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Genetic erosion of traditional varieties of vegetable crops in Europe: tomato cultivation in Valencia (Spain) as a case Study

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Abstract

Ever since the arrival of the tomato to Spain in the 16th century, great diversification of the crop has taken place, giving rise to a rich collection of varietal types. The 'Comunidad Valenciana', with its deep-rooted agricultural tradition, is one of the Spanish regions with the greatest diversity in traditional tomato varieties, characterised by their local adaptation and high fruit quality. Nevertheless, traditional varieties of tomato have been progressively abandoned over recent decades. A survey was carried out in the 'Huerta de Valencia' area of the 'Comunidad Valenciana' in order to evaluate the factors involved in the genetic erosion of traditional tomato varieties, as a model of the process affecting vegetable crops in Europe. The growth of urban areas that absorb horticultural land, the change in agricultural techniques, the low profitability of farms and their small size, the advanced age of farmers, the conversion of vegetable gardens to other crops and the incidence of viral diseases, have been identified as the major factors affecting genetic erosion in this analysis. The development of resistant traditional varieties through a formal plant breeding programme, and the consolidation of the specialised markets that efficiently exploit the organoleptic quality of these varieties, would help to assure the profitability of these varieties, and hence their active conservation on an on-farm basis. Consequently, the loss of these materials that make up gene combinations of an outstanding value could be prevented, and farmers would obtain a profitable alternative in a highly competitive agriculture.

Keywords: Agro-diversity; Germplasm conservation; Plant genetic resources

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most important cultivated vegetable species in the World. With a cultivated area in the year 2005 of 4.6 million ha producing 124.6 t, this autogamous crop shows a growing trend in the last decade with increases of 140.4% in harvested area and 142.2% in production (FAOSTAT, 2006).

At present, it is commonly accepted that the tomato was domesticated from *Lycopersicon esculentum* var. *cerasiforme* in Meso-America, probably in the area of the states of Puebla and Veracruz in Mexico (Jenkings, 1948; Rick and Fobes, 1975). With the arrival of the Spaniards in America, an exchange of crops took place between the New and the Old World, with the tomato reaching Europe in the first half of the 16th century. This crop was unevenly accepted in the Old World due to its taxonomic relation to other *solanaceae,* with toxic effects such as the deadly nightshade and the mandrake. The Mediterranean area was the first to accept the cultivation of this crop, given the ideal agroclimatic conditions for its adaptation, whilst consumption was particularly avoided in northern Europe. Thus, Spain and Italy were the first countries to include this crop in their diets. In the mid 16th century, an Italian physician reported the consumption of tomato in Italy; 'fried with salt and pepper' Matthioli (1544). The first report of this crop in Spain appeared in the shopping list of the 'Hospital de la Sangre' in Seville in 1608 (Hamilton, 1976), which probably indicates that the tomato had become a common vegetable. Years later, in the 18th century, the tomato was considered a basic ingredient in this country, and it was grown all the year round in Valencia (Gómez de Ortega, 1784). Considering that tomato was spread through Europe from Spain, and latter to the rest of the world primarily from Europe, this country along with its domestication area (MesoAmerica) has the longest tradition in the cultivation of this species. Over these years of cultivation, numerous ecotypes adapted to different agroclimatic conditions have been developed. It was the farmers themselves who contributed to the diversification of this crop, by carrying out distinct selections in different cultivation areas. Consequently, in the early 20th century a great diversity of varietal types of tomato existed in the main horticultural areas of Spain.

One of these areas, the 'Comunidad Valenciana' (Figure 1), an autonomous region on the Spanish Mediterranean coast, has stood out for its horticultural tradition for centuries, and many agricultural techniques form part of its culture. Ever since the arrival of the Muslim culture to the Iberian Peninsula, Valencian irrigation network, although initially developed by the Romans, has been considered a reference and the expression 'Valencia, garden of Spain' has been commonly used to describe the importance of its horticulture. For example, the 'Tribunal de las Aguas' (Water Court), created in the 13th century upon the basis of Muslim traditions to solve conflicts related to water distribution, is one of the oldest active courts in Europe (Glick, 1970). It is not surprising therefore the great variability in traditional tomato varieties that were developed in the 'Comunidad Valenciana', given its horticultural tradition. Presently, several different tomato types can still be found with different colours (red, orange, yellow, pink), shapes (heart-shaped, flattened, rounded and intermediate shapes, cylindrical, pyriform, ellipsoid and elongated) and sizes (up to 500g). In fact, approximately 25% of the Spanish tomato accessions held at the COMAV, the most important vegetable genebank in Spain, were collected in the Comunidad Valenciana, thus revealing the importance of the tomato diversity found in the area. In the proximities of the city of Valencia, the variety 'Valenciano' with heart-shaped fruits, is the most appreciated given its internal quality.

