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The purpose of the CGIAR Program on Participatory Research and Gender Analysis for Technology Development and Institutional Innovation (PRGA Program) is to assess and develop methodologies and organizational innovations for gender-sensitive participatory research and to operationalize their use in plant breeding and in crop and natural resource management.

The PRGA Program is cosponsored by the International Center for Tropical Agriculture (CIAT), which serves as the convening center, and by the International Maize and Wheat Improvement Center (CIMMYT), the International Center for Agricultural Research in the Dry Areas (ICARDA), and the International Rice Research Institute (IRRI).

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The PROINPA Foundation is a non-profit organization that is committed to using science and technology to develop sustainable agriculture, while conserving natural resources and alleviating rural and urban poverty. Using participatory methods, PROINPA generates, promotes, and diffuses technological and agroindustrial innovations to improve the food security of Bolivian rural families and the competitiveness of production chains of Andean crops. It also aims to conserve, use, manage, and develop genetic resources for the benefit of farmers in the country's different agroecological zones and of the nation as a whole.

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## CGIAR Systemwide Program on Participatory Research and Gender Analysis

### **Participatory Plant Breeding: A New Challenge in the Generation and Appropriation of Potato Varieties by Farmers in Bolivia**

Julio Gabriel, Jaime Herbas,  
Magaly Salazar, Juan Ruiz, Justo López,  
Jorge Villarroel, and Demetrio Cossio.

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Enquiries at: Fundación PROINPA,  
Av. Blanco Galindo, Km 12.5  
Calle C. Prado s/n  
Casilla 4285  
E-mail: [jgabriel@proinpa.org](mailto:jgabriel@proinpa.org)  
Web site: [www.proinpa.org](http://www.proinpa.org)

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## Synopsis

Experiments on participatory plant breeding (PPB), financed by the CGIAR systemwide program on PRGA and Papa Andina, were carried out with the active participation of farmers from the communities of Piusilla-San Isidro and Compañía Pampa of the Morochata Region in Bolivia. Nine men and eight women farmers were involved.

Conventional breeding takes many years of experimenting to generate varieties for a broad range of environments. It is complicated by the need to develop varieties for particular niches. These varieties must be similar to those already being used, but more productive, more resistant to biotic factors such as late blight (*Phytophthora infestans*) and false root-knot nematode (*Nacobbus aberrans*), and more acceptable to local markets.

The farmers who participated in the experiment, unique for Bolivia, call themselves potato breeders and, jointly with the plant breeders, have generated varieties similar to the cv. Waych'a which is the most widely consumed cultivar in Bolivia, but resistant to late blight (or *t'octu* in Quechua). The joint efforts between farmers and plant breeders resulted in 12 varieties with superior yield (10-25 t/ha) to that of Waych'a (5 t/ha) and possessing the agronomic traits and qualities of Waych'a, the main parent. Three of the varieties showed potential for the potato chip industry, with little burning at the edges, uniform frying, little absorption of oil, being neither porous nor greasy, and possessing good-sized tubers that are larger than those of either Waych'a or Robusta.

Many plant breeders are skeptical of the success of participatory methodologies, arguing that some initial processes of genetic improvement are complex and not easy for farmers. However, our experience has shown that time can be gained, mainly in the stage of adoption, when farmers are engaged early in genetic improvement.

This unique PPB experiment in Bolivia shows the methodology to be attractive for obtaining new varieties. However, bottlenecks still persist, such as multiplication, dissemination, and promotion for more widespread and faster adoption, and which require additional financial support to resolve.

Topics for consideration and discussion among farmers have also been generated on intellectual property rights, procurer's rights, and validity of PPB for other crops of economic importance.

## Introduction

In a specific context, conventional plant breeding (CPB) seeks materials of broad adaptation and is less concerned with the disappearance of native crops, which are often low yielding and susceptible to abiotic and biotic stresses. The PPB program is an alternative that permits the use of local native cultivars, which, from the farmer's perspective, are valuable sources of useful traits. Participatory plant breeding (PPB) is a complement to CPB in which farmer participation begins at the stage of choosing parental materials, and continues with farmers making crosses, monitoring materials from the crosses, receiving training, evaluating and selecting families, and ends with

their choosing clones from particular families for on farm multiplication and use (Gabriel et al. 2000a, b, c; 2001).

PPB followed previous work with participatory varietal selection (PVS) with farmers was carried out in the Department of Cochabamba, in the Morochata Region, where potato late blight is endemic at high altitudes (Thiele et al. 1997; Gabriel et al. 2002a).

This document describes a 5-year PPB project, the objectives of which were to (1) develop and adjust methodologies for obtaining advanced clones with genetic resistance to stresses regarded as priority by farmers; (2) draw out the research capacity of farmers so they may solve the production problems of their own region; (3) train farmers in the techniques of hybridization, and management and selection of seedlings in household seedbeds and in the field to obtain new varieties; (4) contribute to the conservation and use of potato genetic resources; (5) develop varieties with good resistance to late blight, good yield, and acceptable culinary qualities for household and industrial consumption; and (6) conduct economic analyses of CPB and PPB.

Morochata is located in northern Cochabamba at 17°10'1" S and 66°40'52" W, and at altitudes between 2750 and 4250 m above sea level (masl). It is the second municipality of Ayopaya province, and has an area of about 9620 km<sup>2</sup> (i.e., 17.3% of the Cochabamban territory). It is 75 km from the city of Quillacollo, and has a population of more than 27,000 (Trujillo et al. 2002).

According to the Participatory Plan for Sustainable Municipal Development (1998-2002), Morochata is regarded as an eminently agricultural region, where potato growing is the principal activity, with the produce being destined for household consumption and sale in regional and local markets. Other crops cultivated include maize, beans, wheat, oats, barley, oca, and tree pepper (*locoto*), which are less profitable than potato and are mostly destined for household consumption. Other secondary activities include handcrafts and livestock, the latter being for household consumption.

