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Farmers' participation and breeding for durable disease resistance in the Andean region

Daniel Danial · Jan Parlevliet ·
Conny Almekinders · Graham Thiele

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Abstract In the Andean region, the Preduza project and its partners combined breeding for durable disease resistance using locally adapted cultivars and farmer participatory methods. The approach taken resembles participatory variety selection (PVS). Farmers participated in the selection of advanced materials, rather than finished cultivars. This paper describes this approach and reports experiences with farmers–breeders collaboration.

As breeders involved farmers as participants, they learned more about the most important criteria of male and female farmers for preferred cultivars in the marginal environments of Andean cropping systems. This approach encouraged the use of locally adapted cultivars (often landraces), made the breeders less dependent on foreign materials, and has resulted in selection and development of new wheat, barley, common bean, quinoa, potato and maize cultivars.

Breeding programmes based on crossing locally adapted cultivars followed by selection by the breeders in the early phases of the breeding programmes and by participatory selection with the farmers in the more advanced stages of the breeding programmes appeared successful. It became clear that breeders must be well acquainted with the farmer preferences such as the requirements for specific agronomic, storage, processing and marketing traits.

Over a period of five years the centralized formal breeding approach predominantly based on material produced by the international institutes was replaced by decentralized breeding approaches based largely on local germplasm with extensive farmer participation.

Keywords Breeding · Durable disease resistance · Farmer participatory research · Farmers preferences · Capacity building

D. Danial · J. Parlevliet (✉)
Lab. of Plant Breeding, Dept. of Plant Sci., Wageningen University, P.O. Box 386, 6700 AJ, Wageningen, The Netherlands
e-mail: jan.parlevliet@wur.nl

C. Almekinders
Wageningen University, Chair group Technology and Agrarian Development, Hollandseweg 1, 6706 KN Wageningen, The Netherlands

G. Thiele
Centro Internacional de Papa Proyecto Papa Andina (CIP-Cosude), Apartado 17 21 1977, Quito, Ecuador

Introduction

The situation in the Andean region typically confirms the general statements on the success of conventional and centralized plant breeding programmes: significant impact in high input areas but relatively low impact in the marginal and variable small-scale farming sector (Morris & Bellon, 2004). The large environmental and cultural variation in these marginal regions partly explains this lack of impact. There are many examples of new cultivars that were not accepted by the farmers, and

Table 1 A list of cultivars released and rejected by farmers/consumers in Ecuador, Peru and Bolivia and reasons for not adopting the cultivars*

Country	Crop	Cultivar name and year of release	Reason for not adopting the Cultivar
Ecuador	Potato	*Margarita,* 1995	Susceptible to *Erwinia carotovora*
		Isabel, 1995	Susceptible to late blight and no seeds
	Bean	*INIAP 411(Imbabello),* 1992	Low hectolitre weight
	Maize	*INIAP-131,* 1988	Poor grain type
	Wheat	*Cayambe,* 1996	Highly susceptible to yellow rust
		Altar, 1982	Small grain size
	Barley	*Shyri 89,* 1989	Highly susceptible to leaf rust
Peru	Maize	*Canchero 301,* 1983	Hard grain type
	Quinoa	*INIA Quillahuaman,*1992	Very late maturing and small grain size
Bolivia	Quinoa	*Kamiri,* 1986	Medium grain size and poor validation
	Wheat	*IBTA Riera,* 1994	Poor grain quality
		*IBTA Toralapeno,*1995	Poor grain quality

*Source. Danial (2003)

grain quality traits and disease resistance are important explanatory factors (Table 1). Poor diffusion among farmers and lack of seed also played a role (Danial, 2003).

For such marginal regions a decentralized plant breeding approach may be more effective (Morris & Bellon, 2004). Since the farmers in these regions are to a considerable extent also the end users of the food crops they grow, participatory plant breeding (PPB) is considered to be essential in the development of locally well adapted and desired cultivars. And PPB can be quite effective as is shown in several cases such as in barley in the dry Mediterranean regions (Ceccarelli et al., 2001), in rice in the higher altitudes of Nepal (Joshi et al., 2001), maize in Mexico and Honduras (Smith et al., 2001) and in India (Witcombe et al., 2003).

