipe that incorporates corn, potato, meat, cucurbit ("zapallo"), and bean (usually white but coloured ones as well). The fresh pod ("chaucha") is consumed sometimes as vegetable in the NOA. Besides the wild bean was reported as an emergency food when other sources fail (Debouck, 1990).

This kind of primitive germplasm has not been widely studied probably due to its low market value since the best known varieties and extensively grown in Argentina belong to the white large-seeded “alubia” (or “canellini”) market class (Voysest, 2000). Some studies focused on wild types and their relationships with the domesticated ones and the wild-weedy-crop complex, both at the morphological and molecular levels. They revealed a low degree of genetic variation in this germplasm and the need for widening the genetic basis of current domesticated Andean varieties (Beebe et al. 2001, Beebe et al. 1997; Menéndez-Sevillano et al., 1998; Sonnante et al., 1994; Singh et al., 1991b; Singh et al. 1991c). Only a few domesticated accessions from the NOA were involved in those studies, therefore the actual degree of genetic diversity of the primitive bean landraces of this area could not be determined.

However, an efficient use of this genetic resources requires an understanding of the structure of variation in the germplasm collections available. Variation in some quantitative traits revealing agronomic value together with other associated with regional preferences, i. e. seed coat colour and pattern, is presented in the present work. The objective of this paper is to describe the phenotypic variation in the primitive complex landraces of common bean from the NOA with particular attention to the wide diversity found in some small areas and how it is maintained.

Material and Methods

The germplasm studied is part of the collection of primitive NOA bean germplasm in the Plant Genetic Resources Laboratory "N. I. Vavilov" at the Faculty of Agronomy of the University of Buenos Aires (Argentina). The accessions came from different locations in the provinces of Salta, Jujuy and Catamarca (between 1000 _ 3000 masl, 22º _ 24º S, 67º _ 65º W) and they were collected in several explorations (Menéndez-Sevillano, 2002).

Two sources of variation were studied. The first one is a group of 83 accessions shown in Table 1 together with their geographical origin and the year of collection (and local name if available). For some of the accessions different lines were derived according to their seed type to estimate the intra-accession variation characterizating distinctly the different types of beans included in each landrace. This is why some of them could be considered as "complex landraces". For example, MCM-SV was collected in Santa Victoria (Salta) and divided into 11 lines to be studied separately while VAV-3716 was collected in Iruya (Salta) and included 14 lines characterized separately.

These 83 accessions were studied in a field trial carried out in Cachi (25º 04' S, 66º 12' W, 2300 masl, Salta) in 1988-1989 according to a randomized design. The experimental plot consisted of 10 to 20 plants of each accession depending on the availability of seed. Seed colour and pattern and flower colour, that play a relevant role in the choice of varieties by farmers and consumers, together with 11 quantitative traits (Schachl and De la Rosa, 2001; IBPGR, 1982) related with bean racial identification and agronomic performance are presented in this work. The traits included days to 50 % flowering, central leaflet length and width (mm) measured in five leaves of five plants, bracteole length and width (mm) measured in five flowers of five plants, pod length and width (mm) determined in 20 pods of 10 plants, and seed length, width and thickness (mm), and weight of 100 seeds (g), determined in 30 seeds per plot.

Mean, standard deviation, standard error, coefficient of variation (CV) and range of variation were calculated for the 83 accessions studied as well as for the two complex landraces defined as MCM-SV and VAV-3716.

The second source of variation was the germplasm collected in a mission in Santa Victoria (Salta) in 1997 (Table 2). Two accessions named as landraces MCM-292 and MC-298 were characterized for seed traits: length, width, thickness and 100-seeds weight. These two landraces were divided into 14 and 5 lines respectively in the same way described above. Mean, standard deviation, standard error, coefficient of variation and range of variation were computed for the four quantitative traits studied in this case.