Soil types depend on altitude and planting time in the zone. For example, Piusilla-San Isidro is found at high altitudes (3750 to 4200 masl), where soils have a sandy loam texture and are blackish in color. In contrast, Compañía Pampa is located at lower altitudes (2750 to 3000 masl), where soils have a silty clay loam texture and are yellowish coffee in color.

The Morochata farmers handle three agroecological levels or tiers and, in some microclimates, typically carry out as many as four planting times for their potato crop:

- ✓ The first plantings are known as *llojchis* (2750-3300 masl) and are carried out from April to 15 May. About 90% of the production goes to the potato market and the remaining 10% is for household consumption.
- ✓ Plantings for June and July are called *mishkas* (2750-3300 masl), with 90% of the production also going to the market and the remaining 10% to household consumption.

- ✓ The “seasonal” planting is carried out during September to October (3300-3750 masl), when 60% of the production goes to market and the remaining 40% is used as seed.
- ✓ Plantings of varieties Grande and Wata Tarpuy (3759-4200 masl) are carried out from November to 15 December. About 60% of production goes to market and 40% is used as seed.

The farmers of Piusilla-San Isidro still cultivate native varieties for household consumption. These include Yurac Imilla (adg), Papa Paceaña (adg), Yana Lunka (adg), Runa Papa (adg), Q’ochila or Puka Lunka (adg), Puca T’ica (adg), Luk’i (juz), Pali Papa (adg), Ajahuiri (ajh), Papa Carlos (adg), Sutamari (adg), Pinko (adg), Guinda Lunka (adg), K’atawi (adg), Moseña (adg), Canastilla (stn), Sani Imilla (adg), Wallat’a, Saylulu, K’ausillu (ajh), Pili Runtu (stn), and Phurejas (phu)<sup>1</sup> (Herbas et al. 2000).

In their turn, the farmers of Compañía Pampa, 60 years ago, used to cultivate native varieties such as Imilla Blanca (adg), Q’oyllus (stn), Yana Lunka, and Q’ochila or Puka Lunka, which, however, were lost to late blight and insect pests. Today, no one cultivates them (Herbas et al. 2000).

The main constraint to potato production is late blight, caused by the pseudofungus *Phytophthora infestans* (Guamán et al. 1999).

## What We Did

To motivate farmers, we took advantage of the monthly meetings convened by their community organizations (unions), and discussed the objectives, goals, and activities that the PPB project would carry out. At these meetings, interested farmers indicated their willingness to participate in the project and to be part of the participatory breeding group (Herbas et al. 2001b).

The Local Agricultural Research Committees (CIALs, their Spanish acronym) and the Farmer Field Schools (FFSs), used as participatory research and training methodologies in the selected communities, served for applying a methodology with elements of both methodologies.

To prioritize and select progenitor varieties, we first carried out an analysis of the advantages and disadvantages of the different varieties cultivated in each area, using the scenario of late blight as the major constraint to potato production. For the two areas, a list was made of the potato varieties cultivated. Those farmers who knew these varieties’ characteristics and advantages recommended, in consensus with the rest of the group, those that showed the desired traits for participatory breeding (Herbas et al. 2001b).

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1. The abbreviations refer to different species or subspecies of potato: adg = *Solanum tuberosum* subsp. *andigena*; ajh = *Solanum ajanhuiri*; juz = *Solanum juzepczukii*; phu = *Solanum phureja*; stn = *Solanum stenotomum*.



In the survey carried out, through a semi-structured interview, 13 farmers from Piusilla-San Isidro and 7 from Compañía Pampa identified the ideotype of potato that they most preferred, taking into account certain traits such as plant height; number of stems; flowering; and tuber characteristics such as shape, culinary qualities, marketability, storability, resistance to late blight, and yield.

With reference to farmer participation in the Morochata groups, at first, 19 farmers from Piusilla-San Isidro (five were female) and 18 from Compañía Pampa (six were female) participated. However, by the third meeting some participants had abandoned the groups, and women had joined the Piusilla-San Isidro group. Currently, six men and seven women belong to the Piusilla-San Isidro group, and four men to the Compañía Pampa one (Herbas et al. 2001b).

The participation of men and women in both community groups was conditioned by the cultural limitations governing gender. The Cochabamba communities are part of the Quechuan culture. This fact, together with geographical location, presence of institutions, communication media, and language, determined the farmers' level of participation. For example, one limitation that affected participation and its quality was language, where the women speak Quechua and understood very little Spanish. The presence of institutions also influenced women's participation. For example, in Piusilla-San Isidro a tradition already existed of nongovernmental organizations supporting the strengthening of grassroots organizations, agricultural extension, and health programs. Currently, this group is very active (Herbas et al. 2001b).

In Piusilla-San Isidro, five women participated because of factors such as greater contact with markets, access to the Cochabamba-Morochata road, which goes through the community; presence of institutions that work with women, promoting their organization; the level of schooling the women had received; the implementation of an FFS in which women participated, and the predominance of evangelicalism among community members.

In contrast, in Compañía Pampa, women did not participate because, apparently, they did not perceive immediate "benefits" from the project. In previous contacts, institutions had facilitated women's participation by offering short-term incentives such as food (Herbas et al. 2001b).

## ***First phase: 1999-2001***

### ***Implementing the methodology***

Work in the two communities of Piusilla-San Isidro and Compañía Pampa began in January 1999. Developing the methodology involved several stages in which the intensity of incorporating determined aspects was different (sensibilization, survey, prioritization, etc.). In both communities, similar activities were carried out but with adaptations of content and the provision of several training sessions developed with elements from the FFS approach (Gabriel et al. 2000a; Herbas et al. 2001a; Salazar et al. 2001).