To involve farmers in plant breeding programmes various approaches have been described and investigated. Witcombe et al. (1996) distinguish participatory variety (=cultivar) selection (PVS) and participatory plant breeding (PPB). In the first farmers select from existing cultivars or advanced materials, while in the second farmers participate in the selection of segregating material. This distinction basically refers to crops that are self-pollinating or vegetatively reproduced because cross- pollinating crops segregate continuously. Morris and Bellon (2004) identify different potential forms of interaction between farmers and breeders: traditional farmer breeding, complete participatory breeding (CPB), efficient participatory breeding (EPB) and participatory cultivar selection (PVS). The first type refers to the genetic adaptation of crops to the local farming conditions, including the way farmers collect and save seed for the next crop and result in landraces. In the CPB farmers are involved in all the breeding stages from the selection of the parental materials to the cultivar evaluation. This is very demanding for both the farmer and the breeder. With the EPB the farmers participate in the selection of suitable parental material and in the end stage of the breeding, the cultivar evaluation. The fourth type, is similar to the PVS mentioned by Almekinders and Elings (2001). The EPB and PVS are in fact more or less the same because in breeding programmes the parental material for a new cycle of breeding consists largely of advanced lines and released cultivars (Simmonds, 1979). Recommended cultivar lists, were the parentages of recommended cultivars are mentioned, demonstrate this. So if the farmers are participating in the advanced material stages they not only help in the selection of the desired cultivars, they also participate in the selection of parental material for the new breeding cycle.

When considering farmer participation there are two rather than the four basic approaches discussed by Morris and Bellon (2004). The traditional farmer breeding is no option and the EPB and PVS are more or less the same as discussed above. The two remaining approaches are including (CPB) or not including (PVS) the early, segregating generations. Including early segregating populations may be effective in self-pollinating or vegetatively reproduced crops where the individual plants are easily recognizable and the important traits are easy to assess (beans, potatoes). In other crops, such as barley and wheat, where the individual plants are hardly recognizable and the important traits difficult to assess CPB is not advisable.

Given the farming situation in the Andean region it was considered essential to adjust breeding strategies. “Preduza” aimed at contributing to this adjustment by developing adapted cultivars with durable resistance, by enhancing the capacity of national breeders, and including farmers’ participation to make breeding programmes more effective.

Based on the fact that “Preduza” and its partners had only limited means and was dealing with six crops widely different from the breeders’ point of view it was in fact natural to take an approach of the PVS type.

This paper describes and summarizes “Preduza” experiences and achievements in breeding with farmers’ participation for locally adapted cultivars in six widely different food crops in Ecuador, Peru and Bolivia in the period of 2000–2003. It concentrates on the interaction with farmers in the breeding process.

The Andean agro-ecological and socio-economical environment

In the Andean region, maize, potato, wheat, barley, common bean and quinoa are major food crops grown mainly by small-scale farmers. Biotic and abiotic stresses are important limiting factors in the production of those food crops. These stresses affect both the quality and quantity at harvest reducing the income of the small-scale farmers.

Among the important biotic stresses in the major food crops in the Andean region are a range of fungal diseases. The most important ones are mentioned in Table 2. The incidence of the diseases is extremely variable and depends on the cultivars grown and the environmental conditions that prevail in the different ecological zones. For example, yield loss in potato due to late blight in Ecuador can vary between 28% and 100%, depending on the cultivar and the epidemic period during the growing cycle (Morales, 1994).

A cost effective way for farmers to protect their crops against these biotic stresses is through the use of resistant cultivars. Small-scale farmers, with limited resources and access to external inputs, are not able to chemically protect their crops against damaging effects of pathogens (Broers, 1994). Cultivars with resistance to some of the fungal pathogens have been produced and released by the formal breeding programmes, but these are often not well adapted to the environment and farmers’ preferences. Consequently, farmers continue to grow local cultivars, with low yields, poor grain and tuber quality, and so lower prices. Within this context, the breeding programmes of the National Agriculture Research Systems (NARS) in the Andean region are faced with the challenge to meet an increasingly diverse demand for crop and cultivar characteristics as new market opportunities (large cities, export markets) have emerged with requirements often different from those of the local markets and of the small-scale farmers themselves. At the same time a reduction in government support to the public sector in general and agricultural research in particular means that NARS breeders operate with relatively small and uncertain budgets, lack of access to state-of-the-art literature about breeding and limited support from social scientists. Whilst the breeding efforts of NARS and the International Agriculture Research Centres (IARC) have resulted in large improvements in productivity in more favoured areas, there has been a limited impact in the small-scale farming sector of marginal environments like the Andean region. This is in line with experiences