Results and Discussion

Phenotypic variation inside the four complex landraces or mixtures MCM-SV, MCM-292, MCM-298 and VAV-3716 could be considered as very high. However when it was compared to the overall variation in the NOA represented by the sample of 83 accessions a similar pattern of variation appeared to be repeated in each area studied.

Table 3 shows the composition, in terms of lines, of the two complex landraces MCM-SV and VAV-3716, flower colour and the seed colour and pattern of each line (Figure 1). All the lines of these two landraces showed an Andean type T phaseolin. These results indicate that at the biochemical level these landraces show reduced diversity, in agreeement with previous data (Gepts et al., 1986; Singh et al. 1991a; Cattan-Toupance et al., 1998). The reduced phaseolin variation was expected since the different types are genetically fixed more at the racial level than at the population level.

Most of the lines (16) in those landraces had purple flowers, also typical of wild beans. VAV-3716 showed either purple or white bicoloured lines suggesting introgression from commercial cultivars or perhaps mutation of one or two genes responsible for colour of flower wings and standard.

Seed types in general did not match the usual American and European market classes as described by Voysest (2000) and Santalla et al. (2001) (Tables 3 and 4). Those types of mixtures showing seed colour and pattern not usually associated with domesticated bean have been reported by Beebe et al. (1997) in the wild-weedy-crop complex in Peru and Colombia. Gepts and Bliss (1986) reported also intra-accession variation in seed size and phaseolin type in bean germplasm from Colombia. Preferences of different types of mixtures could explain the variation in seed colour and pattern in the complex landraces here described. Kaplan (1981) mentioned the presence of mixtures in local markets in Mexico, composed of 4-6 different lines. Morphological and physiological variation inside bean landraces and cultivation of mixtures in Mexico were reported also by Andrade and Hernández-Xolocotzi (1991), González et al. (1995) and Jacinto et al. (2002). Seed mixtures were also observed by the authors in some NOA local markets. In the complex landraces analysed in this paper, as mentioned before, 11, 14, 14 and 5 lines were identified in MCM-SV, VAV-3716, MCM-292 and MCM-298, respectively. In spite of the fact that some of them could be considered as duplicates, it is clear that the situation in the NOA is more complex that the one described in Mexico and more similar related to that described by Beebe et al. (1997) in the complex wild-weedy-crop of Colombia where between 10 and 26 variants were found inside the accessions studied.

This high variation in seed colour and pattern could be maintained for a long time if common bean was used for aesthetic purposes and/or its fresh pod was consumed as vegetable since in these cases no selection for quality and homogeneous colour of seed was present. A reason for these two uses could be the problem of cooking dry bean seed in the Andean highlands (with the exception of the popping types of bean or “ñuñas”). Boiling water at high altitude (over 2000 masl), where primitive landraces are usually growing is a hard domestic task since it is time and fuel consuming. Additionally, these two uses of bean could explain the presence of antinutritive compounds in the seed since selection for food purposes by farmers may have been minor. Nevertheless consumption of bean mixtures was observed by authors is some farms in the NOA and it has been reported also by Beebe et al. (1997) in Colombia in the wild-weedy-crop complex.

The mean, standard deviation, CV and standard error of the 11 traits studied in MCM-SV and VAV-3716 together with the overall values of the 83 accessions are shown in Table 5. The most relevant differences in mean values among landraces and the general mean were in central leaflet length and width and weight of 100 seeds. The other mean values were similar among landraces. CV demonstrated high phenotypic diversity since the general trend is to be rather high (over 10 % in general and in the landraces values) in days to 50% flowering, central leaflet length and width and 100-seed weight.