### ***Participatory evaluations at flowering***

Participatory evaluations at flowering were carried out in the field, assessing each family of crosses. At both flowering and harvest, each individual or clonal selection was also assessed.

### ***Second phase: 2001-2002***

In the second phase, selected genotypes were evaluated in a participatory fashion in the field at flowering and harvest. In both Compañía Pampa and Piusilla-San Isidro, over two training sessions, farmers learned how to evaluate severity of foliage infection by late blight and how to select clones. The farmers then conducted evaluations over 3 weeks, every 7 and 10 days, respectively, in the two communities. The Compañía Pampa farmers evaluated severity of late blight according to percentages of leaf damage. To compare, the facilitator also performed evaluations.

The second training session was implemented at harvest. The farmers harvested by row and by plants of each clone, leaving the tubers uncovered. Once one family was harvested, the clones were evaluated and selected. Each farmer individually inspected the entire selection plot and began selecting the clones that he or she most liked. Selection was also carried out in group, to see if the criteria discussed and agreed upon were the same or differed from the individuals' criteria. To collect the farmers' selection criteria, an open-ended survey, both individual and in group, was used.

The data of severity obtained from the farmer potato breeders were analyzed statistically according to a randomized complete block design.

### ***Third phase: 2002-2004***

This phase marked a new stage in the PPB project, for the following reasons:

1. Over the previous 3 years, the farmers had selected in the field 22 genotypes of good yield, resistant to late blight, and with floury tubers, like Waych'a (*Solanum tuberosum* subsp. *andigena*), the most widely planted potato cultivar in the Morochata Region.
2. The farmers planned their activities of monitoring and evaluation of genotypes in the field, meeting on several opportunities with the facilitator from Fundación PROINPA. They decided to plant the genotypes during the planting season, so they could compare them with the popular Waych'a variety.
3. The farmers decided to plant the genotypes in both communities in a randomized complete block (RCB) design, with three replications and 10 tubers per row. They justified their decision by indicating that the land is not always the same everywhere and that some sites of a plot are more fertile than others, or that there were risks of losing the genotypes to animals eating them if they were all planted in the one plot.

4. The farmers organized two field days. However, the farmers of Compañía Pampa could only invite local community members because their potato crops flowered during the intense rainy season, which made reaching the cultivation fields difficult and prevented outsiders from visiting.

### ***Field days at Piusilla-San Isidro***

***Implementing a field day on flowering in potato.*** The field day on flowering was carried out on 12 March 2003 with the participation of 9 women and 10 men from the community of Piusilla-San Isidro. Delegates from the union and 3 technicians from Fundación PROINPA also attended.

The Piusilla-San Isidro farmers also invited development institutions, municipality authorities, the union, and community members to:

- ✓ Provide feedback to the community members on the research being carried out to improve the potato crop.
- ✓ Show community members the genotypes, so they may become familiar with them, and can compare them with their own experiences with cv. Waych'a.
- ✓ Encourage community members' interest in the new varieties so they would want to acquire them and become involved in their multiplication and dissemination.
- ✓ Help consolidate a group of farmer potato breeders who will also participate in research on other crops, and eventually set up a CIAL that will become the community's technical arm for validating and generating technologies.

***Developing the event.*** The event, attended by 24 people in all, was initiated with words of welcome from the farmers Justo López and Juan Ruiz. The women then took the floor, and explained in Quechua the process of generating varieties, their failures, and what they learned. They carefully explained the potato flower's organs and how crosses were made in the potato.

The men reinforced the women's explanations and took the visitors to the field to explain resistance to late blight as observed in cv. Waych'a, which was used as a check. They also dug up some plants that showed good vigor to display their tubers. They likewise made a similar and preliminary selection of those genotypes that showed good resistance and vigor, marking them with threads of blue wool.

To finalize the event, a discussion session was held to clarify doubts and expectations. A representative from the community's union took the floor and congratulated the group on its initiative in conducting the work and that the community's farmers were interested in following up the varieties and in participating in the harvest.

***Demonstration day.*** Demonstration day was held on 16 and 22 April 2003 in Piusilla-San Isidro and Compañía Pampa, respectively. The aims were to harvest,

evaluate, and select varieties. It was also an opportunity to discuss seed multiplication. Participants included project-participating farmers (six women and seven men) from the two communities; union members; a technician from ASAR (an NGO); three technicians from Fundación PROINPA; a technician from IPRA-CIAT's Promoting Changes project (Colombia), which is based on Fundación PROINPA's work; and representatives from development institutions such as SEPA (a potato seed production enterprise) and Lucana S.A. (a potato-chip enterprise); municipal authorities; and community members.

The group of farmer potato breeders at Compañía Pampa also invited community members and the unions of Compañía Pampa and Chinchiri.

In both communities, the goals of the demonstration day were to:

- ✓ Evaluate and select genotypes on a participatory basis.
- ✓ Discuss and outline a strategy for multiplying and disseminating the seed of the selected new varieties.
- ✓ Discuss the group's future and its likely direction.
- ✓ Encourage seed companies' interest in the new varieties to multiply them for their dissemination.
- ✓ Encourage industry's interest in the new varieties.

***Developing the event.*** In Piusilla-San Isidro, the farmer Justo López initiated the event by welcoming the participants. Farmer Juan Ruiz then took the floor to describe, together with Justo López, the project group's research activities, and the work it had carried out during the project's 4 years. Later, Felicidad Escobar and Dionicia Katari took the floor, explaining their experiences with the process, difficulties, and the lessons they learned. For example, they described how they made better crosses than the men, because they took more care and were more patient. They were likewise more successful with managing the seedbeds; again, because they took more care than did the men. They clarified that both men and women planted and managed the field.

Then followed a question and discussion session, after which the group organized the harvest, deciding to harvest row by row and plant by plant, and thus ascertain the number of harvested plants, and evaluate the tubers in terms of uniformity, size, number, color, eye depth, and yield.