Table 2 Cultivated area in ha, average yield in tons per ha and the most important fungal diseases of six major Andean food crops in the highlands of Ecuador, Peru and Bolivia together*

Crop	Area	Average yield	Diseases
Maize	515.000	1.2	Ear rot, *Fusarium verticillioides*
Potato	400.000	10.0	Late blight, *Phytophthora infestans, viruses*
Wheat	205.000	0.8	Yellow rust, *Puccinia striiformis* and Septoria Leaf blotch, *Septoria spp.*
Barley	240.000	1.1	Barley leaf rust, *Puccinia hordei*
Bean	190.000	1.2	Bean rust, *Uromyces appendiculatus,* Anthracnose*, Colletotrichum lindemuthianum*
Quinoa	57.000	0.7	Downy mildew, *Peronospora farinosa*

*Source. Broers (1994)

of other environmentally marginal regions (Ceccarelli et al., 2001; Morris & Bellon, 2004).

Resistance breeding has been the subject of important scientific debate, i.e. that between the advocates of race-non-specific or durable vs. race-specific or non-durable resistance (Parlevliet, 2002). The latter is usually major-genic in nature and easy to introduce, the former is usually genetically more complex and less easy to introduce. Many of the newly introduced improved cultivars from elsewhere carried such major-genic resistances and showed the predictable non-durable resistance. For instance, the wheat cultivars Antizana and Tungarahua became very susceptible to yellow rust shortly after their release in Ecuador (Chicaiza, 1997).

The "Preduza" project

In 1997, the "Preduza" project for durable resistance in the Andean region (Proyecto Resistencia Duradera en la Zona Andina) was initiated. It is a collaborative project of the Laboratory of Plant Breeding of the Wageningen University in the Netherlands and the NARS of Ecuador, Peru and Bolivia. It aims at the production of improved cultivars in food crops through combining durable resistance to plant diseases with a good level of adaptation to the marginal conditions in the Andean highlands. Through participatory methodology, the project makes use of the local cultivars and the existing local knowledge of the stakeholders to ensure that developed cultivars are well accepted by the small farmers.

The six crops dealt with (Table 2) have widely different reproduction systems. Different reproduction systems require different selection, seed increase and maintenance schemes (Parlevliet, 2003 and this issue). The reproduction of a crop is based either on cross-pollination (maize), self-pollination (beans, barley, wheat) or on vegetative reproduction (potato). In quinoa both self- and cross-pollination are important. The problems which arise during the maintenance and multiplication of improved cultivars are strongly associated with the reproduction system.

Improved cultivars of cross-pollinating crops such as maize consist of a narrowed gene pool with high frequencies of desirable genes. Such cultivars can only be maintained through a mild, but continuous selection for the desirable plant types. Without such selection the improved cultivar will gradually lose its improved character as it is not possible to keep it genetically isolated from un-improved cultivars due to its open pollination (Allard, 1960; Simmonds, 1979).

Quinoa, being one of the crops with a mix of self- and cross-pollination, suffers similar problems but to a lesser extent than true cross-pollinating crops like maize. Improved cultivars are not easy to maintain. They require regular selection to remove less desirable plant types (Parlevliet, 2003 and this issue).

Improved cultivars of self-pollinating crops such as beans, barley and wheat consist of a small number of very similar genotypes. Due to the self-pollination it is relatively easy to keep the improved cultivars genetically isolated from other cultivars. So deterioration of improved cultivars is much slower compared with cultivars of cross-pollinating crops, provided the seed increase is managed properly (Parlevliet, 2003 and this issue).

