A collection of chili peppers native to Peru supports value chain research

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Distribution of accessions and classification of the chili peppers of Peru

Peruvian cooks say that chili peppers are the DNA of Peruvian food. Foreign literature often uses the term 'ají' to refer to the South American *Capsicum baccatum*, but 'ají' is the equivalent of 'chile' and is used in several countries to designate any pungent *Capsicum* (an exception is the 'ají dulce' of Northern South America, which is usually non-pungent). The genus *Capsicum* originated where the Andes meet the Amazon rainforest. Today, Bolivia has the highest number of wild species of *Capsicum* and Peru, after at least 6,000 years of interaction between people and chili peppers, the highest number of cultivated types of pungent *Capsicum*. Fruits of the five cultivated species of *Capsicum* can still be seen in some Peruvian markets, although the most important commercial species are *C. baccatum, C. pubescens and C. chinense*. Our research project is studying the diversity of pungent *Capsicum* in Peru and assessing different options to intensify the small-scale production and marketing of native chili peppers, many of which are currently grown only in home gardens and face a danger of genetic erosion. Connections with farmer´s organizations, the gastronomic sector and processing companies assure closer linkages and potential uptake of research results.

The *Capsicum* germplasm bank is made of 325 accessions (Table 1) collected throughout the country, mostly from smallholders but also from markets and commercial growers. An initial focus of collection was on the two regions with highest diversity of chili peppers: the Northern Arid Coast and the Northern Mountain Amazon Rainforest. *C. pubescens*, the typical Andean chili pepper ('rocoto'), was barely collected since there is already a large germplasm collection at INIA-Arequipa. The bank now contains accessions from 18 out of 24 political regions of Peru, although with varying intensity of collection (Figure 1). Even though the collection is not yet fully representative of Peru´s *Capsicum* diversity, it covers already most of the country and all the relevant regions, with the notable exception of the mountain rainforest and Amazonian lowland between Cusco, Puno and Madre de Dios, next to the Bolivian border, a region of difficult access. After close botanical evaluation, the taxonomic status of all accessions has been established, not without difficulty, and this calls for a revision of the Latin names assigned to some chili types in the literature. *C. chinense* is by far the species with the highest number of accessions (60%), more or less equally distributed among the Northern coast and the Amazon rainforest. *C. baccatum* comprises 25% of our collection, including several Amazonian types but also different seed selections of 'ají escabeche' (fresh) or 'ají mirasol' (dried), the most important *Capsicum* in the country, grown intensively in the coast for the fresh and processing markets. Both *C. annuum* and *C. frutescens* have very few accessions, mostly from the coast and from the Amazon, respectively.

Table 1. Species and regional distribution of the accessions in the *Capsicum* germplasm bank, UNALM (October 2014).

Species	Regions			Total	
	Coast	Andes	Amazon	Nº	%
Capsicum annuum	12	0	1	**13**	**4.0**
Capsicum baccatum	33	5	42	**80**	**24.6**
Capsicum chinense	92	5	99	**196**	**60.3**
Capsicum frutescens	0	0	8	**8**	**2.5**
Capsicum pubescens	0	10	18	**28**	**8.6**
Number of accessions	**137**	**20**	**168**	**325**	**100**
%	**42.2**	**6.1**	**51.7**	**100**	

Figure 1. Origin of accessions of *Capsicum* and major geographical regions in Peru.

Based on our botanical and horticultural research, we have proposed the first classification of the chili peppers of Peru (Ugás 2013), with 19 basic types in 5 major categories, according to regional distribution and intensity of cultivation (Figure 2): (1) Northern Coast, (2) Coast, intensive cultivation, (3) Amazonian, (4) Andean (*C. pubescens*, today also grown in the Mountain Rainforest), and (5) Miscellaneous. This classification includes the 5 cultivated species of *Capsicum*. *Ex situ* conservation of *Capsicum* germplasm is an essential tool, together with *in situ* approaches and on farm research, to assist in a better understanding of the diversity and to promote advanced value chains that will deliver useful products to the marketplace and, hopefully, increased revenues for smallholders. This should go along the promotion of short marketing chains but also with the exploration of international markets encouraged by the stronger presence of Peruvian food worldwide.

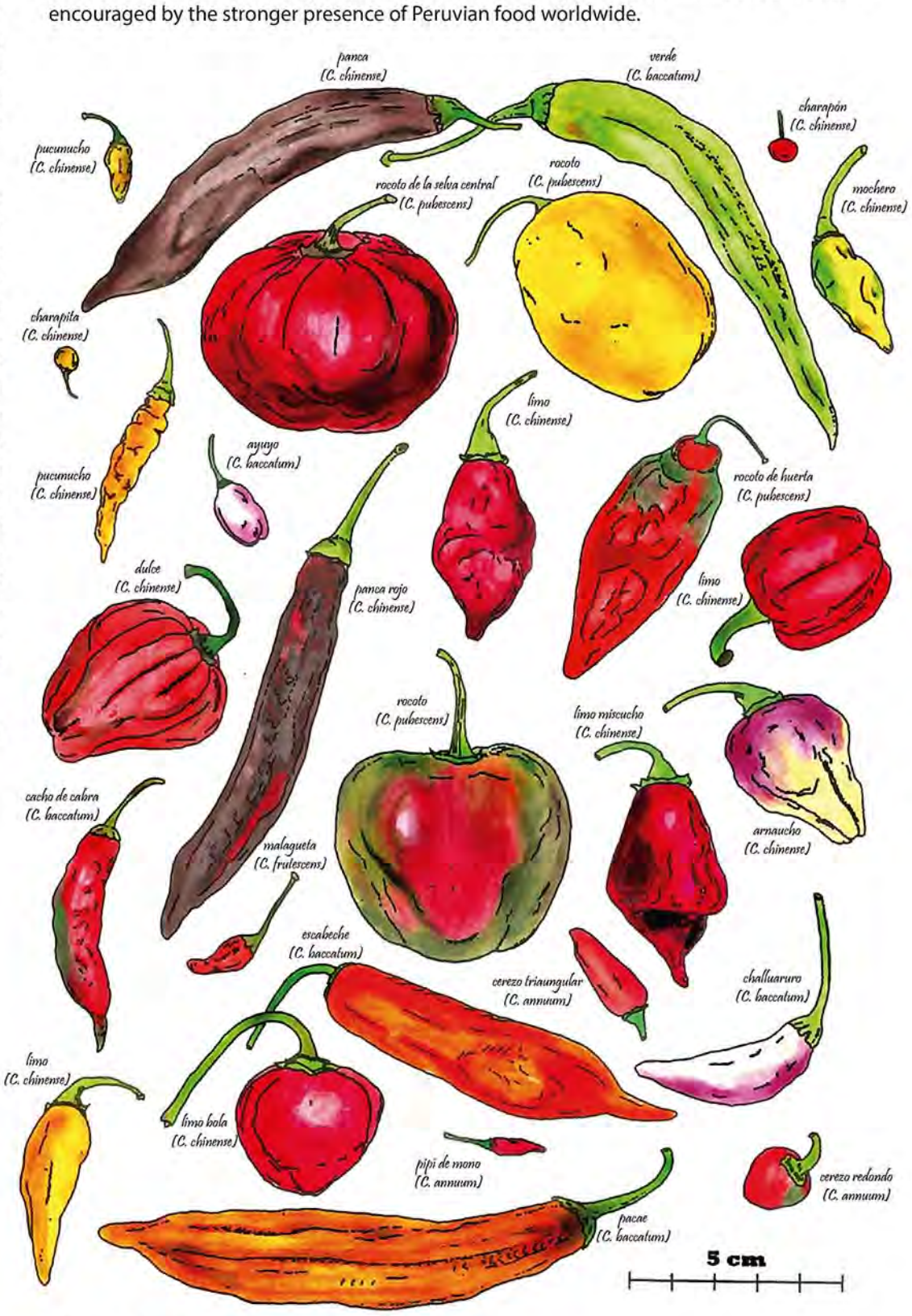

Figure 2. Major chili pepper types in Peru.