After the harvest, all the genotypes were carried in net bags, each with its duly coded identification, to a collecting place and then taken to storage. It was obvious that both men and women farmers had selected their genotypes as they harvested. But to make sure, they lined up the genotypes, numbering each genotype from 1 to 22. Each farmer then checked the genotypes and secretly ranked them.

### ***Field days at Compañía Pampa***

The field day began with farmer Demetrio Cossio welcoming the participants to the event. Jorge Villarroel, a farmer with the project group, then described the group and its work in the previous 4 years of the project. Demetrio then described the experiences the group has had, its difficulties, and the knowledge it acquired.

Then followed a question and discussion session, after which the group organized the harvest, deciding to harvest row by row and plant by plant. The goal was to ascertain the number of harvested plants, and evaluate the tubers in terms of uniformity, size, number, color, eye depth, and yield.

After the harvest, all the genotypes were left in field and each participating farmer was given the opportunity to select the best genotypes. The five most frequently selected genotypes were carried to a collecting place and then taken to storage in net bags, each with its duly coded identification. It was again obvious that the farmers had already selected their preferred genotypes. But to make sure, they lined up the five genotypes, numbering each from 1 to 5. Each farmer then checked each genotype, and secretly ranked it.

The farmers participating in the demonstration day at Compañía Pampa suggested returning to the field to select two more genotypes that had been passed over in the original selection. They chose one more genotype and replaced one that had already been selected. They justified the replacement, saying that they had been attracted by the yield of the eliminated clone, but had not taken into account its color (cream), which would not have been acceptable in the market.

## **Results and Discussion**

### ***First phase: 1999-2001***

#### ***Implementing the methodology***

From the survey of the Morochata farmers, we identified the principal criteria for the potato ideotype. These were early maturity, good yield, resistance to late blight, medium plant height, red-skinned tubers of a floury consistency that is similar to that of cv. Waych'a tubers when cooked, and marketability.

The farmers selected four varieties as parents: Waych'a, the very widespread native variety, and three blight-resistant hybrids that were released by Fundación PROINPA. The native was highly desired by the farmers for its good flavor, floury texture, fast cooking, and high market demand. However, it was susceptible to late blight. The parental varieties were chosen for their resistance to late blight, and the good culinary qualities, roundness, and skin color (red or pink) of their tubers.

The training sessions were evaluated in the field with the farmers. To prepare the PPB training sessions, elements were taken from the FFS approach, which motivates

learning by discovery and monitoring the study plot. Ten training sessions were prepared and implemented (Herbas et al. 2001a). The farmers considered the training as important because, according to them, they needed to know more about obtaining sexual seed from crosses. They also mentioned that, on learning, they gain experience that enabled them to provide support for other communities.

In both the Morochata communities, crosses were first carried out by placing inflorescences in flasks containing water. These were lost to bacterial rot of the stems in the water.

In Piusilla-San Isidro, four families of crosses were made in the field; these were the hybrid cross India (*Solanum tuberosum*) × Waych'a (I × W), Runa Toralapa (RT) × W, Robusta (R) × W, and I × R. The four seedbeds were planted in farmers' plots and the respective farmers were responsible for them. From these crosses, only small berries were obtained because too much rain and hail prevented full development, thus reducing the quantity of sexual seed obtained. So not to delay the experiment, plant breeders from Fundación PROINPA's Toralapa Center, who had been conducting the CPB side of the experiment and had obtained enough true potato seed from their crosses in the greenhouse and seedbeds, gave this seed to the farmers so they could continue with the experiment.

In Compañía Pampa, a communal seedbed was planted. It was divided into three to facilitate individual handling of material from each of three families of crosses, that is, R × W, I × R, and I × W. The farmers were therefore organized into three groups, each responsible for each family.

The percentage of field establishment was evaluated one week after transplanting by counting the initial number of plants per row and the number of plants germinated. The farmer potato breeders performed all the farming tasks of fertilization, first hilling, irrigation, and phytosanitary control with insecticides. The average germination for the families was 95% for the two Morochata communities. The initial 5% loss was caused by problems in transplanting such as damage of seedlings during extraction from the seedbed and during transplanting to the plot.

### ***Participatory evaluations at flowering***

The participatory evaluations were carried out in the field, assessing each family of crosses and each individual or clonal selection at both flowering and harvest.

**Family selection.** At flowering, the farmers mentioned, as relevant criteria, plant size, presence of blight symptoms (leaf spots), and number and color of flowers. Both men and women farmers associated flower color with the tuber's skin color, saying that plants with white flowers will possibly have white-skinned tubers and plants with pink flowers will have either pink or red-skinned tubers, similar to those of cv. Waych'a.

In Piusilla-San Isidro, the family I × W was selected by eight of the nine farmers as being the best of the four families, whereas, in Compañía Pampa, six of the eight farmers selected the R × W family as being the best of their three families.

**Differences of criteria between men and women.** In Piusilla-San Isidro, all the women evaluated the family I × W as “very good” and the family RT × W as “bad”. Two of three men coincided with the selection of the families I × W, R × W, and I × R as “very good”, “good”, and “regular”, respectively, and all the men and women agreed that the family RT × W was “bad” (Gabriel et al. 2000c).

In Compañía Pampa, all six men indicated that the families R × W, I × R, and I × W were “good”, “regular”, and “bad”, respectively. The women, however, selected differently, with all selecting I × R as “the best” (the men had qualified this family as “regular”). The difference may have been a consequence of the women not having participated in the participatory breeding and their decision being based on the plants’ vigor.

**Individual selection of clones.** In Piusilla-San Isidro, the farmer potato breeders, using their criteria for selection, chose, from 607 genotypes belonging to different families, 4 plants from the R × W family (i.e., 0.66%), 6 from RT × W (0.99%), 29 from I × W (4.78%), and 8 from I × R (1.32%).