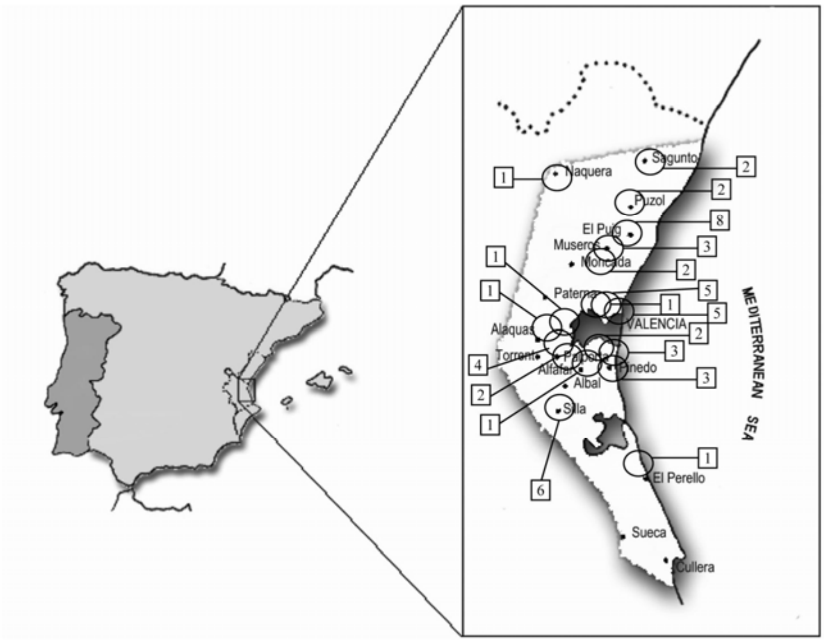

Figure 1. Area surveyed and number of collected accessions. (Dotted line in Spain: the 'Comunidad Valenciana').

Over recent decades in the Comunidad Valenciana, as in other regions of Spain, the structure of agricultural businesses has changed. The former productive units of a family-based nature, in which the wife and offspring cooperated on the land, have become increasingly scarce. New farms arise with a different structure and objectives, where the monoculture is generalised and great quantities of inputs are used, in an attempt to maximise the profitability of the investment. Thus, the necessity to optimise the yield of the plant material employed is stressed, and the cultivation of less productive and disease-susceptible traditional varieties is reduced. This process of loss of genetic diversity between and within populations of the same species is widely known as genetic erosion. It has been associated with progressive agricultural industrialization, and has been reported in other European regions and with other crops (Laghetti et al., 1999; Hammer et al., 1996; Pignone et al., 1997). In the case of tomato, as well as other vegetables, changes in the production-consumption chain have actually worsened the situation. The agents in the chain (seed producer, farmer, wholesaler, retailer and consumer) have different interests, and frequently those of the wholesaler have prevailed, and uniform easy-to-handle-and-store varieties have been imposed. Little emphasis has been placed on the internal quality of the fruits, a characteristic demanded by consumers. It is not strange therefore that the interests of seed producers have focused on the development of varieties with a high general adaptation capability, and whose fruits can be sold on any market. Although traditional tomato varieties have been used in breeding programs, they have not been improved *per se*, i.e. deficiencies have not been overcome while conserving their quality and adaptation traits.

Nevertheless, in horticultural areas where agricultural industrialization is less developed, especially in peri-urban farming systems, the main factor affecting the loss of traditional varieties is not a replacement by modern materials, but the steady disappearance of horticultural land and the lack of interest that farmers show in vegetable production due to the loss of profitability.

In this study, we show the results of a survey carried out in the 'Huerta de Valencia' area, which was aimed at determining factors implied in the genetic erosion process of traditional tomato varieties, as a representative model of the situation in Europe. Accessions of these materials were collected during the survey, determining ethnobotanic components associated with their culture. Since diseases of viral aetiology are the main yield limiting factor of tomato in Spain, (Roselló et al., 1996; Picó et al., 1996), the incidence of the principal viral diseases affecting tomato in Spain was evaluated. The awareness of the present situation of the cultivation of these varieties enables an identification of the deficiencies that should be considered in a recovery programme for these materials in order to promote their on-farm conservation.

Materials and methods

Area of survey

The area surveyed is located on the province of Valencia coastline in the 'Comunidad Valenciana' (Spain). This area consists of a belt centred in the city of Valencia which included the most important horticultural area of the province (Figure 1). It is a plain surface, mainly with sedimentary soils of clayish-sandy texture that has been modified with the addition of sands extracted from river Turia. This river is the primary source of water for irrigation, and the area has one of the most ancient and reknown irrigation systems based on ditches and channels, as the Mediterranea climate of the area involves a limited amount of rainfall.

Several trips were carried out to survey the area to seek traditional tomato varieties on farms and smallholdings placed between rural roads, either in open fields or in greenhouses.