Table 6 includes the ranges of variation of the traits studied in the two landraces MCM-SV and VAV-3716. Ranges of variation between 50 - 75 % of the total of the 83 accessions studied were displayed by some of the traits in the two complex landraces: days to 50 % flowering, central leaflet length, bracteole width and seed length in both landraces while MCM-SV accounted for 55.0 % of the total variation in seed width and VAV-3716 for 62.1 % of the total variation in seed thickness and 63.2 % in weight of 100 seeds. Traits that showed ranges of variation over 75 % were central leaflet width in both complex landraces, pod length, seed thickness and weight of 100 seeds in MCM-SV and pod width and seed width in VAV-3716. MCM-SV reached the 100 % of the total variation of the germplasm studied in seed thickness. Finally pod width in MCM-SV and pod length in VAV-3716 as well as bracteole length in both landraces scored below 50 % of total variation.

From the point of view of morphological traits related with gigantism as a consequence of the domestication syndrome (Hammer, 1984), the central leaflet presented a range of variation between 62.9 and 88.2 % of the total regarding both length and width in the two complex landraces MCM-SV and VAV-3716 and in the same trend bracteole width accounted for more than 50 % of the total variation in the two landraces. Earliness (expressed as days to 50 % flowering) is a trait that showed moderate diversity accounting for the 50 % of the total variation that could be expected from the domestication and the breeding in the early times since this kind of traits could be affected under selection pressure by man when plant height is reduced.

Table 7 shows the mean, standard deviation, CV, standard error and range of variation of the four quantitative seed traits studied in the landraces MCM-292 and MCM-298. There was a wide range of variation in all the traits, mainly in seed weight. Standard errors were low and CV were high (over 10 %) in the four traits, particularly in seed weight that scored 40.5% in MCM-292 and 31.0 % in MCM-298.

When the use of these primitive landraces is discussed one must take into account the traits affecting the seed as a reference since they are probably considered by ancient farmers to select their varieties either for aesthetic purposes or as a food source perhaps only in emergency situations. In these two cases, large seeds were probably preferred so the presence of extra-large and large seed in the four complex landraces evaluated could be explained.

One of the most important characters for breeders and farmers is seed size. Seed size mean showed values over 40 g/100 seeds in the overall value in the 83 accessions from the NOA and in all the complex landraces. In MCM-SV it ranged from medium weight (MCM-SV-016) to extra-large (MCM-SV-044) and in VAV-3716 seed size ranged between the medium size of VAV-3716-B and the large size of VAV-3716-P. Regarding the other two landraces, seed size ranged from small in MCM-292-M (probably a wild or weedy type) to extra-large MCM-292-J and from small in MCM-298-E (probably a wild or weedy type also) to extra-large in MCM-298-D.

If a horticultural use was considered, pod traits could be regarded more important that seed ones in the accessions studied. Since the use of bean as vegetable was sometimes observed by the authors (fresh pod called “chaucha”) and reported also by Beebe et al. (1997) in other Andean areas, scores indicating high horticultural values must expected. In fact MCM-SV-044 has a pod 147.8 mm long and VAV-3716-G a pod of 15.1 mm wide, which can be considered as appropriated values for the use of the bean pod as a vegetable. Selection by farmers for the use of edible pods would result in more uniform and larger ones but not affecting the variation in dry seed types - except size that probably varies together with pod size - since this quality was not taken into account for an horticultural use.

From the results shown in the present paper and the evidence from other authors (Acosta, 1590; Burkart, 1955; Debouck, 1989, 1990; Menéndez-Sevillano, 2002), three uses of common bean in the NOA have been found: 1) dry seed, 2) fresh pod and 3) aesthetic and children toy. The first one would be responsible for large and extra-large seed size, the second could explain the variation in traits related to pod size and the third one the diversity in seed colour and pattern.

Evidence about the high diversity in the area as well as the presence of mixtures in several crops was recently reported by De la Cuadra et al. (2000) in a collecting mission in Salta in several locations. In these locations the authors collected a high number of primitive bean accessions mentioned in Table 2. White commercial seeds were rare among them. Some other that probably correspond to wild or weedy types were found with seed size similar or a little bigger than the wild ones. It means that the general situation in the NOA could be the one presented in this paper regarding the four complex landraces studied that account for a high phenotypic diversity in small areas.