Improved cultivars of vegetatively reproduced crops such as potatoes consist of a single genotype, which is easy to maintain and to multiply true to type. But here the problem is to keep the improved cultivars (clones) free from pathogens that are carried by the propagules used for the reproduction. In potatoes especially a broad range of viruses and some fungi may accumulate over generations in the selected cultivar.

If farmers wish to maintain improved cultivars they have to take these differences among crops into account. This requires some knowledge to be provided by the breeders.

"Preduza" phases I and II

In phase I, 1997–2000, 12 sub-projects, directed at supporting existing plant breeding programmes in six food crops, were established in Ecuador, Peru and Bolivia. The emphasis was on the development of advanced lines and populations and at the same time on capacity building of the national breeding programmes in the food crops, mentioned in Table 2, through on-the-job training, workshops and seminars (Danial, 2001a and 2003). Yearly visits of a team made up of a breeder, pathologist and sometimes a social scientist were important in discussing and evaluating the breeding programmes. Various procedures were developed to measure and evaluate disease resistance in various patho-systems; sources of resistance among native cultivars were identified and incorporated in the breeding programme which resulted in developing a large number of segregating populations (Danial, 2003; Silva et al,. this issue).

In this phase a start was made with farmer participation, using the skills and experience of the International Centre for Tropical Agriculture (CIAT), the Participatory Research Project in Agriculture (IPRA) and the International Potato Centre (CIP); (Andrade & Cuesta, 1997; Thiele et al., 1997; Gabriel et al., 2002).

In Phase II, 2001–2004, there was a strongly increased emphasis on farmer participation. The major justification was to ensure that plant materials developed in phase I would be adopted by the participating farmers. Farmers were given the opportunity to evaluate new advanced materials and select those which best fitted their needs and preferences. In addition, this approach was expected to enhance farmers' self-esteem, increase their influence in the breeding programme, increase their awareness of the importance of improved seed production and provide the breeders an improved insight what traits they should select for.

The approach

The project approach combines three strategic components which are logically interconnected: the selection of durable resistance, the use of local cultivars and the participation of farmers in the selection in advanced stages of breeding.

Durable resistance

The breeding in the various sub-projects followed the durable resistance breeding strategy. This type of resistance is of a quantitative nature and is assumed to be durable (Parlevliet, 2002). Part of the strategy is to identify sources of quantitative resistance in local cultivars and accumulate this quantitative resistance through crossing and subsequent selection. Screening procedures developed in the project (Danial, 2003; Silva et al., this issue) showed that most local cultivars possess varying levels of quantitative resistance that are frequently higher than that of improved materials from elsewhere (Danial, 2001b). The local potato cultivars in Bolivia exemplify this. They vary greatly in quantitative resistance to late blight, *Phytophthora infestans*, several cultivars having a high to very high level of resistance (Gabriel et al., this issue).

Local materials

The good adaptation of local cultivars is a reason for using them as parental materials in crossing programmes. High variability of environmental conditions and farmer preferences in the Andean region are at the root of the limited success of breeding programmes. Breeders were not able to develop adapted materials that meet the variable cultural preferences of farmers for grains and tubers meant for consumption (Table 1). These mosaics of local types of preference are unimportant at a global scale and, thus, difficult to address by breeding programmes with a global mandate. Use of local cultivars in crossing programmes is one way of dealing with the challenge of generating adapted cultivars that are attractive to farmers. The prominent use of local cultivars also implies that this breeding strategy has great potential to contribute to sustainable use of local crop genetic resources. At the same time, NARS working with "Preduza" use the international nurseries in the CGIAR system as sources of relevant genes that, in combination with the genes in the local cultivars, may result in a surplus value.

Farmer participation in selection

Given agro-ecological and culturally variability in the Andean region, decentralisation is a condition to make breeding programmes more effective in addressing a multitude of niches. For this reason, farmer participation has become part of the approach and should ensure that newly developed materials are accepted by farmers and also that breeders should become acquainted with farmer preferences (Almekinders & Elings, 2001; Sperling et al., 1993, 2001).