Passport data and accession collection

The position of each farm planted with traditional varieties was determined using a Global Positioning System (Magellan, Meridian XL, San Dimas, California). Passport data was recorded at each location, following the indications of the International Plant Genetic Resources Institute descriptors (IPGRI, 1997). Ethnobotanic data and other information of interest regarding aspects related to the genetic erosion process were also recorded. This data was obtained through semi-structured interviews with farmers in a similar way to that proposed by Martin (1995). Seeds were obtained from fruits collected on the farms (point sampling along transects, with 10-20 points per site), and occasionally they were directly supplied by the farmers. Collected seeds were delivered to the Institute for Conservation and Breeding of Agrodiversity (COMAV), which holds a genebank specialised in the conservation of traditional varieties of vegetables (Nuez and Picó, 1999).

Viral disease incidence determination

In each location, the incidence of four viral diseases of significant importance in Spain was evaluated. Specifically, those caused by the *Tomato mosaic tobamovirus* (ToMV), the *Tomato spotted wilt tospovirus* (TSWV), the *Pepino mosaic potexvirus* (PepMV) and the *Tomato yellow leaf curl begomovirus* disease (TYLCD), caused by species TYLCV, TYLCSV and TYLCMalV. With this aim in mind, vegetative samples were taken from randomly selected plants and from plants showing viral disease symptoms. The possible incidence of TYLCVD was evaluated via visual symptoms estimation. Infection by the viruses ToMV, TSWV and PepMV was determined with DAS-ELISA tests (Clark and Adams, 1977), using specific polyclonal antibodies to these viruses supplied by Loewe (ToMV, TSWV) and DMSZ (PepMV).

Results

Accessions collected

Fifty-three accessions of traditional tomato varieties were collected during the survey. Most of them, forty two, belonged to the local type ‘Valenciano’, confirming its importance in the area. This type is characterised for displaying two distinct fruit morphologies on the same plant. The common name applied to each kind of fruit depends on the fruit blossom end shape. The first kind, named ‘femella’ (female) has slightly-flattened heart-shaped fruits and the blossom end is usually indented. The second kind, named ‘masclet’ (male), has heart-shaped fruits with a pointed blossom end and a fruit length/fruit width ratio greater than 0.9. Both kinds of fruit have green shoulders, an orange colour at maturity and a moderately depressed shoulder. These fruits have a large core and numerous locules, which result in a plump and firm fruit (Cebolla-Cornejo et al., 2000). The ‘masclet’ kind is more appreciated on the market. Nevertheless, these fruits ripen quickly (a characteristic also observed in other traditional tomato varieties, Granges et al., 1995) and are pointed, which hinders packing and transport. These traits may have contributed to the abandonment of this varietal type, as the wholesalers demand highly uniform varieties with a rounded or slightly flattened shape that can be easily handled and stored for a long time until distribution.

In this varietal type, great variability was found between and within accessions. Differences were detected in blossom end shape of the ‘masclets’ (degree of point), in the presence of vertical stripes in mature fruits, and in the yield and fruit size. The proportion of ‘masclets’ per plant is variable, and in some accessions all the fruits belonged to the ‘femella’ kind. It is not known how the expression of this trait can be influenced by the environment, since the proportion of ‘masclets’ is much lower in late crops with fruit collection starting in August.

Among the rest of the collected accessions, three had a rounded shape and an intense red colour (all of the receiving the name of the nearest town: ‘Puigenc’, ‘Castellarenc’ and ‘Picanyer’), two were a cherry type (probably old cultivars) and one was a ‘Pera’ type, with a medium-small ellipsoid fruit (normally used for cooking). Five accessions had large flattened fruits. Four of these had a yellow skin at maturity, a variety referred as ‘Gigante rojo’, and one had a colourless skin and a pink external colour, referred to as ‘Gigante rosa’. This last type is found in other areas not included in this survey, and is appreciated locally.

Factors affecting the cultivation of traditional varieties

Once all the data collected during the survey had been analysed, several factors that either directly or indirectly affect the cultivation of traditional varieties were identified. Some of these factors are related to horticulture in general, while others only affect the cultivation of traditional varieties. Both factor types are associated with the genetic erosion process.

Expansion of centres of population and disappearance of horticultural land.

The city of Valencia has 807,396 inhabitants, with a municipal area of 13,465 ha (Ayuntamiento Valencia, 2006). There is a belt of towns associated with this city, which is gradually being absorbed by the city itself. At present, population growth is steady, and more construction land is in demand. In almost all cases, the advance of urban areas is being made at the cost of horticultural land, and quite a lot of farmers are waiting to sell their land in order to retire.

Changes in agricultural techniques

The irrigation system traditionally used by farmers in this area is a flooding irrigation system obtained from the rivers Turia or Júcar. But in some areas closer to cities or towns, water pollution, due to urban waste dumped directly in the irrigation network, flowing in the irrigation ditches or channels has been detected, (Marco et al., 1994), thus forcing the use of wells to obtain clean water. This fact, added to the lack of water and its increase in price lead to the installation of drip irrigation systems. Consequently, 28% of the visited farms or smallholdings used this kind of irrigation system (Table 1). The reduction of soil tillage is associated with this kind of irrigation, which can lead to a worsening of the soil structure. The use of fertirrigation is usually accompanied by an indiscriminate use of mineral fertilizers, and these varieties, which have been selected under manure fertilization, tend to show excessive vegetative growth, so that their full yield potential may not be obtained. In two cases, accessions were collected from greenhouses. Protected cultivation is used to take advantage of the considerable higher price paid for these varieties at the beginning of the season. It is important to control vegetative growth under these conditions, and the farmers confirmed the sensitivity of traditional varieties to high temperatures. In the smallholdings with a flooding irrigation system and a small number of plants, fertilization only consisted in manure fertilization following the traditional cultivation system.