Complex landraces or varietal mixtures are seen in gardens and in markets through the highlands in other regions where they are grown and sometimes marketed as mixtures but they could be separated into different types or landraces according to seed colour and pattern (Freyre et al., 1996; Kaplan, 1981). It means that ecological and human factors account for the existence and stability of the mixtures. An experiment mentioned by Kaplan (1981) showed that germination was delayed for the total of the seeds of a mixture which means that in nature the period of emergence will be increased which could be an advantage since the spring rain when bean is planted is uncertain so with different rates of germination average survival of a mixture could be improved.

Another reason for the maintenance of this wide phenotypic diversity displayed by the four complex landraces studied could be the proximity of wild beans. Gene flow is not shown in this study but the authors observed that wild populations grow quite close to the domesticated ones in many villages in the NOA. Furthermore farmers keep the seeds that often show intermediate aspects regarding flower (Hoc & Amela, 1999; Hoc et al., 2001) and seed shape, size and colour (as observed by the authors in several collecting missions in Salta and Jujuy) in a similar situation to that described by Beebe et al. (1997) and Menéndez-Sevillano et al. (1998) regarding the complex wild-weedy-crop in the Andean region. Some possible intermediate forms have been identified in the landraces studied like MCM-292-A, MCM-292-L, MCM-292-M, MCM-292-N and MCM-298-E (Figure 1), with seed size, colour and pattern which resemble the wild or weedy ones. Hybrids between wild and domesticated beans are fully fertile and show no major reproductive isolation barriers. These crosses would contribute to broaden the genetic base of cultivated forms, for instance increasing the durability of resistance to diseases (Singh, 2001) in spite of the fact that the only successfully breeding achievement coming from crosses among wild and cultivated bean was the introduction of resistance to bruchids by Kornegay et al. (1993).

How evolutionary forces have been affected the history of the current primitive bean landraces in the NOA is another aspect for discussion. The geographical situation is quite different in this Andean region compared to other areas of domestication and/or early use of domesticated forms. Many villages are located in small isolated valleys separated by mountains 2500-6500 masl. Communication has traditionally been very limited up until today. This fact have probably limited markedly the exchange of seeds in spite of the evidences for exchange of seeds in Southern Andes (Debouck & Smartt, 1995) and the movement of *Phaseolus* species and varieties along the same area described by Kaplan and Kaplan (1988). So the adaptive selection process after domestication would occur separately in many different places almost simultaneously but under different environmental conditions. In this scenario, the role of genetic drift could be relevant and would explain why very different and highly diversified landraces are growing in those isolated valleys in relatively close proximity.

Another evolutionary force is outcrossing as the origin of genetic flow. In spite of its autogamy, outcrossing has been reported (Ibarra-Pérez et al., 1997). Additionally, the recombinant forms between Andean and Mesoamerican germplasm found in Southern Europe and documented by Santalla et al. (2002) are also the result of genetic flow between the two gene pools of common bean that resulted in different evolution under the European conditions. If outcrossing occurred, mixtures would appear from outcrossing within the isolated valleys in the NOA since insects are not able to fly above the mountain ranges between them so each landrace probably has evolved separately on its own under the human pressure for the food and non-food uses.

Closely related to outcrossing is the introgression of wild germplasm inside the primitive landraces. As mentioned above the data presented in this paper as well as the authors observations demonstrated the coexistence of wild forms inside or quite close to some farms in the NOA, sometimes in mixtures maintained actively by farmers as MCM-292. Reasons for that attitude are not clear but they could be related to ancient customs and the diversity of uses of dry bean. NOA common bean germplasm could represent a real opportunity for breeding, mainly regarding the domesticated varieties from the Andean gene pool currently displaying a narrow genetic basis.

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Table 1. Origin of the 83 common bean accessions studied.