PPB can be carried out in many ways, depending on the objectives and means (McGuire et al., 1999; Weltzien et al., 2000; Sperling et al., 2001). "Preduza" means were limited, providing NARS with limited additional funding to complement and modify existing programmes, and the objectives were primarily the production of cultivars adapted to the needs and requirements of the end-users. Complete participatory breeding (Morris & Bellon, 2004), involvement in all stages of the breeding process, is considered to enhance the probability of adoption. The high demands for both breeders and farmers are a disadvantage especially when it is meant to be a long term activity. Another disadvantage is the fact that management of and selection among large numbers of entries with a great genetic diversity is tedious, while the pay off for the farmer is in the distant future. "Preduza" therefore chose to involve the farmers in selection during the advanced stages of the breeding process. This would improve selection efficiency in these stages directly but also at all other stages of the breeding process as it would enhance the breeders' knowledge of farmers' criteria. Within this context farmers were also brought on station to select materials for subsequent testing on farm (Sperling et al., 1993). So the PPB approach chosen was a researcher-led, collaborative type, using breeding materials in the advanced stages.

Bringing about the required changes

To work effectively along the lines described above, a refocus of NARS breeding practices was necessary. Training and technical assistance provided through "Preduza" helped breeders to become aware of the value of the local cultivars in their region. In the three countries involved, breeders used these materials in the crossing programme and could see the increased levels of resistance. In addition, collaboration with farmers in earlier stages of the breeding cycles has required breeders to change attitudes and practices. "Preduza" sub-projects drew on CIAT and CIP experience and methodologies in participatory approaches as well as existing capacities of NARS partners (Gabriel et al., 2000). "Preduza" organised seminars, meetings, workshops and training courses on these topics that were jointly implemented with the national and international agriculture research institutions such as el Proyecto de Fortalecimiento de la Investigación y Producción de Semilla de Papa en el Ecuador (Fortipapa) in Ecuador and CIAT itself.

Small grants were used to facilitate and stimulate existing breeding programmes of the national research institutes to breed for resistance through participatory research. The participatory advanced line selection trials allowed the breeders to connect with the farmers' reality and become aware of their priorities and preferences. This brought about changes in the breeding activities because the breeders had to adapt their ideas about the desired plant type. For instance, barley breeders in Ecuador were unaware that women prefer six-rowed barley over two rowed barley in the Cotopaxi area.

Experiences with farmer-collaboration in selection

Methodology of participation

"Preduza" collaborated basically with two types of farmer groups; farmer researcher committees or CIALs (Comite Investigacion Agricola local) and organized groups, selected by the farmers community in a particular location. Both types included both men and women and consisted of 5–12 people. The farmers were asked to evaluate a restricted number of advanced entries from the breeding programmes. The evaluation methods included absolute evaluation and preference ranking methods. The evaluation was done at farmers' fields and less often on experimental stations. At the farmers' fields advanced entries were chosen. At the experimental station less advanced stages, when small amounts of seeds are available, were chosen. This was meant as a preliminary selection for the most important traits. In addition, inviting farmers to the Experimental station helped strengthen the link and build confidence between farmers and researchers. Farmers could see for themselves and understand the additional selection process occurring on station such as tests for grain quality and seedling tests for disease resistance.

Working with early generations in crops such as maize, wheat, barley, and quinoa were considered not or less effective. The disadvantages of working with entries representing early phases in the breeding programmes consists of the large number of entries, the lack of identity of the entries as they are still fairly heterogeneous and the lack of sufficient plant material (potatoes, beans, barley, wheat). Increased numbers of entries on smaller plots and with a reduced uniformity within the plots always reduce the selection efficiency as the heritability of especially quantitative characters is reduced. For untrained farmers this effect is much stronger. McElhinny et al. (this issue), working with quinoa in Ecuador, observed that farmers had great problems in choosing from a large number of such entries; they got bored when evaluating large numbers of lines and plots.

Understanding farmer preferences

Determining farmers' preferences is essential for breeders, and provides a mechanism for farmers to have their opinion heard. Through the participation of the farmers in the breeding process, breeders became acquainted with preferences of both men and women farmers in the various crops they are working with (Bentley & Hogenboom, 2003). Farmer participation made breeders realize how variable the preference of farmers from one location to another could be. For instance in Ecuador, farmers and consumers in the provinces of Imbabura and Pichincha prefer yellow, soft type of maize, while in the province of Tungarahua the white floury type is popular. In the province of Bolivar white soft maize is popular, and in Canar, in the south of Ecuador, farmers prefer white semi-hard types of maize. In the case of barley, farmers in the province of Cotopaxi prefer six-rowed barley while in Saraguro they prefer two-rowed barley. Similarly farmers in the Chota valley in north of Ecuador prefer to grow and consume the red-colour beans, while in the south (Loja), white beans are more preferred. Table 3 presents the major overlapping preferences in various crops.