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Evaluation of six formulations of organic fertilizers and guano de islas in chili (*Capsicum annuum* L.) var. 'cerezo'

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Introduction

Peru is home to the world's highest diversity of cultivated chili peppers ('ají', in South American Spanish), but only a few commercial types can be found in national markets. Regional or village markets, on the other hand, often show an abundance of fruit shapes, sizes and colors coming from smallholder farming systems. The 'cerezo' (cherry) chili pepper is well known in the arid coast of Northern Peru (mainly Lambayeque) and is one of the few *Capsicum annuum* chili peppers available in the country, with a fruit shape ranging from globular to conical. Increasing interest in the gastronomy of Northern Peru, as well as other processes of economic intensification in the region, may provide new market opportunities for smallholders, potentially connected with specific claims like organic certification, geographical indications or collective marks. The conical 'cerezo' ranked very high in our kitchen evaluations with cooks in Lima (Valderrama and Ugás, 2009), in terms of flavor and aroma, with a medium-high pungency. Chemical analysis and processing tests are being conducted at UNALM and in Belgium.

Materials and methods

A field trial was established at the organically managed experimental farm of Programa de Hortalizas, UNALM, Lima, Peru, to assess the effects of different formulations of organic fertilizers on the performance of conical 'cerezo' chili pepper (Fig. 1). The experiment was conducted with furrow irrigation in a late season (February 2011 transplant, June-August harvest) in a sandy loam soil: pH 7.45, 1.9% organic matter, E.C 2.53 dS/m. The experimental design was randomized blocks with three replications. Organic fertilizers used where dairy cattle manure, compost, MO-STD (a commercial product made of fermented cattle manure, rumen and blood) and 'guano de islas' (sea-bird excrement) (Table 1). The quantities of organic fertilizers were based on local practices and commercial technical recommendations (Table 2). Application was made as basal fertilization prior to transplanting and as side-dressing (25 and 55 days after transplanting). Side-dressing was done either with the same fertilizer used in the basal fertilization or with 'guano de islas', which has a much higher concentration of nitrogen, also more readily available. Estimation of available nitrogen was made following Eghball (2002) and Pettygrove (2009).

Figure 1. Variability of fruit shape in 'ají cerezo'.

Table 1. Organic fertilizers used in the experiment.

Organic fertilizer	Hum. (%)	CE (dS/m)	N (%)	P_2O_5 (%)	K_2O (%)	CaO (%)	MgO (%)
Cattle manure	6.6	12.6	1.4	1.5	1.6	3.0	1.1
Compost	24.5	23.1	1.5	1.3	1.6	6.2	1.2
MO-STD	25.4	40.2	1.4	2.6	3.4	5.2	1.5
Guano de islas	-	-	17.8	15.4	3.7	8.0	0.5

Table 2. Treatments applied.

Basal fertilization		Side-dressing				Mineral N kg/ha/year
	quantity (t/ha)	1	quantity (t/ha)	2	quantity (t/ha)	
control	0	control	0	control	0	0.0
cattle manure	10	cattle manure	5	cattle manure	5	81.2
compost	10	compost	5	compost	5	23.0
MO-STD	6	MO-STD	3	MO-STD	3	22.2
cattle manure	10	guano de islas	0.5	guano de islas	0.5	116.3
compost	10	guano de islas	0.5	guano de islas	0.5	87.1
MO-STD	6	guano de islas	0.5	guano de islas	0.5	86.8

Results

The crop showed a good performance. Treatments with organic fertilizers produced between 62 and 93 more leaves per plant than the control, with a highly significant difference. A higher number of leaves may support higher yield but also protect fruits from sunburn, a frequent problem in Northern Peru. In spite of this, there were no statistical differences in days to flowering, with an average of 49 days after transplanting, making 'cerezo' one of the earliest chili peppers in Peru (Table 3).

Table 3. Effect of organic fertilization on 'cerezo' chili pepper.

Treatment	Number of leaves	Days to 50% flowering	Side-dressing				Fruit per plant	Yield kg/ha
			Weight g	Length cm	Diameter cm	Flesh thicknes cm		
Control	200 b	54 a	5.1 cd	3.9 bc	1.8 bc	0.26 b	74 d	7872 c
Cattle manure + cattle manure	279 a	44 b	5.2 bcd	4.0 abc	1.8 bc	0.29 a	94 c	10370 b
Compost + compost	267 a	50 ab	6.0 ab	4.3 ab	1.9 ab	0.30 a	80 d	10147 b
MO-STD + MO-STD	293 a	48 ab	5.4 bcd	4.1 ab	1.8 bc	0.29 a	118 a	13152 a
Cattle manure + guano de islas	286 a	49 ab	5.8 abc	4.3 ab	1.8 bc	0.29 a	101 b	11986 a
Compost + guano de islas	262 a	53 a	6.3 a	4.4 a	2.0 a	0.29 a	90 c	11581 ab
MO-STD + guano de islas	264 a	48 ab	4.5 d	3.7 c	1.7 c	0.30 a	113 a	10518 b
Mean	265	49	5.5	4.1	1.8	0.29	96	10803
Statistical significance	**	n.s.	**	*	*	**	**	**
C.V.	6.5%	7.0%	8.2%	5.7%	4.5%	2.6%	3.9%	10.6%

Values in columns followed by the same letter do not differ significantly at p=0.05

Yield showed highly significant differences. Not surprisingly, treatments with either MO-STD and 'guano de islas' obtained higher yields, up to 13 tons per hectare or 67% more than the control, which is much higher than reported in the very limited literature on this chili pepper. A similar pattern was found for the number of fruits per plant, with 59% more fruits when fertilized with MO-STD alone with regards to the control. Replacing the basal fertilizer for 'guano de islas' as side-dressing was beneficial, except for MO-STD, which showed a higher yield when side-dressed with MO-STD again. Cattle manure and compost performed similarly in terms of yield, either with the same fertilizer in the side-dressing or with 'guano de islas'. The evolution of harvests (Fig. 2) shows a marked increase in the third harvest (139 days after transplanting) for the treatment of MO-STD alone, accounting for much of the difference in total yield. An economic analysis showed that the highest profitability was achieved with the treatment of cattle manure and 'guano de islas'. Estimated availability of nitrogen was higher for cattle manure and 'guano de islas', although more research is needed to improve these estimations and understand the availability throughout the cropping season.