In Compañía Pampa, the farmer potato breeders, again using their criteria for selection, chose, from 2146 genotypes belonging to different families, 38 plants from the I × R family (1.77%), 17 from I × W (0.79%), and 13 from R × W (0.60%).

In both communities, the principal criteria used were the similarity of appearance of the leaf and flower with those of cv. Waych’a, plant vigor and size, formation of berries (*aylinkus* in Quechua), leaf health (no disease), number and thickness of branches, minimal damage by insects such as the *piqui piqui* (as the *Epitrix* beetle is popularly known), erect growth, and presence of flower buds.

### **Participatory evaluations at harvest**

At harvest, eight farmers from Compañía Pampa (all men) and seven farmers (four women and three men) from Piusilla-San Isidro participated in clone evaluation and selection. The criteria mentioned by the farmers as being the most relevant referred to tuber color, shape, and appearance; yield; and presence of eyes. Tuber shape and color were related to similarity to those of cv. Waych’a; yield to the number and size of tubers; and presence of eyes to the quality of seed tubers, that is, to the number of shoots that the tubers could have. The tubers’ healthy appearance was determined in terms of the *llosq’etas*, that is, a smooth, uniform skin.

### **Second phase: 2001-2002**

The analysis of variance for the area under the disease progress curve (AUDPC) for *Phytophthora infestans* did not detect significant differences ( $P = 0.05$ ) among the

evaluations of severity by both farmers and facilitator. Neither did the test of comparisons of means at  $P = 0.05$  detect significant differences between farmers and facilitator. This indicates that the training was effective, and that the farmers had handled, with sufficient precision, the evaluation of severity.

In the analysis of variance for families, the means test for AUDPC detected highly significant (at  $P = 0.01$ ) differences for evaluating severity of late blight in the families (Table 1). Although families  $I \times W$  and  $R \times W$  did not differ significantly for AUDPC, they did differ significantly from cv. Waych'a and family  $I \times R$ .

Table 1. Means for area under the disease progress curve (AUDPC) of potato clones evaluated by farmers in the Morochata Region, Bolivia.

Family	Genealogy of clone	AUDPC <sup>a</sup>
Waych'a	Waych'a	1203 a
00-1	India $\times$ Waych'a	485 b
00-3	Robusta $\times$ Waych'a	346 b
00-2	India $\times$ Robusta	124 c
		HSD 1203

- a. Values followed by the same letter in the column are not significantly different according to Tukey's honest significant difference (HSD) test.

### ***Selected clones and criteria of selection***

In Compañía Pampa, a total of 244 clones were planted, comprising 26 clones from family  $I \times W$ , 199 from  $R \times W$ , and 19 from  $I \times R$ . At harvest, the farmers selected 4 clones from  $I \times W$  (i.e., 1.6% of the original selection of 244; one clone from  $R \times W$  (0.4%); and 14 clones from  $I \times R$  (5.7%).

Most of the clones selected by the community of Compañía Pampa had tubers that were uniform in size, either round or oblong, and with a red or pink skin color, and cream and/or yellow flesh. The eyes were medium-deep or shallow, and yields were good. Such selection showed that the farmers, even though preferring varieties with deep eyes like those of variety Waych'a, are tending to change to varieties with tubers possessing shallow and/or medium-deep eyes because of easier peeling and the demands of fast-food restaurants.

At harvest, 22 potato clones were selected in participatory fashion. The men and women farmers coincided in their selection for 6 clones (27%), but 6 (27%) were selected only by the men and 10 clones (46%) only by the women. Such divergence in clone selection was a result of the women being more concerned with details, and regarding eye depth and ease of peeling as two of the important criteria. Table 2 lists the different clones selected by men and women.



Table 2. Differences in selection of 22 improved potato (*Solanum* spp.) clones between men and women farmers, Morochata Region, Bolivia.

Family <sup>a</sup>	Clone	Farmers by gender			Criteria
		Both	Women	Men	
00-1 (RT × W)	00-1-1	X			Round shape, good yield,
	00-1-5	X			red skin, large size
	00-1-6	X			White and big tubers and with flat surface
	00-1-7		X		Round tubers and good yield
	00-1-8			X	Red skin and big tubers
00-2 (I × R)	00-2-2			X	Red skin tubers, good yield and aptitude for marketing
	00-2-6			X	Oval tubers and superficial eyes
00-3 (R × W)	00-3-5	X			Red tubers, good yield and aptitude for marketing
	00-3-7	X			
	00-3-2		X		Good yield and red eyes
	00-3-3		X		Red tubers with flat surface
	00-3-11			X	Round and big tubers with big eyes
	00-3-14			X	Big tubers and good yield
00-4 (I × W)	00-4-28	X			Big tubers with semi-superficial eyes easy to peel
	00-4-2		X		Similar to the variety Tomasa
	00-4-5		X		Red potatoes with big eyes
	00-4-17		X		Red and big tubers, it seems good to sell
	00-4-20		X		Similar to the “potato varieties Q'oyllu”
	00-4-13			X	Big tubers with good yield
	00-4-14			X	Red tubers, good yield and it seems capable for the sale
	00-4-16			X	Oval tubers
	00-4-18			X	

a. RT × W = Runa Toralapa × Waych'a; I × R = India × Robusta; R × W = Robusta × Waych'a; I × W = India × Waych'a.

### **Workshop for the farmers**

Toward the end of the project, after the harvest, a workshop was organized to enable the farmer potato breeders of Piusilla-San Isidro and Compañía Pampa to share their experiences and plan for the monitoring and evaluation of the activities in the participatory breeding experiment. By the end of the workshop, they had prepared a strategy for multiplying and disseminating the seed of new genotypes selected as potential varieties (Gabriel et al. 2002b). To analyze the different themes of participatory improvement, the farmers formed three groups, one with four men farmers from Compañía Pampa, the second with four men farmers from Piusilla-San Isidro, and the third with five women farmers from Piusilla-San Isidro.