Farmer participation may require more time but the chance of adoption by the farmers of a released cultivar may increase strongly. For instance, in 2003 the barley cultivar Cañicapa was released with success in Saraguro, Ecuador, based on the farmers' evaluation in an advanced line participatory programme. The farmers especially liked its large grain size and good culinary aspects.

Role of gender

Breeders observed that the involvement of women farmers' in the assessment and evaluation of plant materials improved the quality of the evaluation. This observation is consistent with other participatory plant breeding experiences (Salazar et al., 2001). This is due to the fact that women's selection criteria often differ partially from those of men (Table 3). Men in general appeared more interested in characteristics that are of importance during growth and harvest, while women were more concerned in culinary and post harvest characteristics. Another reason why women should be fully involved in participatory plant breeding is that they have increasingly become involved in farm management as a significant proportion of the men migrated to earn cash.

Breeders' practices in participating with farmers

For the assessment of breeders' material through farmers' participation, there is no standard methodology available. This is not surprising as the optimal approach almost certainly varies with the crop depending on its reproduction method, its reproduction rate (potato less than 10 times per cycle, versus quinoa with over 1000 times per cycle) and whether the plants can be individually assessed (beans, maize and potato) or not (barley, wheat) at all stages of selection.

The breeders in the "Preduza" project mentioned that they had good experiences in working with farmer-groups. They felt that working with a group of farmers as compared to working with individual farmers contributed to the efficiency of assessment. It also strengthened the positive effect of the assessment on the farmers themselves and gave the breeders more certainty about characteristics desired by the farmers. Breeders compared experiences in working with groups and came up with the following considerations which are broadly valid for different crops and regions.

Number of farmers per group

This varied from 5 to 12. The number of women in the groups was on the low side and varied from 0–7. Having become more aware of the important role of women in cultivar choice, the breeders feel that the participation of women needs more attention.

Number of entries

The number of units (lines, clones or populations) to be evaluated depends on the crop and on the selection phase. For instance, during the first farmers' assessment in 2001, the number of entries varied from 10 (in beans) to about 100 (in maize). Farmers considered this number of entries in the trials to be adequate and easy to handle. Nevertheless breeders thought that handling a large number of entries could be tiring, boring and confusing for the farmers, especially if they are not sufficiently trained in this type of activity. In the second assessment cycle of 2002, the number of entries was reduced and ranged from 3 to 20 in the various crops. Breeders got the impression that approximately 15 entries is an ideal number for farmers to handle. This number provides a fair diversity, assuming the breeder

Table 3 List of the most important farmers' preferences for both men and women observed during the participatory assessment of promising entries of maize, potato, wheat, barley, common bean and quinoa in Ecuador, Peru and Bolivia in 2001, 2002 and 2003*