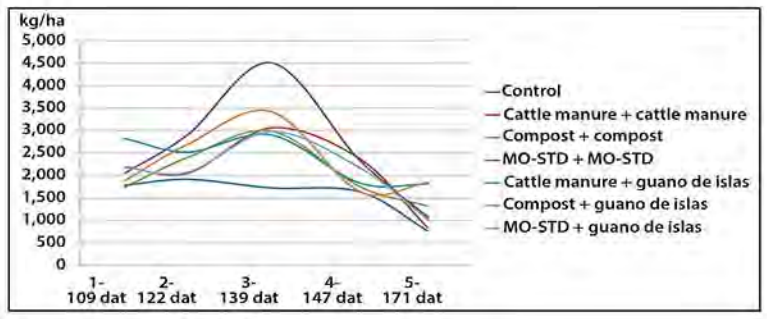

Figure 2. Yield per harvest (kg/ha).

Dry matter distribution (Fig. 3) showed that the control accumulated more dry matter in the roots (59%) as compared to all the treatments with organic fertilizers (55%), with a parallel reduction in the dry matter in fruits (11% versus 14 to 16%, respectively). This is explained by the fact that a non-fertilized plant, even in a soil with intensive year-round cultivation, needs to develop larger and more active root systems to get the nutrients needed for growth and development. The percentage of dry matter allocated to leaves and stems remained more or less similar. Significant differences were found for all parameters of fruit quality, with highly significant differences for fruit weight and flesh thickness, two parameters that contribute to total yield, although there was no clear pattern for fruit weight. Fruit size and thickness are very relevant in 'cerezo' since one potential use is as stuffed chili pepper, or sweetened and canned. Fruit shape, however, was highly variable (Fig. 1), showing that breeding research is needed.

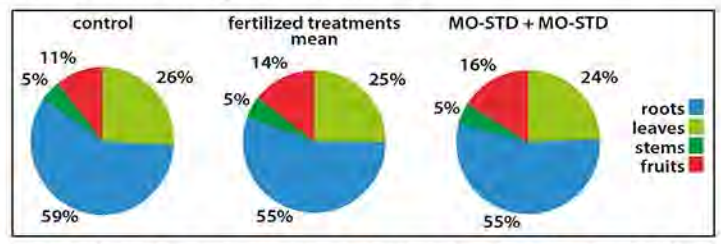

Figure 3. Dry matter distribution of 'cerezo' chili plants in response to organic fertilización.

Conclusions

This trial of organic cultivation of 'cerezo' chili pepper has shown a good performance of the crop, the feasibility of organic production and the benefits provided by the use of organic fertilizers, produced either on farm (cattle manure, compost) or externally (MO-STD, 'guano de islas'). These results also show that an expensive source of organic matter like MO-STD can be effectively replaced with compost or cattle manure provided they are enriched with a side-dressing of 'guano de islas'. The availability of this fertilizer, however, is very limited and subject to the ecological condition in the Peruvian islands of the Pacific Ocean. The 'cerezo' chili pepper requires further research in order to understand the best characteristics demanded by different markets, to get advanced selections and to produce seed well adapted to the conditions of smallholders in order to develop improved value chains for biodiversity.

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Comparative trial of 14 selections of 'ají amarillo', Peru´s leading chili pepper

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Introduction

'Ají' is how chili peppers are called in most of Spanish-speaking South America. Peru´s leading chili pepper is *Capsicum baccatum* var. *pendulum*, commercially grown in irrigated fields in the arid coast of the country. When fresh this chili pepper is called 'amarillo'(although the color of the fruit is a deep orange) and when it is sundried it is called 'mirasol', with different culinary uses throughout the whole range of regional cuisines in the country. 'Amarillo' can be either 'escabeche', a fruit of medium size, cultivated in the Central and Northern coast, or 'pacae', with very long fruits and cultivated in the Southern coast (Fig. 1). Besides the traditional uses, there is a growing demand of this chili pepper for the processing industry, made into sauces and pastes, as main ingredient or mixed with other vegetables and herbs. Moreover, there is also a still small but increasing export business, which also includes frozen and pickled preparations. In spite of this, there have been no significant or persistent efforts towards breeding to obtain superior types with regards to yield, adaptation to climate and soil conditions, tolerance to pests and diseases or suitability for processing. Most seed of 'ají amarillo' available is not certified and is generally not produced following basic agronomic requirements. Farmers may use their own seed, without the necessary controls in order to prevent cross-pollination or reduce seed-borne diseases, among others. This trial was established in order to analyze the characteristics of 'ají amarillo' from different sources and locations when grown in a commercial farm, and to provide information to support more consistent efforts towards breeding of superior varieties.

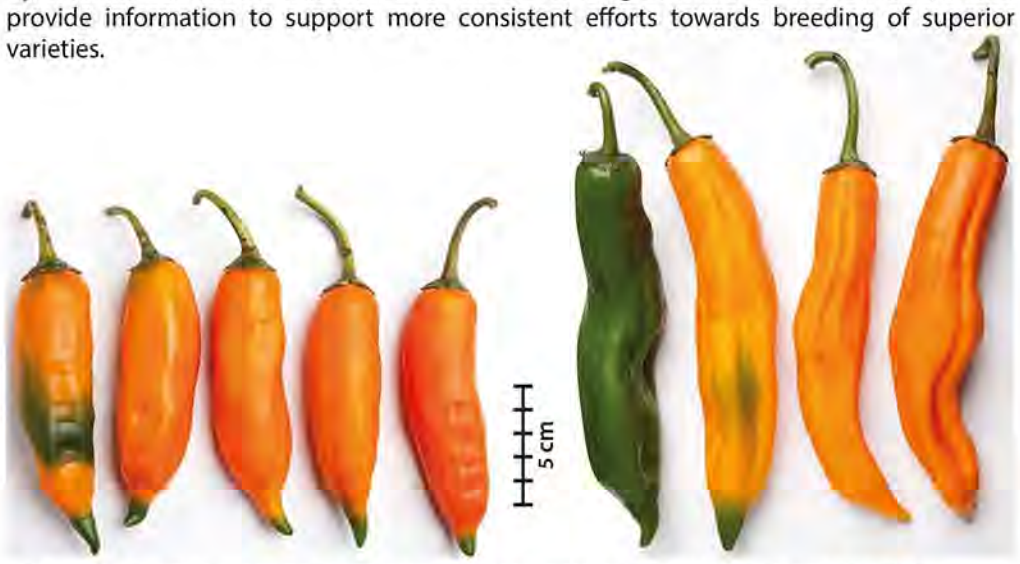

Figure 1. The two main types of 'ají amarillo': 'escabeche' (left) and 'pacae' (right).

Materials and methods

Seed of 14 regional types of 'ají amarillo' was collected in farmer´s fields, markets or local seed suppliers, from the border with Ecuador in the North down to the border with Chile in the South, along the arid coast where the intensive cultivation of this chili pepper is widespread. Nine types were 'escabeche' fruits while other four (treatments 11, 12, 13 and 14) were typical 'pacae'. Treatment 8 showed some characteristics of both fruit types. The experiment was located in a medium-size farm in the Casma valley (Fig. 2), 355 km North of Lima, surrounded by fields of paprika *Capsicum* and asparagus, mostly export crops with a high use of external inputs (agricultural chemicals and others) and furrow irrigation.Seedlings were started in a plastic tunnel and later transplanted in a randomized block design, with 4 blocks and an estimated density of 33,000 plants/ha. The agronomic management of the trial was very similar to the paprika pepper, with frequent application of insecticides (to control *Prodiplosis* fly as well as *Spodoptera* and other cutworms and fruitworms). Wilt (*Phytophthora capsici*) caused the loss of some plants but severity was low. A fertilization rate of 350-100-350 NPK was applied. Several parameters were measured throughout the growing season, including indicators of growth and development, yield and fruit quality.