One relevant aspect of the event was that the women's group indicated that it will continue with the activities because its members were interested in learning and in multiplying good seed. They were afraid that, possibly, there would be no more projects that support farmers.

A challenge for the workshop was to determine the modality of work for the farmers, because the project was winding up its activities and the possibility existed that everything would finish on its conclusion. On analyzing the matter, the farmers from Compañía Pampa determined that they would continue working together to obtain a larger quantity of seed and had selected three varieties. The men and women farmers from Piusilla-San Isidro also decided to continue as a group, but with only one farmer being in charge of carrying out the necessary farming tasks while the other participants would provide support in planting, evaluating, and harvesting the genotypes. The group had other greater ambitions, such as sending the selected varieties for viral cleaning, and the group becoming seed suppliers for the community.

The women also mentioned that if the wife does not understand what her husband is training for, she would discourage him from attending by asking him not to go to any more meetings.

The group from Compañía Pampa mentioned that the women do not have time to farm potatoes as they are in charge of grazing the animals (cows, sheep, goats), meaning that they must cook early before going with the livestock to distant places—there are no nearby places where animals can graze—and returning when it is dark, when they have to cook again.

The women mentioned that both men and women can carry out the crosses but that the women have more patience. The men agreed and added that the women also have more patience to obtain seeds from the berries. To select clones, everyone agreed that both men and women should work together because then they could discuss and thus select better.

### ***Third phase: 2002-2004***

#### ***Piusilla-San Isidro***

Toward the end of the project, the farmers counted, helped by the participating technicians, the frequency of the most voted genotypes, and were able to select six new genotypes, ranked in their order of preference (Table 3).

Of the six selected genotypes, four were from the family  $I \times W$ , and two were from the family  $RT \times W$ . The last two genotypes were chosen on an individual clone basis, under different criteria, even though the farmers gave the family  $RT \times W$  an overall evaluation of "bad". In both cases, the male parent was cv. Waych'a, the reference variety for the farmers. The other two families ( $R \times W$  and  $I \times R$ ) were discarded. However, the farmers decided that those who had participated should also choose from

Table 3. The new selected potato genotypes ranked by farmers in order of preference, 2002/03 season, Piusilla-San Isidro, Morochata Region, Bolivia.

Genotype	Genealogy <sup>a</sup>	Preference	Designated names
00-04-14	I × W	1st	Ch'aska Waych'a
00-04-02	I × W	2nd	Piusilleña
00-01-08	RT × W	3rd	Puka Ñawi
00-04-05	I × W	4th	Puka Waych'a
00-01-01	RT × W	5th	Sinchi Waych'a
00-04-13	I × W	6th	Puka Chola

a. I × W = India × Waych'a; RT × W = Runa Toralapa × Waych'a.

among the discarded clones for testing in the following season. The farmers took care to record which genotype was taken by which farmer.

After the participatory selection, the farmers gave the varieties provisional names (Table 3), and then nominated a “godfather” so he would not forget that he had “godchildren” and would keep monitoring them. Lastly, they took a small sample (1 kg, because they had few tubers to continue with the experiment) of each of the six selected varieties to Lucana S.A. to evaluate the varieties' traits for industry. This company is the largest enterprise of potato chips in Cochabamba.

At the project's final meeting, the farmers in the PPB group expressed some closing words, followed by the union representative who declared that the union was proud of its colleagues and congratulated them on behalf of the entire community. The union suggested that these initiatives should be followed up and copied by all present.

**Yield analysis.** In Piusilla-San Isidro, the analysis of variance for yield between the genotypes evaluated and the check (cv. Waych'a) showed highly significant differences (Tukey's test at  $P = 0.01$ ) (Table 4), with a coefficient of variance of 33%. In general, the six selected genotypes all had yields (0.24 to 0.56 kg/plant) that were superior to the check Waych'a (0.11 kg/plant), which had suffered a severe attack of late blight, as confirmed by the farmers themselves.

In contrast, in Compañía Pampa, no significant differences were found among the evaluated genotypes, with the selected genotypes having yields between 0.18 and 1.65 kg/plant (7 to 25 t/ha). Comparisons in this case could not be made because the farmers had not planted a check (i.e., Waych'a). Instead, comparisons were made among the genotypes evaluated.

**Selection criteria.** The farmers used the following selection criteria:

- ✓ *Tuber shape.* Because the farmers knew this variety very well and commonly grew it, cv. Waych'a was used as benchmark for this trait.
- ✓ *Yield.* While noting yield per se, the farmers also associated this trait with the trait for resistance to late blight as observed during flowering.

Table 4. Analysis of yield means (kg per plant) of 22 potato genotypes and 1 check evaluated by the group of farmer potato breeders at Piusilla-San Isidro, Morochata, Bolivia, 2002/03 season.

Genotype		Yield <sup>b</sup>
Name <sup>a</sup>	Code	
Ch'aska Waych'a	00-04-02	0.56 a
Piusilleña	00-04-13	0.52 a b
	00-04-17	0.51 a b c
	00-02-06	0.48 a b c d
Puka Ñawi	00-01-01	0.42 a b c d e
	00-04-18	0.40 a b c d e f
Puka Waych'a	00-04-14	0.32 a b c d e f g
Sinchi Waych'a	00-04-05	0.31 a b c d e f g
	00-03-11	0.31 a b c d e f g
	00-02-08	0.30 a b c d e f g
	00-03-03	0.30 a b c d e f g
	00-03-07	0.26 b c d e f g
Puka Chola	00-01-08	0.24 b c d e f g
	00-04-28	0.30 c d e f g
	00-01-06	0.20 d e f g
	00-03-14	0.19 e f g
	00-04-20	0.19 e f g
	00-03-02	0.19 e f g
	00-04-19	0.18 f g
	00-01-07	0.18 e f g
	00-03-05	0.17 e f g
00-01-05	0.13 f g	
Waych'a (check)		0.11 g

- a. Genotypes eventually selected by the farmers.  
b. Values followed by the same letter in the column are not significantly different according to Tukey's test.