Accession (local name)	Year of collection	Province	Department	Coordinates	Altitude (masl)
MCM-002	1986	Salta	Iruya	22º S 65º W	2800
MCM-005	1986	Salta	Iruya		
MCM-009	1986	Salta	Iruya		
MCM-010 Gateao/hosco	1986	Salta	Iruya		
MCM-SV-014	1986	Salta	Santa Victoria	22º S 64º W	2400
MCM-SV-015	1986	Salta	Santa Victoria		2400
MCM-SV-016	1986	Salta	Santa Victoria		2400
MCM-SV-026	1986	Salta	Santa Victoria		2400
MCM-032	1986	Salta	Santa Victoria		2600
MCM-037	1986	Salta	Iruya	22º S 65º W	3000
MCM-042	1986	Salta	Santa Victoria	22º S 64º W	2800
MCM-SV-044	1986	Salta	Santa Victoria		
MCM-045	1986	Salta	Iruya	22º S 65º W	2900
MCM-062	1986	Salta	Iruya		
MCM-070	1986	Salta	Santa Victoria	22º S 64º W	2600
MCM-072	1986	Salta	Iruya	22º S 65º W	2900
MCM-SV-073	1986	Salta	Santa Victoria	22º S 64º W	2400
MCM-074	1986	Salta	Iruya	22º S 65º W	2900
MCM-SV-075	1986	Salta	Santa Victoria	22º S 64º W	2400
MCM-SV-078	1986	Salta	Santa Victoria		
MCM-082	1986	Salta	Iruya	22º S 65º W	2900
MCM-SV-083	1986	Salta	Santa Victoria	22º S 64º W	2400
MCM-084	1986	Salta	Iruya	22º S 65º W	2900
MCM-SV-085	1986	Salta	Santa Victoria	22º S 64º W	2400
MCM-087 A	1986	Salta	Santa Victoria		
MCM-088	1986	Salta	Santa Victoria		
MCM-089	1986	Salta	Santa Victoria		
MCM-090	1986	Salta	Santa Victoria		
MCM-099	1986	Salta	Santa Victoria		

Table 1. Continuation.

Accession (local name)	Year of collection	Department	Location	Coordinates	Altitude (masl)
MCM-SV-100	1986	Salta	Santa Victoria	22º S 64º W	2400
MCM-101	1986	Salta	Iruya	22º S 65º W	2900
MCM-104	1986	Salta	Santa Victoria	22º S 64º W	2400
VAV-3716-A Bayo chispeao	1971	Salta	Iruya	22º S 65º W	2900
VAV-3716-B Ahumado/aguilo	1971	Salta	Iruya		
VAV-3716-C Negro overo	1971	Salta	Iruya		
VAV-3716-DB Blanco calzao	1971	Salta	Iruya		
VAV-3716-E Overito colorado	1971	Salta	Iruya		
VAV-3716-F Bayo/amarea	1971	Salta	Iruya		
VAV-3716-G Colorado gateao	1971	Salta	Iruya		
VAV-3716-H Trigona overo	1971	Salta	Iruya		
VAV-3716-I Colorao calzao	1971	Salta	Iruya		
VAV-3716-J Negro/torito	1971	Salta	Iruya		
VAV-3716-L/N/O Zorrino calzao	1971	Salta	Iruya		
VAV-3716-P	1971	Salta	Iruya		
VAV-3716-U	1971	Salta	Iruya		
VAV-3716-V/W	1971	Salta	Iruya		
VAV-3733-A Blanco calzao	1972	Jujuy	Tilcara	23º S 65º W	
VAV-3733-C	1972	Jujuy	Tilcara		
VAV-5672-A Colorao chispeao	1977	Jujuy	Tilcara		
VAV-5672-B Colorao calzao	1977	Jujuy	Tilcara		
VAV-5672-C Bayo	1977	Jujuy	Tilcara		
VAV-5672-D	1977	Jujuy	Tilcara		
VAV-5674-A Overito colorao	1977	Jujuy	Tilcara		
VAV-5674-B Bayo chispeao	1977	Jujuy	Tilcara		2400
VAV-5674-C Bayo	1977	Jujuy	Tilcara	23º S 65º W	2400
VAV-5674-D	1977	Jujuy	Tilcara		

Table 1. Continuation.