Figure 2. View of the experimental field in the Casma valley, Northern Peru.

Results

Highly significant statistical differences were found for most characteristics (Table 1), except for days to the first harvest, which fluctuated between 123 and 188 days, although the 'pacae' types showed a late maturity, several weeks later than the 'escabeche' types. Yields were very high for some treatments, 8 of which produced more than 30,000 kg/ha. The 'pacae' types produced between 9,000 and 18,000 kg/ha. The very good yield of many of the 'escabeche' types, particularly those from the valleys of Casma, Huarmey and Cañete, are most probably a consequence of traditional seed selection processes undertaken by farmers and a few seed suppliers, although this is not formally recorded and remains out of the radar of seed authorities. Quite often, these selections are the result of the innovative nature of some individual farmers. The fact that the 'pacae' types produced very low yields as compared with the 'escabeche' types is probably more related to the specific climate conditions in Casma, which may vary considerably from those in Arequipa and Tacna, than to a specific yield superiority of the 'escabeche' types.

Table 1. Main results from comparative trial of 'ají amarillo' from 14 locations in Peru.

Treatment Origin	Days to first harvest	Total yield kg/ha	Fruit length cm	Fruit width cm	Flesh tckness mm	Fruit weight g
1 Piura	123 a	31,223 abc	11.7 c	2.7 d	2.6 e	14.4 c
2 Chiclayo	129 a	34,206 ab	12.3 c	2.8 d	2.9 bc	19.2 abc
3 Chiclayo	130 a	33,023 ab	12.0 c	2.8 d	2.9 bc	19.5 abc
4 Casma	125 a	34,293 ab	11.7 c	2.9 bc	2.7 cde	18.4 abc
5 Casma	134 a	36,997 a	11.6 c	3.2 bc	3.1 ab	17.5 bc
6 Huarmey	130 a	37,206 a	11.1 c	3.2 bc	3.1 ab	22.4 abc
7 Barranca	163 a	28,875 bc	12.1 c	3.2 bc	3.1 ab	19.9 abc
8 Chancayllo	162 a	25,531 c	15.8 ab	3.1 bc	3.2 a	31.8 ab
9 Manchay	167 a	35,258 ab	11.3 c	3.5 a	3.2 a	19.6 abc
10 Cañete	129 a	36,495 ab	11.5 c	3.1 bc	2.9 bc	22.2 abc
11 Arequipa	182 a	9,224 f	14.6 b	3.1 bc	2.7 de	22.2 abc
12 Cuzco	188 a	13,368 e	16.5 a	3.3 ab	2.9 bc	36.3 a
13 Tacna	180 a	14,365 de	16.2 a	3.1 c	2.9 bcd	30.9 ab
14 Tacna	175 a	18,497 d	16.0 a	3.3 bc	3.0 ab	34.2 a
Statistical significance	n.s.	**	**	**	**	**
C.V. %	9.1	8.3	3.4	2.2	2.5	18.4

Earliness is an important parameter for farmers and businesses, particularly when considering the stability of their supply to markets and processing companies and the potential need of different seed selections for specific growing areas in order to extend harvest seasons. The 'escabeche' types concentrated between 50% and 70% of total harvest in the first 4 harvests, while the 'pacae' concentrated between 24% and 54% in the same period (Fig. 3). Fruit length was considerably higher in the 'pacae' types (which is why they receive the name of 'pacae', the local name for the long and slender fruits of the guava tree), and also fruit weight was higher, but these are not enough to determine market quality. Equally important are fruit width and flesh thickness, characteristics for which treatment 9 (Manchay) showed the highest results.

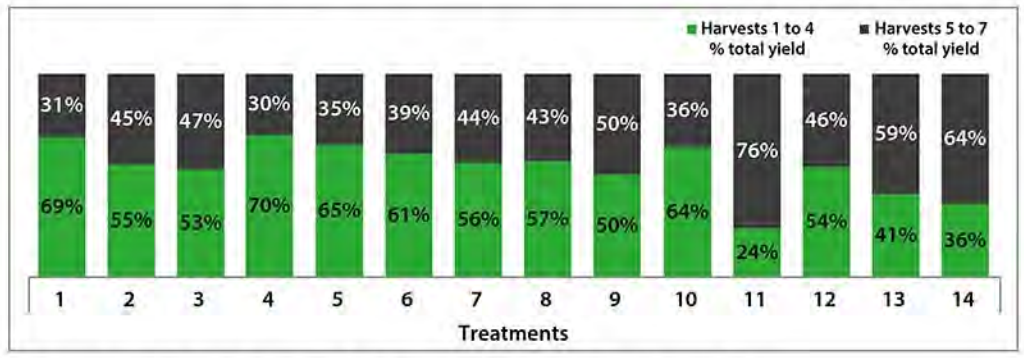

Figure 3. Yield distribution of ají amarillo from 14 locations in Peru.

Conclusions

It is clear from our trial that the 'pacae' types have a strong relationship with the climate, soils and crop management from the Southern coast and do not respond well in a Northern location like Casma. The 'escabeche' types produced very high yields with very good fruit quality and are a promising start of potential breeding work with these chili peppers, particularly those from Casma, Huarmey and Manchay. Further research related to the the commercial production of 'ají amarillo' for the local and foreign markets should identify specific seed selections from major producing regions as the basis for breeding and formal seed production. Eventually, specific varieties might be developed for the most important growing regions.

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Preliminary results of a morphological characterization of Amazonian chili peppers from Peru

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Introduction

In spite of having the highest number of cultivated chili peppers, the diversity of the genus Capsicum in Peru has received very little attention from the research community. Among these chili peppers, the Amazonian types show an enormous variability of fruit shapes and colours, but are generally of small or very small sizes. These chili peppers are considered to be very pungent, with exception of the 'ají dulce', which is normally non-pungent and is the only one that receives the common name 'ají' without being pungent. Amazonian chili peppers are almost entirely grown and conserved in home gardens, where plants very often grow as perennials. Among these, "charapita" is probably the only one that has reached national markets on a regular basis, generally pickled. But even within 'charapita' there is quite a large diversity of fruit sizes, shapes and colors. It is clear that basic research is needed in order to be able to include more of this chili peppers in advanced value chains linked to the gastronomic sector, small processing companies or others. This thesis research dealt with the morphological characterization of 63 Amazonian accessions from UNALM Capsicum germplasm bank.

Materials and methods

We selected seed from 63 Amazonian accessions of pungent Capsicum, most of all originally from the regions of Amazonas, San Martín, Loreto and Ucayali. Plants were grown in a nursery and transplanted in the open field during the summer at UNALM´s experimental field in La Molina, Lima. We understand that the climate and soil conditions are different from those in the Amazon region but we nevertheless expected to gather basic information to analyze the diversity in this collection. It is clear that a definitive characterization will require growing the plants in its original environment. The accessions were grouped according to their local denominations, the most common of which are shown in Table 1. Plants were grown organically, which is more or less the usual way in the Amazonian homegardens. Morphological characterization was done throughout the growing season, based on the list of descriptors proposed by IPGRI (1995).