These changes in agricultural techniques do not directly affect the cultivation of these crops, but the new production systems, such as greenhouse cultivation or fertirrigation, have not been developed for the cultivation of traditional varieties, but rather of modern cultivars. In order to exploit the full yield potential of traditional varieties, it would be necessary to carry out assays to determine the appropriate conditions for these materials.

Some farmers confirmed that small local nurseries directly offer plants of traditional varieties ready for planting. There is a risk that farmers could decide to obtain the plants from these nurseries instead of selecting their own seed each year. This situation would probably lead to a decrease in the genetic variability of the materials being grown.

Table 1. Description of accessions, collection sites and incidence of viral diseases.

	Flooding (furrows)				Drip	
Irrigation system	79.2 %				20.8 %	
	Valenciano	Flattened, red	Flattened, pink	Cherry	Rounded	Ellipsoid
Fruit morphology	79.2%	7.5%	1.9%	3.8%	5.7%	1.9%
Transplanting date	February	March	March/April	April	May	June
	7.5%	18.9%	11.3%	56.6%	3.8%	1.9%
ToMV Infection	75.5%					
TSWV infection	18.9%					
TYLCV infection	0%					
PepMV infection	0%					

Aspects associated with the low viability of farms

Small farm size and age of farmers

In previous decades, the horticultural land of this area was made up of a patchwork of small farms. Exploitation was highly intensive, and therefore the land was occupied all year round with rotations including all kinds of vegetable species. Within each species, the farmer could choose from a large number of distinct varieties. A homeostatic system was established as a result of this diversity, and adaptation to local pests and diseases was achieved to a certain extent. Over recent decades, a certain tendency to pseudo-monoculture has developed, as the low prices of vegetables force farmers to grow only those considered to be more profitable. Therefore, few species coexist in the area at the same time, and the number of varietal types available of each species is reduced (Burriel, 1971). In addition, new pests and diseases break down the homeostatic system that had minimised the losses caused by these agents. The small size of farms makes mechanization inadvisable, and traditional varieties are susceptible to the main diseases affecting tomato in Spain, thus many farmers constantly abandon the agricultural commercial activity or retire, as the farmers themselves have stated.

More than one third of farms (36.3%) with traditional tomato varieties had less than 40 plants (Table 2). These smallholdings are maintained by retired farmers (older than 60) who keep a small garden with all kind of species for self-consumption (tomatoes, onions, beans, pumpkins, peppers, lettuces, etc.), thus they hold the most horticultural genetic resources. These farmers recognise the loss of quality in modern cultivars and prefer the taste of the vegetables that they have been producing throughout their working lives. One third of exploitations had between 40 and 100 plants, and these were maintained by farmers aged between 50 and 60 years (Table 2). These smallholdings target the production for self-consumption, and sales in small markets. Occasionally, the farmer owned a store in the market and supplied his own business. The remaining farms (30.3%) had a primarily commercial outlook, with production aimed at wholesalers. However, the size of the farms is limited even in these cases, and the average number of plants per farm was 654 (Table2).

It is easy to infer the progressive abandonment of the horticultural land by observing this distribution of farms, as only 43% of farms were commercial producers, while the remaining 57% are kept by farmers who will probably abandon the horticultural sector in a period no longer than 10 years. This latter group makes up the remainder of farms that had been larger in previous years. In the case of smallholdings or gardens kept by retired farmers, as there is no generation replacement, it would be difficult to prevent definitive loss in any way other than through conservation in gene banks. In this sense, farmers pointed out that horticulture does not offer a good future for the new generations, and their offspring choose their job in other production sectors. Consequently, the solution to conserve traditional varieties on an on-farm basis relies on the guarantee of profitable production for the farmer. This profitability can only be reached by obtaining new lines of traditional varieties with higher productions or through the consolidation of high selling prices that make up for the lower yield of these varieties.

Table 2. Classification of collection sites according to their size (no. of plants).