- ✓ *Tuber size.* The farmers classified tuber size accordingly: *chapara* (extra big), *qolque* (big), *murmu* (seed), and *chili* (small). They also noted the uniformity of tuber size that each variety yielded.
- ✓ *Tuber health.* This trait was observed with care, the farmers disqualifying any variety that had symptoms of disease or presented tubers with cracks, which indicated an inability to cope with severe water stress.
- ✓ *Eye depth.* The farmers checked the number of "good" eyes, that is, those that had visible "eyelashes", associating them with the number of shoots and vigor of the potential plant.

***Trials with agroindustry.*** On 12 May 2003, the farmers of Piusilla-San Isidro took to Lucana S.A. 1-kg bags of tubers from each of the six varieties selected in the current cropping season, for trials on culinary qualities as potato chips. The clones that performed best in these trials were varieties Ch'aska Waych'a, Piusilleña, and Puka Chola from the family I × W (Table 3). They showed little burning at the edges, fried uniformly, absorbed little oil, were not porous or greasy, and tuber size was adequate.

In contrast, chips from the variety Sinchi Waych'a (family RT × W) absorbed a large quantity of oil and took considerable time to fry. The color of the chips was very yellow and unattractive, with apparent problems of greening. Varieties Puka Ñawi and Puka Waych'a burned more quickly than any of the others.

### ***Compañía Pampa***

The genotypes selected are listed in Table 5.

Of the six selected genotypes, five were from the family I × R and one was from the family I × W. The farmers of Compañía Pampa did not have a preference for Waych'a; instead, their appraisals were in terms of resistance to late blight, yield, red skin color, and medium-deep eyes. After the participatory selection, the farmers gave the varieties provisional names, as listed in Table 5.

Table 5. The new selected genotypes ranked by farmers in order of preference, 2002/03 season, Compañía Pampa, Morochata Region, Bolivia.

Genotype	Genealogy <sup>a</sup>	Preference	Designated names
00-01-21	I × W	1st	Puyjuni Imilla
00-02-51	I × R	2nd	P'alta Chola
00-02-48	I × R	3rd	Waych'a Roberta
00-02-9	I × R	4th	Cholita Rosada
00-02-29	I × R	5th	Villaco
00-02-11	I × R	6th	Super Waych'a

a. I × W = India × Waych'a; I × R = India × Robusta.

At the project's final meeting, the farmers in the PPB group spoke some closing words, followed by the union representative who declared that the union was proud of its colleagues and congratulated them on behalf of the entire community. The union also suggested that these initiatives should be followed up and copied by the farmers present.

### ***Comparative analysis of costs for PPB and CPB***

The PPB and CPB process are complementary activities, but we considered that is important to understand how much each process costs, because the PPB involved the farmers at the beginning of the process, and the CPB process involved the farmers

3 or 4 years before releasing the varieties. These aspects are very important when the technologies are transferred and adopted by the farmers.

The comparative analysis of costs between PPB and CPB was carried out only for the Piusilla-San Isidro community to estimate the cost of obtaining a clone through PPB versus obtaining one through CPB. To make this estimate, we saw as desirable to assess the time of advisers, technicians, thesis students, and farmers, and to include other aspects such as inputs, that were directly related to the generation of the technologies. To assess the time invested in each activity, we decided to use the “hour” as a unit of measure, and the “American dollar” as the monetary unit.

For PPB, a total of US\$7490 was invested in a total of 1087.95 h of work (i.e., at about \$6.88/h). The highest expenses corresponded to technicians, totaling \$3190 (43%, rounded figures), followed by farmers at \$732 (10%), gasoline at \$983.20 (13%), rent and electricity for housing for the researchers at \$910 (12%), and opportunity costs for the advisers’ time at \$880 (12%). The lowest costs were inputs at \$481 (6%), research work at \$60 (1%), and miscellany at \$220 (3%). The farmers’ time was not remunerated, but assessed economically (Montaño 2003).

For CPB, a total of US\$1782 were invested in a total of 395 h of work (i.e., at about \$3.30/h). Although the absolute spending on CPB was a little less than one-sixth of that for PPB, the rate per hour was only about half. The opportunity costs for the researcher (a thesis student) were \$348 (27%), maintenance for the researcher at \$317 (24%), services provided for screening plantlets in the laboratory and greenhouse at \$277 (21%), rent for the greenhouse at \$172 (13%), opportunity costs for the adviser at \$110 (8%), inputs at \$66 (5%), and opportunity costs for the laborer at \$12 (1%).

The much greater expenses involved in PPB are explained by the technicians’ initiating their activities by first identifying and selecting communities, preparing the training guide, and reviewing and executing the training sessions. These activities required 581 h and an investment of \$2905. Another variable—the farmers’ level of knowledge—also strongly affected the costs of PPB, as the farmers had to be trained (\$880). The total costs for these two variables alone were US\$3785.

With less intervention by technicians in PPB, and a more developed sense of responsibility in the farmers, costs could be reduced by at least 40% (by about US\$3000, including reduced expenses for the technicians and gasoline).

For CPB, which was carried out on PROINPA’s experiment station, with the same genotypes, the most costly stages of varietal selection were making the crosses at US\$281 (taking 86 h), screening the adult plants at \$277 (46 h), and maturation, harvest, and processing of the berries at \$121. Sowing sexual seed and caring for the seedlings required 32 h, with another 31 h to evaluate the plantlets.

Although both methodologies differed greatly in the steps they executed, they shared the same objective, making the acquisition of the first 22 genotypes their principal point for comparison.