Table 1. Main groups of Amazonian chili peppers in UNALM Capsicum germplasm bank.

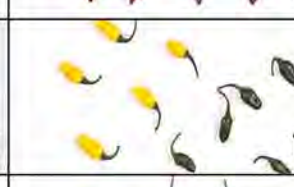
Group	Examples of accessions	
Ajíes dulces *C. chinense*	171	169
Challuaruro *C. baccatum*	117	129
Charapita *C. chinense*	130	 151
Malaguete *C. frutescens*	139	142
Miscucho *C. chinense*	182	174
Motelito *C. chinense*	187	122
Pucunucho *C. chinense*	175	123
Warmiucho *C. chinense*	140	137

Table 2. List of descriptors.

	Quantitative variables	Qualitative variables		
Seedling	Cotyledonous leaf length	Hypocotyl colour		
	Cotyledonous leaf width	Hypocotyl pubescence		
		Cotyledonous leaf colour		
Plant	Plant height	Stem Colour	Stem pubescence	Leaf density
	Stem diameter	Nodal anthocyanin	Plant growth habit	Leaf colour
		Stem shape	Branching habit	Leaf shape
			Tillering	Lamina margin
				Leaf pubescence
Inflorescence and fruit	Corolla length	Days to flowering	Corolla colour	Filament colour
	Anther length	Number of flowers per axil	Corolla spot colour	Stigma exertion
	Filament length	Flower position	Corolla shape	Calyx pigmentation
			Anther colour	Calyx margin
				Calyx annular constriction
Fruit	Fruit length	Days to fruiting	Fruit colour at mature stage	Fruit blossom end appendage
	Fruit width	Anthocyanin spots or stripes	Fruit shape	Fruit cross-sectional corrugation
	Fruit weight	Fruit colour at intermediate stage	Fruit shape at pedicel attachment	Fruit surface
	Fruit wall thickness	Fruit set	Neck at base of fruit	Ripe fruit persistence
	Number of locules		Fruit shape at blossom end	Placenta length
Seed	Seed diameter	Seed colour	Seed size	
		Seed surface	Number of seeds per fruit	

Results

Observation-based taxonomic assessment confirmed that most of the Amazonian chili peppers were *C. chinense*, with a few groups assigned to *C. baccatum* and *C. frutescens* (Table 1). This is a relevant finding since most small-sized Amazonian chili peppers are often assigned to *C. frutescens* in scientific and popular literature, but we have found that there is only one clearly *C. frutescens* in the Amazonian region ('malaguete') while most of the others are *C. chinense*, including 'charapita' the most ubiquitous in the Amazon regions. This, of course, will need to be reviewed when new accessions come, particularly from the very poorly explored region in Southern Amazonia, next to the Bolivian and Brazilian borders.

Morphological data from the characterization were arranged a dendogram. Preliminary results show a high variability for quantitative descriptors and a high ratio of similarity for qualitative descriptors. Although considering geographical origin, the studied chili peppers were from different regions but the morphological dendrogram could not fit them correspondingly and cluster analysis only slightly reflected the geographical origin of populations. Groups more or less coincide to the generic terms used locally to designate the chili peppers, with notable exceptions among 'pucunucho' and the 'ají dulce'. Two accessions called 'ayuyo' were clearly misnamed and belong to other groups. The cluster with the highest similarity (98.1%) was the 'charapita'.

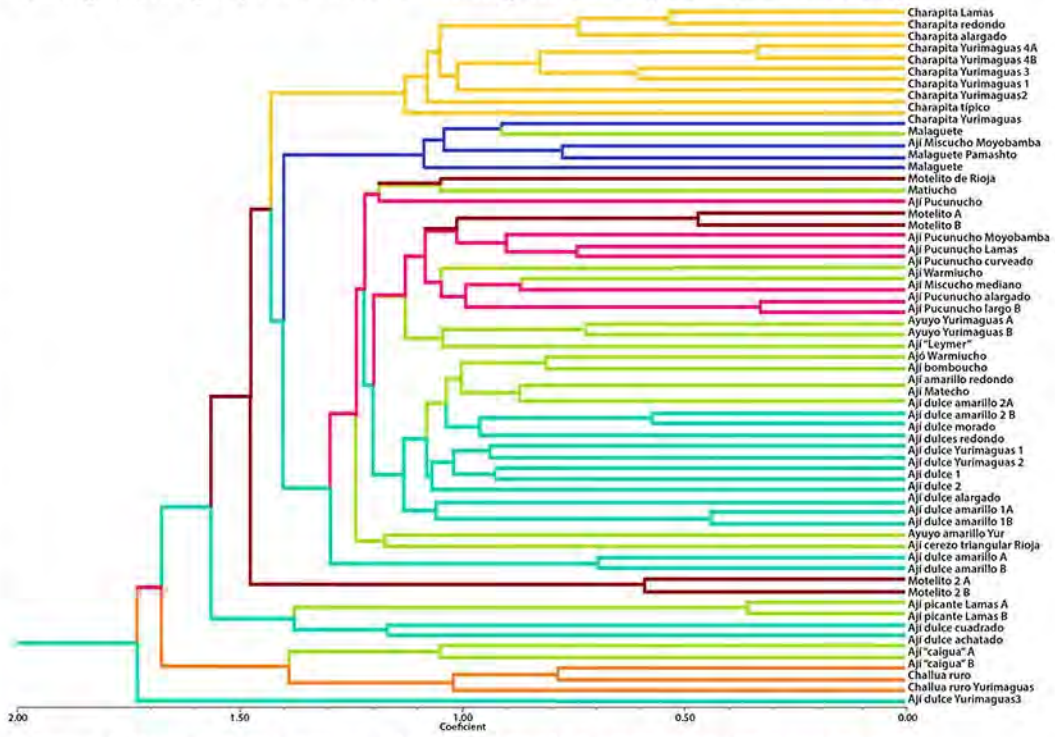


Figure 1. Dendrogram for morphological traits of 63 Amazonian chili peppers.

Conclusions

This research is in progress. The main contribution is to be the first morphological characterization of a significant sample of the Amazonian populations of chili peppers in Peru. Results will be the basis for future conservation, breeding and promotion of advanced value chains.

Literature cited:

IPGRI, AVRDC and CATIE. 1995. Descriptors for Capsicum (Capsicum spp.). International Plant Genetic Resources Institute, Rome, Italy; the Asian Vegetable Research and Development Center, Taipei, Taiwan, and the Centro Agronómico Tropical de Investigación y Enseñanza, Turrialba, Costa Rica.

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Characterization of fruits of twenty Peruvian chili peppers for processing purposes

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Introduction

Chili peppers originated in South America. They are widely consumed in Peru but not have been properly assessed in terms of their industrial use. The main problem is lack of raw material characterization. A basic characterization for this purpose requires measuring capsaicinoids, color (carotenoids being the most important color component) and pectin levels (with influence in the consistency of chili pepper pastes). In this study we characterized 20 accessions of UNALM Capsicum germplasm bank in terms of the capsaicinoids profile, color, total pectin and consistency of their derived pastes.

Materials and methods

Capsicum fruits: twenty accessions of chili peppers from UNALM Capsicum germplasm bank. Bostwick Index: Christiaens et al.(2012) with slight modifications; Pectin content: Christiaens et al. (2012) with slight modifications; Colour (L,a*, b*): Romano et al. (2012); Capsaicinoids: Collins et al. (1995); Statistical analysis: one way ANOVA and Tukey pairwise comparisons.