	Percentage of sites	Mean no. of plants	Average age of farmers
Less than 40 plants	36.3	25	>60
40 - 100 plants	33.3	72	50-60
More than 100 plants	30.3	654	< 50

Imbalance between selling prices and production costs

The low selling price of produce appears to be one of the principal problems that the horticultural sector faces, as put forward by farmers. However, consumers pay considerably high prices for traditional varieties, reaching in the market up to 6-7 euros a kilo in the case of ‘Valenciano’, or even 9 euros a kilo in the case of variety ‘Raff’. Obviously, wholesalers and retailers obtain the greater shares of these high values, thus assuring their profits. In the meantime, high competition among growers hinders the possibility of obtaining better prices. The rise in production costs worsens this situation, limiting the farmer's profitability. This trend can be also observed if we analyse the data provided by the Spanish Ministry of Food, Agriculture and Fisheries. Whilst the farmer's selling prices of products have been kept stable or have undergone small increases (taking into account the Consumer Prices Index), the production costs (excluding labour costs) have grown at a much higher rate (Figure 2). The difference is much higher when labour costs are considered, especially as women's emancipation and the lack of interest of offspring, limit labour availability to the farmer himself. As a result, the profitability of horticulture in general has been steadily decreasing. This reduction in profitability is especially accentuated in the case of farms with traditional tomato varieties due to the small size of the farms. Farmers stated that a minimum production of 6 kg per plant is necessary to assure profitability, a threshold not always feasible as traditional varieties as 'Valenciano' have low yields. Thus, selections aimed at improving yield and uniformity would be advisable.

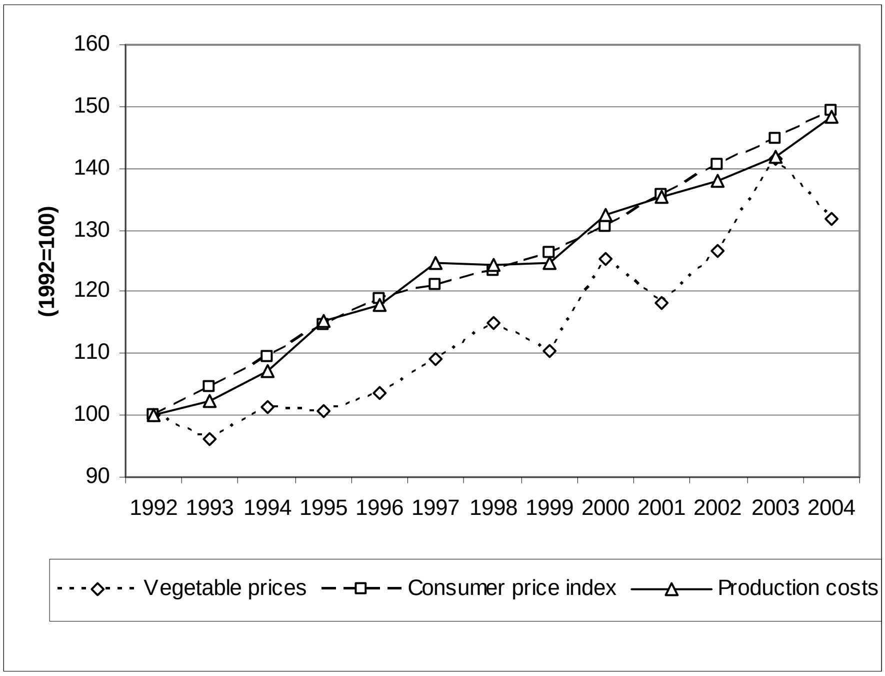

Figure 2. Evolution of vegetable prices perceived by farmers, Consumer Prices Index and mean production costs in Spain during the period 1992-2004 (Base: 1992=100. Source: MAPA, 2006).

Part-time agriculture and conversion of horticultural land to citrus cultivation.

As a result of low profitability of farms, many farmers have been forced to obtain an additional source of income, resorting to part-time agriculture. In Valencian agriculture it is commonplace to find farmers who own a farm, and who work as labourers in other exploitations or sectors at the same time (Arnalte et al., 1990). In the tomato crop, labour requirement is constant from the time of planting and throughout the whole growing cycle (planting, vertical training, pruning, phytosanitary treatments, collection). Consequently, it is more difficult to combine a part-time activity that can assure a source of income for the farmer. This leads to the progressive abandonment of cultivating traditional varieties of vegetables and horticultural land is converted to citrus cultivation. This crop is the most widely extended in the 'Comunidad Valenciana'. In year 2004 it occupied 169,249 ha with a production of 3.49 million tons (CAPA, 2006). Numerous national and international distribution channels exist (2.33 million tons are exported from the Comunidad Valenciana, representing 76.3% of the whole Spanish citrus exportation), and more importantly, its cultivation is compatible with part-time work.

With the progressive substitution of the cultivation of vegetables for citrus fruits, a drastic change in landscape takes place, and a monotonous layer of green replaces the rich and varied diversity in colours and shapes of horticultural land. In order to protect this landscape diversity and cultural heritage, citizen movements such as 'Salvem L'Horta' (Save Produce Lands) have emerged. At the same time, a change in the nature of the crops and associated agricultural techniques involves a shift in the distribution of weed and insect populations of the area, with those species usually found in the citrus agro ecosystem developing at a higher rate.