Accession (local name)	Year of collection	Department	Location	Coordinates	Altitude (masl)
VAV-5675-A	1977	Salta	Santa Victoria	22º S 64º W	
VAV-5675-C	1977	Salta	Santa Victoria		
VAV-5675-E	1977	Salta	Santa Victoria		
VAV-5868-D	1977	Salta	Santa Victoria		
VAV-5868-E	1977	Salta	Santa Victoria		
VAV-5871 Bayo chispeao	1978	Salta	Santa Victoria		2500
VAV-5874-A	1978	Jujuy	Tilcara	23º S 65º W	2400
VAV-5874-B	1978	Jujuy	Tilcara		
VAV-5878-A	1978	Jujuy	Tilcara		
VAV-5878-B	1978	Jujuy	Tilcara		
VAV-5878-C	1978	Jujuy	Tilcara		
VAV-5879	1978	Jujuy	Yavi	22º S 65º W	3000
VAV-5881	1978	Salta	Santa Victoria	22º S 64º W	2500
VAV-5882-A	1978	Salta	Santa Victoria		
VAV-5882-B	1978	Salta	Santa Victoria		
VAV-5882-H	1978	Salta	Santa Victoria		
VAV-5882-I	1978	Salta	Santa Victoria		
VAV-5883-B	1978	Salta	Santa Victoria		
VAV-5883-C	1978	Salta	Santa Victoria		
VAV-6151	1980	Jujuy	Humahuaca	22º S 65º W	2400
VAV-6153-A	1980	Salta	Iruya	22ª S 65º W	2900
VAV-6153-D	1980	Salta	Iruya		
VAV-6198-H	1981	Salta	Santa Victoria	22º S 64º W	2500
VAV-6360-A	1987	Catamarca	Belén	26º S 67º W	2000
VAV-6360-B	1987	Catamarca	Belén		
VAV-6361	1987	Catamarca	Belén		

Table 2. Primitive common bean accessions collected in the mission in the department of Santa Victoria, Salta, in 1997

	Locations			
	La Misión 22º 14' S 64º 41' W 1350 masl	**Arazay** 22º 14' S 64º 42' W 1690 masl	**Los Toldos** 22º 17' S 64º 42' W 1630 masl	**El Condado** 22º 26' S 64º 40' W 1340 masl
Nr of accessions	12	2	44	30
Observations		Mixtures with wild and weedy types	6 with mixture of white (commercial) seeds	11 with mixture of white (commercial) seeds 3 accessions coming from Mamora (Bolivia) are included

Table 3. Composition in lines of the complex landraces MCM-SV and VAV-3716, flower colour, seed colour and pattern of each one.

LINES	FLOWER COLOUR	SEED COLOUR / PATTERN
MCM-SV (11 lines)		
MCM-SV-014	purple	black, brown /mottled
MCM-SV-015	purple	black
MCM-SV-016	purple	brown, black / mottled
MCM-SV-026	purple	brown, black / mottled
MCM-SV-044	white	black, white / mottled
MCM-SV-073	purple	brown, black / mottled
MCM-SV-075	white	white, black / hilum spotted
MCM-SV-078	white	white, purple / speckled
MCM-SV-083	purple	cream, black / stripped
MCM-SV-085	purple	brown, black / mottled
MCM-SV-100	purple	brown, black / mottled
VAV-3716 (14 lines)		
VAV-3716-A	purple	black, purple / mottled
VAV-3716-B	purple	black, purple / mottled
VAV-3716-C	white	white, black / spotted
VAV-3716-DB	white	white, black / hilum spotted
VAV-3716-E	white	white, purple / speckled
VAV-3716-F	purple	brown, purple / mottled
VAV-3716-G	purple	brown, purple, black / stripped
VAV-3716-H	purple	white, black / spotted
VAV-3716-I	white/purple	white, purple / bicolor
VAV-3716-J	purple	black
VAV-3716-L/N/O	white	white, brown / speckled
VAV-3716-P	white/purple	white, pink / spotted
VAV-3716-U	purple	brown, purple / stripped
VAV-3716-V/W	purple	brown, purple / stripped