Table 1: Twenty accessions of chili pepper from Peru (UNALM germplasm bank).

Sample number	Accession	Local name	Species
1	69	Miscucho	*Capsicum chinense*
2	85	Miscucho	*Capsicum chinense*
3	42	Chico	*Capsicum baccatum*
4	132	Picante	*Capsicum chinense*
5	10	Mochero	*Capsicum chinense*
6	60	Arnaucho	*Capsicum chinense*
7	2	Escabeche rojo	*Capsicum baccatum*
8	5	Cacho de cabra rojo	*Capsicum baccatum*
9	200	Verde	*Capsicum baccatum*
10	202	Bola	*Capsicum chinense*
11	271	Escabeche	*Capsicum baccatum*
12	3	Cerezo redondo	*Capsicum annuum*
13	4	Cerezo triangular	*Capsicum annuum*
14	357	Limo	*Capsicum chinense*
15	72	Cacho de cabra amarillo	*Capsicum baccatum*
16	86	Miscucho naranja	*Capsicum chinense*
17	358	Panca	*Capsicum chinense*
18	318	"Limo"	*Capsicum baccatum*
19	323	Verde-Rojo	*Capsicum baccatum*
20	324	Verde-Naranja	*Capsicum baccatum*

Results

The flow behaviour of the chili pepper pastes was empirically tested using a Bostwick consistometer. Fig. 1 shows the Bostwick consistency index of the different samples with a distinction between the pulp and serum fraction. Sample 13 had a high resistance to flow, which was directly correlated to the highest content of pectin (Fig. 2). In Fig 2 we can see that 20% of samples had low values of pectin content (5, 13, 29 and 32). Christiaens et al. (2014) said that high a Bostwick consistency index for the pulp fraction corresponds with a low consistency or low resistance to flow. In addition, 50% of sauces didn't show syneresis. That could means that these raw chili peppers do not need a blanching operation (blanching has the aim of inactivating pectin methyl esterase enzyme which is the responsible of syneresis).

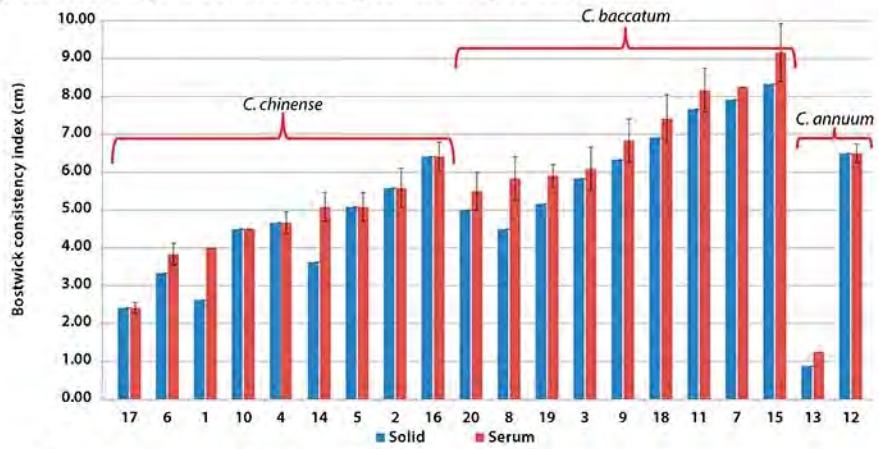

Figure 1. Consistency of pastes from 20 chili peppers.

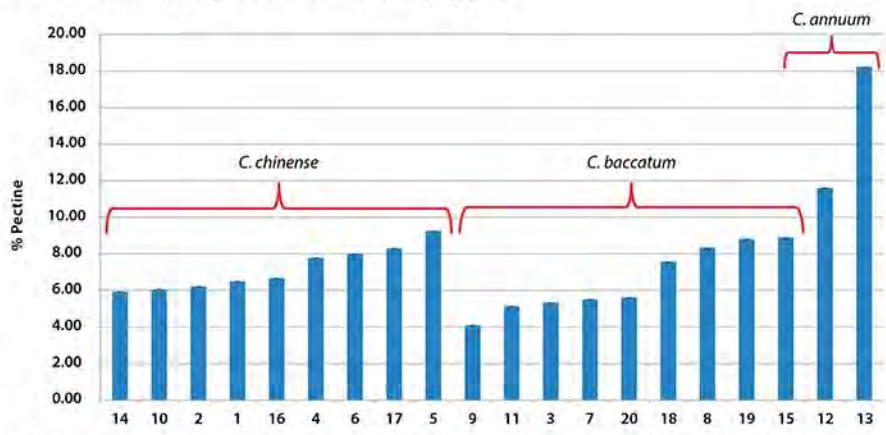

Figure 2. Pectin content of pastes from 20 chili peppers (per cent in dry basis).

Figure 3. Fruits of selected accessions of Capsicum. Clockwise: samples 3, 9, 13 and 17.

Fig 6 shows the capsaicin and dihydrocapsaicin content in the the 20 accessions of chili pepper. 'Chico' chili pepper (sample 3), of very limited distribution in the region of Huánuco in the Andes, showed the highest pungency. Sample 6 showed the highest content of capsaicin (200.19 mg/g) whereas 15% of samples showed low values, between 13.28 and 16.95 mg/g. On the other hand, sample 3 contained 141.78 mg/g of dihydrocapsaicin (the highest value) and 10% of chili peppers contained low values (between 3.37 and 5.09 mg/g). On this topic, Cisneros et al. (2007) say that the variation in capsaicinoids quantity can be attributed to intrinsic genetic factors to each cultivar or to the environmental conditions where they were cultivated.

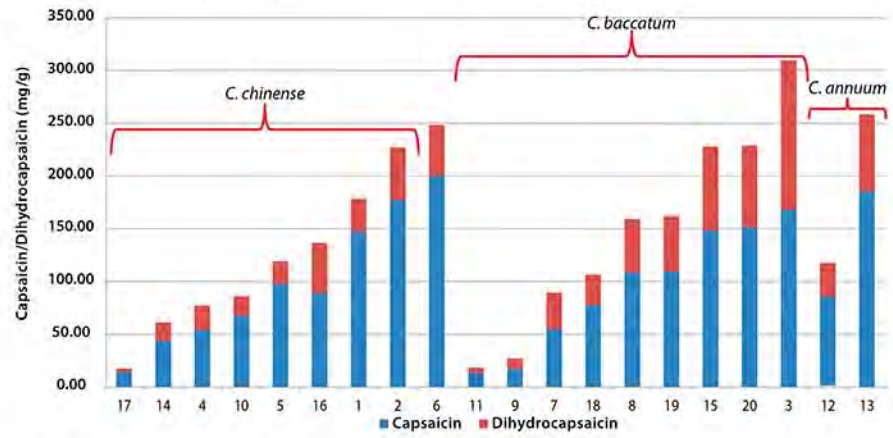

Figure 4. Capsaicin and dihydrocapsaicin content.

Conclusions

It was posible to characterize 20 native Peruvian chili pepper accessions in terms of capsaicinoids profile, color, total pectin and consistency of their derived pastes. These are the first studies of potential for processing done with a diversity of underexploited chili peppers of Peru belonging to 3 species of Capsicum. The 3 species showed a wide variation of results in all characteristics analyzed.