Incidence of viral diseases

In order to check the effect of these viruses on traditional varieties in the field, the incidence of ToMV, TSWV, TYLCV and PepMV in the surveyed area was determined. A proportion of 66.7% of farms or smallholdings were infected with ToMV (Table 1). Most of them had plants with marked mosaics on the leaves, and floral abortion. This may be one of the primary causes of low production observed in these varieties (added to floral abortion due to lack of nutrients as a result of development in the first trusses of large fruits). The presence of TSWV was only detected in 17.5% of the farms, coinciding with shoot necrosis symptoms. Nevertheless, farmers described typical symptoms of this disease in plantations of previous years, linked to serious losses. The PepMV infection was not detected during the survey, although the recent appearance of this virus in Spain has been reported in the South of the Comunidad Valenciana (Soler et al., 2004). Typical symptoms of TYLCVD were not observed either. Although TYLCVD was not detected during the survey, it was considered as the first limiting factor of tomato production in the Comunidad Valenciana two years later.

In the case of traditional tomato varieties, as well as in other vegetables (melon, pepper, etc.), farmers have pointed out that these plants are highly susceptible to all kinds of diseases of a recent apparition. Most of them have reported that their neighbours have abandoned the cultivation of traditional tomato varieties and melon as 100% of the crop could be lost due to the incidence of diseases. This situation leads to classify the cultivation of traditional varieties as 'high risk', because practically the entire production may be lost at any moment.

The transmission of the afore-mentioned viruses, either mechanically or by highly efficient insect vectors, such as thrips or whiteflies, is almost impossible to control using physical, chemical or biological methods. There are no curative methods available, and the development of resistant varieties is the best management strategy. Traditional tomato varieties have not been subjected to formal plant breeding programs, so they do not carry typical disease resistance genes.

Discussion

In the limited number of smallholdings that still grow traditional varieties, a great variability is observed. It is probably the method used by farmers to multiply their seed from year to year that determines the observed variability. Farmers do not collect seeds from randomly selected plants, rather they try to follow a maintenance breeding, as described by Zeven (2000), by carrying out a selection of the crop. However, it is not plant-based selection they perform, but a fruit-based selection; this means that most farmers do not select plants for their remarkable yield nor for the morphology of their fruits, rather they select the fruits with the best morphology and colour characteristics from different plants, a technique influenced by the belief that inheritance is based on a ‘fruit-to-seed’ transmission and not on a ‘plant-to-seed’ transmission. In this way, they select seeds on a yearly basis from plants with quite different yield characteristics and with a high degree of variability in fruit shape. Given this kind of selection, a considerable degree of variability has been maintained over the years. Nevertheless, a plant-based selection is being carried out on those farms cultivated by younger farmers, and on those with a market destined production, which enables the trend to standardise the varieties cultivated by each farmer.

Another practice that may have contributed to the maintenance of variability in these materials is seed replacement. Most of the farmers interviewed held the idea that seed degenerates, and that the cultivation of traditional varieties cannot be extended for more than 5 to 10 years on the same farm. For this reason, seeds are constantly exchanged among farmers, and eventually seeds from different origins get mixed. This idea of seed degeneration and replacement is not restricted to this region, as not only has it also been reported in other European countries, but also in other crops (Zeven, 1999).

In all the visited farms and smallholdings, the abandonment of horticulture in general was the observed trend. Family-based productive units are increasingly scarce due to women’s emancipation and the new generations´ preference of other productive sectors. Labour has to be hired, and when increase of production costs is taken into account, profitability steadily decreases. Farmers with commercial perspectives often choose high-response modern cultivars adapted to high-input agriculture that also exhibit disease resistance. Agricultural industrialization not only has affects within the species variation, but it also restricts the number of species cultivated and imposes shifts in the species receiving priority. In Spain, as in other developed countries, the importance of the agricultural sector is continuously decreasing, the agricultural population is markedly ageing, and the risk of loss of traditional varieties is increasing. This situation worsens in peri-urban farming areas where agricultural land is being urbanised. Nevertheless, some farmers are still growing traditional varieties with a commercial inclination. These farmers have identified the added value of these varieties, that stand out for their organoleptic quality, and they sell their production in quality markets.

The degree of genetic erosion of the case being analysed could not be quantified in figures, as other authors have proposed (e.g. Hammer et al., 1996). Although collections in the area were carried out during the eighties, the surveys were not thorough and the methodologies used were different. In addition, published data during the last century regarding tomato cultivation does not differentiate between traditional and commercial varieties. Nevertheless, farmers provided unpublished data of great interest. All the farmers interviewed agreed that traditional tomato varieties are no longer grown, mainly because of their lower yields and their high susceptibility to diseases. In fact, they highlighted that tomato cultivation (traditional or modern varieties) had increasingly decreased since the early nineties due to the impact of a disease causing the bronzing of leaves and stem necrosis (TSWV). The consequences of disease susceptibility on the abandonment of a cultivation was not restricted to tomato, but was pointed as the cause of the absence of melon cultivation in the area (which was extensively grown) following several years of total production loss by the incidence of melon dieback. Pepper cultivation has also been affected by the incidence of TSWV.