Once the 2505 and 186 genotypes were identified by CPB and PPB, respectively, the total cost of both methodologies to the eventual selection of 91 and 54 clones was US\$5568, of which 32% corresponds to the CPB and 68% to the PPB (adjusted to one year). The cost of obtaining one clone through CPB was \$19.58/clone and \$70.11/clone through PPB. This shows that obtaining one clone through PPB costs 3 to 4 times as much US\$37.44 as obtaining one clone through CPB.

Through PPB, a cycle was gained in selecting the clones in the field because the farmers of the community of Piusilla-San Isidro, could plant and select varieties twice a year, unlike with the CPB, which took a year longer for the clones to enter the first clonal selection. Through PPB, the farmers adopted new technologies earlier by being part of the process for generating, evaluating, and selecting genotypes, and obtaining the new varieties more quickly.

The two methods of genetic improvement can complement each other during some stages of the process, such as generation, evaluation, and selection of hybrids in the first phases. That is, through CPB, hybrids could be generated and selected from the parental materials that farmers most prefer. The hybrids could then be given to the farmers to select the best genotypes according to traits for resistance to late blight and yield.

One aspect that became evident is that farmers in PPB need permanent technical assistance, particularly in the first phases when many genotypes are still being selected. Even in the later phases, they may need technical help to organize plantings and select appropriate experimental designs for evaluating genotypes.

## **Final Comments**

### ***Impressions of technicians***

According to the visiting technicians, the participatory selection process was a relevant experience in several aspects, one being the versatility with which the men and women farmers, who were part of the participatory breeding group, managed the technical vocabulary to describe the PPB process.

### ***Genotypes***

The men and women farmers of Piusilla-San Isidro selected potato genotypes by comparing morphological traits with those of cv. Waych'a, the most widely cultivated variety. The genotypes selected showed the Waych'a phenotype, as their names demonstrate. Other traits also considered were yield and resistance to blight. In contrast, the farmers of Compañía Pampa selected their genotypes based on traits such as resistance to blight, yield, eye depth, and red skin color. Likeness to Waych'a was not observed as a parameter of selection.

In Piusilla-San Isidro, most of the selected genotypes were from the family  $I \times W$ , whereas, in Compañía Pampa, they were from the family  $I \times R$ .

## ***Strategies***

The farmer potato breeders considered that the varieties selected should be evaluated in parallel at different altitudes in their communities and in large plots. They also felt that the varieties should be cleaned and multiplied, and decided to conduct a health check for viruses before implementing a viral cleaning.

Aspects of multiplication and dissemination will become fundamental if organized associations take the initiative to multiply and disseminate the varieties developed by the farmers. If successful, this aspect could lead to wider adoption and sustainability.

## ***Procurer's rights and intellectual property rights***

These are two new themes that must be discussed within Fundación PROINPA and in consensus with the farmers. A situation could arise whereby the farmers could become owners and PROINPA the strategic partner, particularly when registering released varieties.

We are aware that not all the 12 new varieties obtained by the farmers will be multiplied and disseminated, but at least one or two in each of the two communities will be prioritized in the coming years.

## ***Adjusting the methodology***

The participatory methodology still needs adjusting, particularly as the current participatory selection process could not collect all the valuable criteria that farmers use when selecting varieties. We had had to adapt to conditions and, in the time they had to carry out this work, they nevertheless were the ones who convened the meeting realized in the third phase.

## ***Impact on farmers' attitudes***

Motivated by the results they obtained in the PPB project for potato, the farmers have initiated research with other crops such as quinoa and strawberry.

With respect to potato, they want to initiate a new stage of variety generation, using their best varieties from the participatory breeding to cross with other native potato varieties that are resistant to the false root-knot nematode (*Nacobbus aberrans*), another serious problem of the potato crop.

More farmers, both men and women, have been integrated into the participatory breeding group. They are evaluating new potato genotypes from conventional breeding programs and are participating in the selection of varieties. The farmers are motivated and want to continue with the experiment until they achieve a variety that is promising for their areas.



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## Acronyms and Abbreviations Used in the Text

adg	<i>Solanum tuberosum</i> subsp. <i>andigena</i>
ajh	<i>Solanum ajanhuiri</i> Juz. & Bukasov
ASAR	Asociación de Servicios Artesanales y Rurales, Bolivia
AUDPC	Area under the disease progress curve
CGIAR	Consultative Group on International Agricultural Research, based in Washington, DC
CIAL	<i>Spanish acronym for</i> Local Agricultural Research Committee
CIAT	<i>Spanish acronym for</i> International Center for Tropical Agriculture, based in Colombia
CIP	<i>Spanish acronym for</i> International Potato Center, based in Peru
CPB	Conventional plant breeding
cv.	Cultivar
FFS	Farmer field school
HSD	Honest significant difference ( <i>statistical test</i> )
I	India ( <i>potato cultivar</i> )
IPRA-CIAT	Investigación Participativa en Agricultura/ <i>Participatory Research in Agriculture of</i> CIAT
<i>juz</i>	<i>Solanum x juzepczukii</i> Bukasov
masl	Meters above sea level
phu	<i>Solanum phureja</i> Juz. & Bukasov
PPB	Participatory plant breeding
PREDUZA	Proyecto Resistencia Duradera en la Zona Andina ( <i>of the WAU and national programs in the Andean Region</i> )
PROINPA	Fundación “Promoción e Investigación de Productos Andinos”
PVS	Participatory varietal selection
R	Robusta ( <i>potato cultivar</i> )
RCB	randomized complete block experimental design
RT	Runa Toralapa ( <i>potato cultivar</i> )
SEPA	Unidad de Producción de Semilla de Papa, Bolivia
stn	<i>Solanum stenotomum</i> Juz. & Bukasov
W	Waych’a ( <i>potato cultivar</i> )
WAU	Wageningen Agricultural University, Netherlands