Table 4. Composition in lines of the complex landraces MCM-292 and MCM-298, seed colour and pattern of each one.

LINES	SEED COLOUR / PATTERN
MCM-292 (14 lines)	
MCM-292-A	black, brown / stripped
MCM-292-B	black
MCM-292-C	white, black / bicolour
MCM-292-D	brown, black / stripped
MCM-292-E	brown, purple / spotted
MCM-292-F	brown, purple / stripped
MCM-292-G	black, brown / stripped
MCM-292-H	brown
MCM-292-I	brown, purple, black / stripped
MCM-292-J	brown
MCM-292-K	brown
MCM-292-L	brown, black / stripped
MCM-292-M	brown, purple, black / stripped
MCM-292-N	brown, black / stripped
MCM-298 (5 lines)	
MCM-298-A	white, black / hilum spotted
MCM-298-B	brown, purple / stripped-spotted
MCM-298-C	brown
MCM-298-D	white, purple / speckled
MCM-298-E	brown, black / stripped

Table 5. Mean, standard deviation, coefficient of variation (CV) and standard error of the 11 traits studied in 83 accessions and two complex landraces

Origin	Days to flowering (50%)	Central leaflet length (mm)	Central leaflet width (mm)	Bracteole length (mm)	Bracteole width (mm)	Pod length (mm)	Pod width (mm)	Seed length (mm)	Seed width (mm)	Seed thickness (mm)	Weigth of 100 seeds (g)
Total (83 accessions)											
Mean	80.3	70.8	41.7	4.36	2.93	111.9	10.98	13.00	8.03	5.93	44.6
Standard deviation	11.97	9.71	7.28	0.398	0.263	13.05	1.268	1.215	0.508	0.509	7.78
CV (%)	14.9	13.7	17.5	9.1	9.0	11.7	11.5	9.3	6.3	8.6	17.4
Nr observations	38	57	56	76	67	78	78	83	83	83	83
Standard error	1.94	1.29	0.97	0.046	0.032	1.48	0.144	0.133	0.056	0.056	0.854
MCM-SV (11 lines)											
Mean	81.4	78.0	46.4	4.33	2.89	114.6	10.82	13.10	8.09	5.92	46.1
Standard deviation	9.90	8.53	6.18	0.235	0.193	13.94	0.527	1.127	0.401	0.733	7.47
CV (%)	12.2	10.9	13.3	5.4	6.7	12.2	4.9	8.6	5.0	12.4	16.2
Nr observations	7	10	10	11	11	11	11	11	11	11	11
Standard error	3.74	2.70	1.95	0.071	0.058	4.20	0.159	0.340	0.121	0.221	2.252
VAV-3716 (14 lines)											
Mean	76.7	72.2	43.2	4.30	2.95	110.2	11.52	12.79	8.04	5.84	42.5
Standard deviation	9.43	8.1	7.21	0.210	0.229	8.94	1.508	1.286	0.389	0.459	7.29
CV (%)	12.3	11.2	16.7	4.9	7.8	8.1	13.1	10.1	4.8	7.9	17.2
Nr observations	9	13	13	14	13	14	14	14	14	14	14
Standard error	3.14	2.25	2.00	0.056	0.064	2.39	0.403	0.344	0.104	0.123	1.948

Table 6. Range of variation in 11 quantitative traits inside the complex landraces MCM-SV and VAV-3716 and total variation in the germplasm studied.