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Evaluation of maturation and ripening of six Capsicum accessions

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Introduction

Chili peppers originated in South America. The culinary use of chili peppers has been dated back to 6,000 years ago in Peru and today they are still widely consumed in Peru in the country. The Programa de Hortalizas of UNALM maintains a germplasm collection of over 300 native chili peppers but most of it has not been valorized in terms of their industrial use and there is a lack of raw material characterization. To date, growth patterns for defining proper harvest time of fruits destined to the processing industry do not exist. The objective of this study was to evaluate the effect of maturity on the physicochemical and physiological characteristics of the fruits of 6 accessions of Capsicum during its growth and development in order to determine the optimum time of harvest through the relative growth rate.

Materials and methods

Seed from 6 Capsicum accessions from the species C. baccatum and C. chinense (Capsicum germplasm bank, Hortalizas-UNALM). Moisture: AOAC (2005) ; Longitudinal and transversal diameter: IBPGR (1995); Colour (L, a*, b*): Minolta CR 400 colorimeter (Lee and Coates, 1999); Capsaicinoids: HPLC method (Collins et al., 1995); Acidity: AOAC (2005); Soluble solids: AOAC (2005). The experiment was done in a completely randomized design, with three replicates. Statistical analysis: ANOVA and Tuckey test.

Results

Fruits of the 6 accessions of Capsicum were evaluated for 7 weeks., from the formation of the first fruits. The results show that the mass (g) on a dry basis (db) , wet basis (wb) and longitudinal diameter (mm) exhibited a single sigmoid growth behavior for all the accessions, except for Pucunucho, which present no significant changes throughout the evaluation (Figure 1). While the evolution of equatorial diameter (mm) was mixed, accessions like Mochero and Pucunucho only had significant increases during the first few weeks, while Arnaucho, Miscucho and Cacho-de-cabra showed increases until the fourth week, and in Limo-encerado such increases were evident until the fifth week.

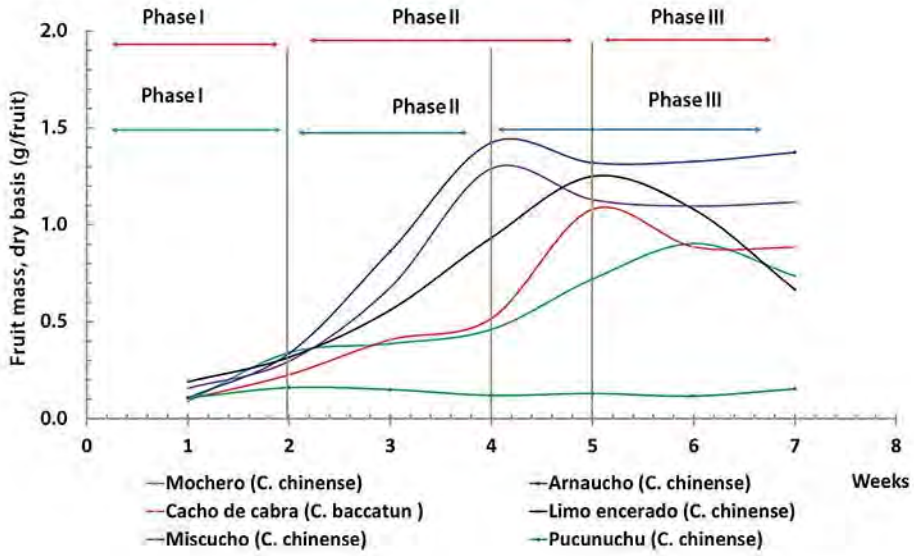

Figure 1. Evolution of fruit mass per unit (g/fruit) in six Capsicum accesions.

Soluble solids (%) exhibited significant increases after the fourth week for all accessions, while the acidity expressed as citric acid (%) showed a negative trend in general, obtaining the minimum values in the last weeks of evaluation.

Figure 2. Evolution of color in Arnaucho.

Figure 3. Evolution of color in Limo-encerado.

Pungency showed great variation between accessions and, in some cases, during the maturation and ripening process (Table 1). Highest pungency was found in Pucunuchu, a small Amazonian type, in the 7th week, and the lowest in Mochero, a medium-sized Coastal type, in the 4th week. Pungency is also affected by physiological maturity (Fig. 4). Only Cacho de cabra showed an increase in pungency up to physiological maturity, declining during senescence (Figure 4). The fruits of Arnaucho and Limo-Encerado reached physiological maturity 5 weeks after fruit set, while Miscucho, Mochero, Cacho-de-cabra and Pucunucho took 6 weeks to get to that state.

Table 1. Evolution of pungency (S.H.U.) in 6 accessions of Capsicum.

Accession	Pungency (S.H.U.) in several harvest time		
	4th week	6th week	7th week
Mochero (C. chinense)	846.6aA	3308.3cA	1971.9bA
Arnaucho (C. chinense)	2715.2cA	2706.2bAB	12281.8eB
Cacho de cabra (C. baccatum)	1935.4bA	10573.5eB	5530.1cA
Limo encerado (C. chinense)	3644.4dA	1706.8aB	1359.8aB
Miscucho (C. chinense)	4045.4eA	4830.8dA	9612.5dA
Pucunuchu (C. chinense)	9768.6fA	12666.4fA	31844.9fA

Small letters show the difference within the same column.
Capital letters show the difference within the same row.

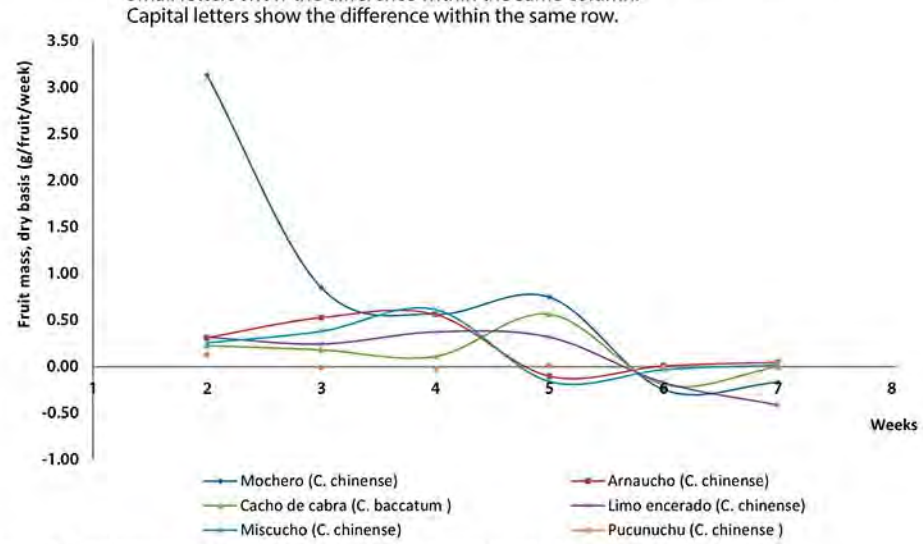

Figure 4. Evolution of the average relative growth rate (g/week).

Conclusions

The fruits of Arnaucho and Limo-encerado reached physiological maturity at the fifth week after fruit set, while Miscucho, Mochero, Cacho-de-cabra and Pucunucho accessions reached maturity at six week. There is a large variation among accessions, which calls for further research if these underexploited chili types are to be promoted among farmers and processors.