Country	Crop	Major men preferences	Major women preferences
Ecuador	Maize	Depends on the location and cultivars cultivated, mainly healthy plants, grain type, yield, early maturity and ear rot resistance	Position of ears on the plant should not be high
	Potato	Late blight resistance, early maturity, yield, red or pink colour peel in north and central part, and crème colour in south	Yellow flesh, soft texture, rapid cooking
	Wheat	Resistance to yellow rust, large grain size, clear colour and high yield, high hectolitre weight	Easy threshing, white flour, culinary aspects
	Barley	Resistance to leaf rust, yield, high hectolitre weight	Culinary aspects such as taste, six rows, large grain size, thin shell and oval shape
	Common bean	Number of pods, vigour, and resistance to white fly, yield, early maturity	Clear colour of grain, time of cooking
	Quinoa	Large ear, large grain size, high yield	Culinary aspects such as white grain, sweet taste
Peru	Maize	Well-filled, large and soft grains, high number of rows per ear and ear rot resistance	Culinary aspects depend on the way of preparation: smooth for toasting, round grain for flour and mote, soft grain for boiling
	Quinoa	Large ear and grain size, white colour, resistance to mildew, early maturity and uniformity, and yield	White and or yellow grain, green leaves, thick stem, culinary aspects
Bolivia	Maize	Healthy plants, resistance to ear rot, large ear size, ear coverage, early maturity, large grain size, easy access of ears during harvesting	Large grain and ear size and white grain colour
	Potato	Flowering: Uniform and healthy plants, resistance to late blight, round /elongated tubers, red/pink peel colour and cream/yellow flesh. Culinary aspects: not bitter taste, soft texture, fast cooking	Eye depth in tuber, rapid cooking, soft texture and good taste
	Wheat	Tall and thick straw, high number of grain per ear, clear white grain,	Good baking quality
	Quinoa	South Altiplano: large ear size, large grain size, early maturity, medium tall, bitter taste, white colours after washing. Central Altiplano: the same as in north but with sweet or bitter taste North Altiplano: semi-late maturity, sweet taste and white colour	White colour, easy to wash and thresh, less cooking time

*Source. Danial (2001a, 2002)

did select the entries on the basis of diversity within the advanced material in his programme. It also is easy for the farmer to maintain oversight of the differences between the entries. In addition, such smaller numbers make evaluations easier to organise in terms of the area required (see also next point) and summarising and discussion of the collected data. This is not in accordance with Ceccarelli et al. (2001), where over 200 entries were compared on relatively large plots by 24 farmers on their farms in three countries in the Mediterranean region. These farmers, many not being small-holders, varied greatly in the size of their farm, from 2 ha to 500 ha, and in their educational level. It in fact shows that it is difficult to compare the experiences in one region with those in another.

Plot size of entries to be assessed

Usually evaluation takes place in small plots, especially in the first selection cycle when a limited amount of seed is available in most crops. In our case, plot size varied strongly from 1 row $\times$ 3 meters long (quinoa in Bolivia) to 100 m^2. Farmers prefer to evaluate larger plots because they can easier distinguish between entries in larger plantings. On the other hand, if sufficient seed is available it is often hard to find a sufficiently large and not too heterogeneous field to implement the assessment.

Optimal assessment time

For the six food crops dealt with, the evaluation at flowering and at or after harvesting proved to be adequate for selection of the desired traits. Breeders feel that more frequent evaluation is not necessary. It increases costs without clear improvement of the outcome. This is an important point as most of the breeding programmes have very limited funding. More frequent evaluation raises the opportunity costs to farmers of their participation. In addition, breeders observed that the last evaluation was the most important for the selection of accessions by the farmers as earlier evaluations were easily overridden by the selection based on the final performance.

Type of participating farmers

Participating farmers were often organized in different types of groups, including groups set up for advanced material evaluation and farmer research committees (Comité Investigación Agrícola Local - CIAL). In Bolivia a farmer-field school took part in assessment and selection of quinoa lines. Breeders mentioned that farmer-groups that deal with several crops formed efficient collaborators.

Involvement of other market chain actors during assessment

So far, only the potato programmes in Ecuador and Bolivia involved market chain actors in their evaluations. This was mainly due to the lack of experience among the subprojects and the weak links between the researchers and other end-users. Breeders are aware of the need for additional efforts in this area to ensure new cultivars satisfy all stakeholders and not only the farmers.

Capacity building of breeders and farmers

Familiarising researchers with the importance of this new approach and relevant methodologies was an essential first step in implementation of farmers' participation. Initially, when "Preduza" introduced the concept of farmer's participation in the breeding programmes of the subprojects, most breeders opposed this initiative. The breeders now consider they have a better understanding of farmers' demands for improved cultivars and knowledge (Bentley & Hogenboom, 2003). Reflecting on their initial negative reaction, the breeders explain that because they lacked experience about farmer participation they were convinced at the time that their current practice was correct.