TRAIT	TOTAL 83 accessions 100 %	MCM-SV 11 lines 13.3 %	VAV-3716 14 lines 16.9%
	RANGES OF VARIATION		
Days to 50 % flowering	**70 - 110 40 days - 100 %**	**70 -90 20 days - 50 %**	**70- 90 20 days - 50 %**
Central leaflet length (mm)	**41.8 - 87.1 45.3 mm - 100 %**	**58.5 - 87.0 28.5 mm - 62.9 %**	**49.3 - 81.9 32.6 mm - 72.0 %**
Central leaflet width (mm)	**27.5 - 56.3 28.8 mm - 100 %**	**32.5 - 56.3 23.8 mm - 82.6 %**	**27.5 - 52.9 25.4 mm - 88.2 %**
Bracteole length (mm)	**3.37 - 5.96 2.59 mm - 100 %**	**3.82 - 4.73 0.91 mm - 35.1 %**	**3.94 - 4.60 0.66 mm - 25.5 %**
Bracteole width (mm)	**2.38 - 3.66 1.28 mm - 100 %**	**2.65 - 3.32 0.67 mm - 52.3 %**	**2.53 - 3.34 0.81 mm - 63.2 %**
Pod length (mm)	**86.3 – 147.8 61.5 mm - 100 %**	**93.9 - 147.8 53.9 mm – 87.6 %**	**89.2 – 118.8 29.6 mm – 48.1 %**
Pod width (mm)	**8.2 - 15.1 6.9 mm - 100 %**	**9.9 - 11.5 1.6 mm - 23.2 %**	**9.7 - 15.1 5.4 mm - 78.3**
Seed length (mm)	**9.9 – 16.3 6.4 mm - 100 %**	**11.1 – 15.7 4.6 mm – 71.9 %**	**10.2 – 14.2 4.0 mm – 62.5 %**
Seed width (mm)	**7.1 – 9.1 2.0 mm - 100 %**	**7.5 – 8.6 1.1 mm – 55.0 %**	**7.1 – 8.6 1.5 mm – 75.0 %**
Seed thickness (mm)	**4.7 – 7.6 2.9 mm - 100 %**	**4.7 – 7.6 2.9 mm – 100 %**	**4.9 – 6.7 1.8 mm – 62.1 %**
Weight of 100 seeds (g)	**28.9 – 67.4 38.5 g - 100 %**	**35.1 – 64.4 29.3 g – 76.1 %**	**30.3 – 54.3 24.0 g – 62.3 %**

Table 7. Mean, standard deviation, coefficient of variation (CV), standard error and range of variation of the traits studied in the landraces MCM-292 and MCM-298

Origin	Seed length (mm)	Seed width (mm)	Seed thickness (mm)	Weight of 100 seeds (g)
MCM-292 (14 lines)				
Mean	13.62	8.25	5.85	51.12
Standard deviation	22.74	13.56	9.72	20.69
CV (%)	16.7	16.4	16.6	40.5
Nr observations	14	14	14	14
Standard error	6.08	3.62	2.60	5.53
Range of variation	16.85 - 10.14 6.71 mm	9.95 - 5.84 4.11 mm	7.10 - 3.85 3.25 mm	77.83 - 18.75 59.08 g
MCM-298 (5 lines)				
Mean	13.99	8.57	5.86	52.18
Standard deviation	19.87	9.84	11.68	16.18
CV (%)	13.6	11.5	19.9	31.0
Nr observations	5	5	5	5
Standard error	8.48	4.40	5.22	7.23
Range of variation	15.17 - 10.66 4.51 mm	9.47 - 7.13 2.34 mm	6.73 - 3.83 2.90 mm	64.17 - 24.00

Figure 1. Seeds of the different lines of the landraces MCM-SV, MCM-292, MCM-298 and VAV-3716.