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Students involved in *Capsicum* research and extension in the Mala valley, Peru

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Introduction

Research and extension are key responsibilities of UNALM´s Vegetable Crops Research Program. At the same time, students of agricultural sciences require close interaction with the farming communities in order to be able to understand reality and contribute to rural and economic development. Colectivo Ayni is an officially registered student group at UNALM, established in 2007 with the purpose to carry interdisciplinary activities connected to rural development and the understanding of traditional farming systems. This poster describes the joint experience of Colectivo Ayni and the Capsicum Project of the VLIR-UNALM Program to reduce the gap between farmers and the university with intensive student involvement and on farm research.

The farm

Mala is a valley of the Peruvian coast, located at 85 Km south of Lima and UNALM campus (Fig. 1). It is located in an arid region but relative humidity can be very high and sunshine very low during the winter months. There are about 6,000 cultivated hectares in the valley, irrigated with water coming down from the Andes, and the area is well known for the production of high quality apples and a particular type of bananas. Vegetable crops are also important due to the relative short distance from Lima, the main market in the country. Biofruit is an association of organic farmers linked to the National Association of Ecological Producers (ANPE Peru). Pedro Francia (Fig. 2) is one of the leaders of the group and owns a small family farm (El Refugio) where he grows certified organic (since 1998) apples, peaches and vegetable crops and raises sheep. He is also involved in small scale processing of fruits, producing jelly, wine and other products. Additionally, he is promoting El Refugio as a pilot agroecological small farm for purposes of agroecotourism and training.

Figure 1. Panoramic view of the Mala valley.

Figure 2. Pedro Francia.

Some of El Refugio´s activities are shown in Figure3: (clockwise) Pedro Francia explaining the philosophy behind organic farming; sheep that provide useful products and manure for composting; snails are used to prepare a fermented biofertilizer and pest repellent; produce ready to be taken to the weekly organic farmer´s market in Miraflores, Lima.

Figure 3. Different aspects of life at El Refugio organic farm.

The student experience

Students from different areas (Agronomy, Agricultural Engineering, Biology, etc.), members of Colectivo Ayni, started their research as thesis students, with the following trials implemented in El Refugio and in neighboring farms:

1. Comparison of different sources of organic fertilizer and products containing lactic acid bacteria on the growth and development of chili pepper.
2. Comparison of different inputs to facilitate the release of nutrients from organic matter and biological activity in the rhizosphere and its effects in chili pepper.
3. Use of the partial root drying method for the irrigation of chili pepper as a tool to increase water use efficiency.
4. Comparison of promising types of native chili peppers from UNALM Capsicum germplasm bank under organic management.
5. Evaluation of the entomofauna associated to the joint cultivation of fruit crops and chili pepper.

In Figure 4 we show different examples of the student intervention at El Refugio: (clockwise) Students gather around Pedro Francia; transplanting of yellow chili pepper; evaluation of promising lines of chili peppers; dialogue between farmer, researcher and students; installing water pipe for the study of the partial root drying method; collecting beneficial insects for identification.

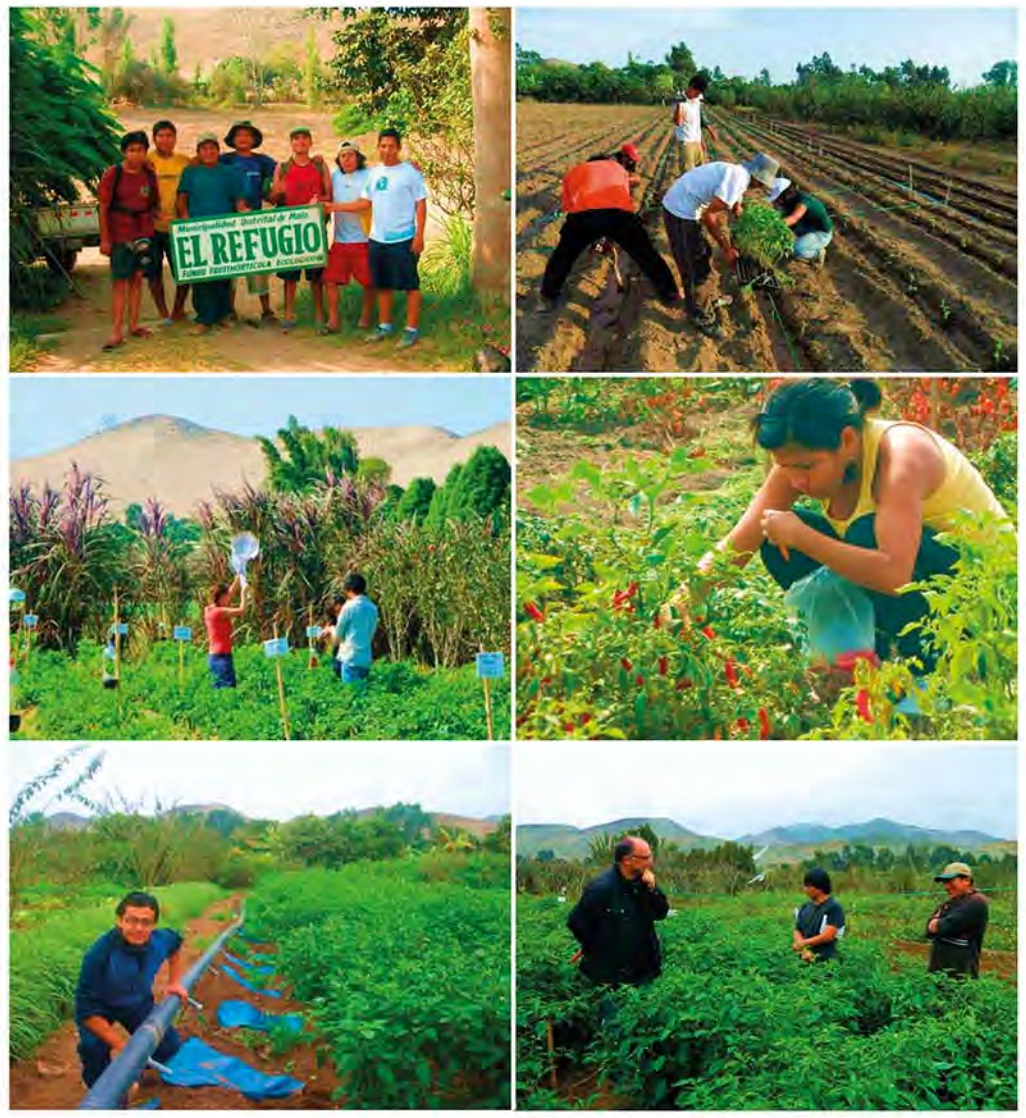

Figure 4. Different activities with student participation at El Refugio.

Conclusions

This has been a highly successful experience for us, the students, since it not only complemented our education and allowed us to conduct on farm research, but also we were able to understand how a farm works through direct engagement and friendship with Pedro Francia, his family and neighbors. We also contributed to the slow transformation of the farm into a pilot farm for agro tourism and training, although further investments are needed. We are committed to continue this engagement and to understand the role of agroecology and the criteria to assess small farm sustainability taking into consideration biological, economic, social and environmental perspectives.

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