Globalisation of the economy and the frequent transaction of produce between different countries have caused crop diseases to spread. Accordingly, short intervals of time elapse between the first report of a disease in a certain country and the first report in bordering countries, or in those countries with continuous exchanges of plant material with the former. With these dynamics, globalisation of viral diseases occupies an outstanding place due to high efficiency in transmission. In this context, tomato crops in Spain have been seriously affected by the entrance of viruses like TSWV in 1989 (Jordá and Osca, 1991), TYLCV-Sr (species Sardinia) in 1992 (Moriones et al., 1993), and the subsequent diffusion of TYLCV-Is (species Israel) in 1997 (Navas-Castillo et al., 1997) or of PepMV in the year 2000 (Jordá et al., 2000).

Local varieties obtained in traditional agricultural environments are frequently adapted to marginal environments under high pest and disease pressure (Hawtin et al., 1996). Nevertheless, the continuous entrance of viral diseases of different genera from foreign environments can be a devastating blow to the cultivation of these crops as the adaptation process has not taken place. It has already been proved in laboratory assays that most traditional Valencian tomato varieties are highly susceptible to diseases caused by ToMV, TSWV, TYLCV and PepMV (data not shown).

An indirect risk assessment of the genetic erosion of these varieties in this area was made by taking into account factors such as: number of farmers maintaining traditional varieties, number of plants cultivated by each farmer, purpose of production (commercial vs. self-consumption), profitability of these varieties, generation replacement, and age of farmers. All these factors confirmed that the risk is high, and the same conclusion is obtained from the guidelines proposed by Guarino (1995).

In Europe, a trend to avoid quantity-based agriculture has been established as more emphasis is being stressed on the development of quality-based agricultures (Bouma *et al*. 1998). From this point of view, the future of traditional varieties depends on the exploitation of their quality characteristics. In some cases like traditional Italian lentil varieties, the crops cultivation maintenance is associated with the development of quality marks within the European Union (Piergiovanni, 2000). This could be the course to follow for the traditional Valencian tomato varieties. In addition, as stated by Frese (2002), there are reasons supporting the possibility of subsidizing farmers to cultivate obsolete varieties on the farm, as the management of these genetic resources may be considered to be a service which has to be rewarded by society.

Recovery programme

In the area surveyed, horticulture is characterised by small-scale farming, which is a factor that restricts the reduction of costs in order to compete with other production areas, such as those of Almería on the Spanish south-easterly coast. In this context, the cultivation of traditional varieties may become an alternative as these varieties are appreciated by consumers who are willing to pay up to 4.7 times the price of commercial varieties (Figure 3). During the survey, we verified that the two main disadvantages to be overcome in order to promote cultivation were lower yields and susceptibility to diseases (especially those caused by virus). A recovery programme has been carried out over a five-year period based upon the survey results. The aim of this programme was to develop the *in situ* conservation of these genetic resources, and its main lines were:

Characterization: 106 accessions of different varieties held at the COMAV Genebank have already been characterised using 67 descriptors. The information gathered will enable the optimization of accession selection by potential users of this diversity.

Evaluation of fruit quality: As fruit quality determines selling price, thus the profitability of these varieties, its evaluation has become a central key within the recovery programme. Single sugars and organic acids profiles have been obtained for most characterised accessions. In addition, a relation between these profiles and sensory analysis is being carried out and at the moment aroma profiles are being obtained.

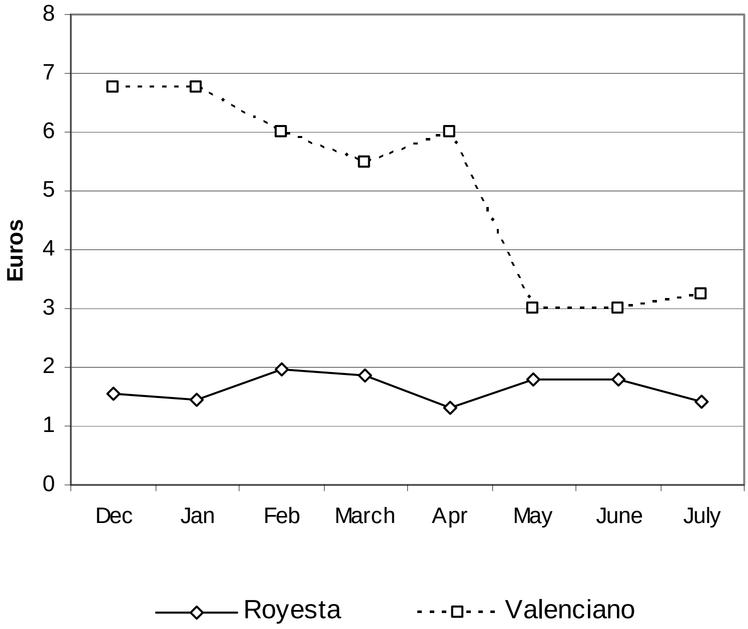

Figure 3. Evolution of prices paid by consumers for the traditional variety ‘Valenciano’ and the commercial variety ‘Royesta’ during campaign 2001/2002 (Source: El Corte Inglés, S.A.).