Breeders mentioned that their knowledge increased and that they came to understand the potential roles of both men and women in participatory selection. For instance, in Ecuador, breeders realised that male farmers were more concerned and interested in controlling late blight in potato and consequently, more training in this area was provided to male farmers. Since women farmers were more interested in seed storage and testing for culinary aspects, it is clear that training in this field should focus on women farmers. Breeders also noticed that men are now more willing to allow their wives to participate, which suggests a change in attitudes. More women are participating as they apparently can see the socio economic benefits they obtain.

Results of the approach

The "Preduza" approach has been successful in increasing the effectiveness of breeding programmes in the Andean region. This is seen in an increased availability of promising entries with a high level of resistance to the most important fungal diseases, improved adaptation to local farming conditions and matching farmers' preferences. In Ecuador, two barley cultivars (Cañicapa and Pacha) and one wheat cultivar (Zhalao) were released (Rivadeneira et al., 2003) while in Bolivia the maize cultivar Sintetico 2 was released for the Tarija area (Claure, 2003). In addition, one quinoa cultivar in Bolivia was registered as Jach'a grano for the farmers in the altiplano (Bonifacio, 2003). At this moment, a range of other entries in the pipeline out-perform currently planted cultivars in terms of resistance, yield and farmer preference. Many promising entries are expected to be released in the coming years in maize, potato and beans. Although successful in producing improved cultivars the essential aspect is of course the adoption of the released material. But for that aspect it is still too early for any conclusion.

Breeding strategy

Breeding materials and crosses

The breeders of the NARS who participated in "Preduza" now agree that the breeding strategy for durable resistance based on local germplasm allows for a more strategic use of the CGIAR international nurseries. Instead of selecting from the international nurseries promising materials for testing and release as new cultivars, they now select the materials for relevant genes that can be transferred into their local germplasm. While this sounds a more laborious route to improved cultivars than selecting and releasing materials from international nurseries, it turned out to be a very effective strategy: materials obtained through this route are well-adapted to the agro-ecological conditions and farmers' and local market preferences. This implies that this breeding strategy has a great potential to contribute to sustainable use of local crop genetic resources while increasing their yield potential. At the same time, developing the local crop genetic resources reduces dependence on materials supplied through international nurseries. This was in fact a change from the centralized breeding efforts coordinated by the CGIAR group of international institutes to a decentralized form of breeding in which farmers are involved along the lines as described very recently by Morris and Bellon (2004).

Selection and farmer-participation

Involving farmers in the selection together with the use of local germplasm in the breeding programmes resulted in the selection of materials better fitting the requirements of the farmers. At the same time it probably improves the farmers' awareness of the type of crop he/she requires. This may include new insights such as the usefulness of partial resistance to the prevailing diseases. Through this improved awareness of the farmer future participatory selection programmes may be facilitated and improved.

Conclusion

The combination of breeding for durable disease resistance using adapted local germplasm together with farmers' participation appears to be a good strategy for improving the effectiveness of national plant breeding programmes for marginal, heterogeneous environments. Working with six major food crops, seven years after the start of the "Preduza" project, the first cultivars were released and many more are in the pipeline. Crucial elements in the strategy have been the combination of small grants and capacity building. Small grants to existing breeding programmes were effective in stimulating the breeders in implementing alternative set-ups with farmer-participation. Complementing the practical exposure and experiences in these activities with capacity building of breeders through on-the-job support and training provided an experiential learning that explains the effective implantation of the "Preduza" strategy.

While effective in changing the strategies in the various breeding programmes, based on the use of local materials and sensitizing the breeders to the farmers' reality, the remaining challenges for the programme are still great. Large scale impact in farmers' field has yet to be realized, the materials released and those in the pipeline still have to find widespread adoption in farmers' fields to show the success of the described three component-approach.

A very important issue that has to be addressed in a long term PPB approach is the multiplication and maintenance of the cultivars produced. Improved cultivars selected with the aid of the farmers will ultimately loose their advantage if they are maintained and multiplied by the local farmers themselves. Contamination, mixing, mutations and propagule borne diseases all will ultimately result in a loss of the genetic gain. This is especially so for cross-pollinators such as maize (Parlevliet, 2003 and this issue).

World-wide many regions, such as the Andean region, characterized by highly heterogeneous environments and widespread marginal and variable small-scale farming, exist. It would be worthwhile to consider the implementation of the approach described here for other comparable regions of the world.

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