Breeding for virus resistance: With the data obtained during the characterization, several accessions of different varieties where selected on the basis of their morphologic and agronomic behaviour. These accessions were introduced in a breeding programme in order to introgress the genes *Tm-2*^{2}, *Sw-5* and *Ty-*, which confer resistance to ToMV (Hall, 1980), TSWV (Stevens et al., 1992) and to the complex TYLCV (Zamir et al., 1994), respectively. Since no sources of resistance to PepMV have been reported, screenings in several species of the genus *Lycopersicon* are being conducted.

It shoud be noted that it is impossible to carry out a classical breeding program without modifying the genetic background of traditional varieties. Two of the main values of these crops are their quality characteristics and their adaptation to local environments. Both are complex characters, and are therefore controlled by a great number of genes. Thus, it is complicated to deal with the introgression of resistance genes with a backcrossing program, and to keep the initial crops characteristics without any alteration. In this context, genetic engineering would appear to be a useful tool to maintain the biodiversity found in traditional varieties. With these techniques, it is possible to introduce resistance genes without altering the genetic background that we want to preserve. Although it may appear to be paradoxical, genetic engineering can be a valuable ally in the active conservation of our horticultural patrimony

Breeding for higher yield and uniformity: It is difficult to ensure that the lines derived from the backcrossing programmes will be exactly equal to the recurrent parents. In order to avoid this situation, and to provide alternatives to farmers in areas with low virus incidence, simple selections are also being conducted to obtain lines with higher uniformity and yield. The selection pressure applied is considerably low, as it could lead to a loss of diversity, and a high fruit load could decrease fruit quality (Bertin et al., 2001).

Selection of lines adapted to organic farming: Organic farming has become an agricultural sector with a high expansion rate. Consumers are willing to pay higher prices for this kind of products, not only demanding the absence of pesticide traces or an agriculture environmental-friendly aspect as compensation, but also a high organoleptic quality. In this context, traditional varieties can be excellent materials for organic farmers as, apart from their quality, they are also adapted to local agro-climatic conditions. In order to promote the use of these varieties in organic farming, as an on-farm conservation alternative, several studies are being carried out at the moment to select the best adapted accessions to this farming system (taking agronomic and organoleptic traits into account).

Genetic engineering: Presently, several strategies can be followed in order to introduce virus resistance *via* genetic engineering, including the use of pathogen-derived resistance and cloned host-resistance genes. This approach would enable the development of resistant lines without affecting the genetic background that should be preserved. In the future therefore, genetic engineering may become a useful tool to promote on-farm conservation. In this context, *in vitro* regeneration methods have been currently optimised for selected accessions, and *Agrobacterium*-mediated transformations are being conducted.

Promotion: It is essential for farmers to realise that traditional varieties can become a profitable alternative by exploiting the existence of quality markets. In this sense, a promotion programme has been developed by organising several conferences in agricultural cooperatives in the area. As a result, advice was required by one cooperative for it to improve its seed selection process. Government cooperation promoting awareness campaigns emphasizing the quality of traditional varieties would also be advisable.

Conclusion

A significant part of agrodiversity is being rapidly lost in the 'Comunidad Valenciana' (Spain) area surveyed not only as a result of the abandonment of traditional varieties, but also of horticulture in general. Obviously, agricultural industrialization has contributed to these varieties being substituted by modern cultivars. However, the present-day major risk factor of genetic erosion is the loss of profitability: farmers cannot face high production costs at the prices they are obtaining. In this context, traditional varieties can become an alternative if their profitability is assured. In order to achieve this objective, plant breeding programmes for resistance to diseases, especially those of a viral etiology, are necessary. In this way, the marketable production would be increased, and the risk of losing the whole production in years, with an important incidence of viral diseases, would be decreased. On the other hand, it is necessary to obtain a higher selling price for these varieties in comparison with modern cultivars. Presently, traditional varieties already have a sector in the market that is prepared to offer a higher price for higher quality. Nevertheless, this sector must be consolidated and expanded by establishing quality brands associated with the traditional tomato varieties.

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References

Arnalte, E., Estruch, V., Muñoz, C., 1990. El mercado asalariado en la agricultura del litoral Valenciano. Agricultura y Sociedad 54, 193-228.

Ayuntamiento de Valencia., 2006. Anuario estadístico de la ciudad de Valencia 2006. http://www.valencia.es /ayuntamiento2/estadistica.nsf/principalweb?OpenFrameset&lang=1&nivel=1

Bertin, N., Guichard, S., Leonardi, C., Longuenesse, J.J., Langlois, D., Navez, B., 2000. Seasonal evolution of the quality of fresh glasshouse tomatoes under Mediterranean conditions, as affected by air vapour pressure deficit and plant fruit load. Annals of Botany, 85 (6), 741-750.

Bouma, J., Varallyay, G., Batjes, N.H., 1998. Principal land use changes anticipated in Europe. Agr. Ecosyst. Environ. 67, 103-119.

Burriel, E.L., 1971. La huerta de Valencia, zona sur: estudio de geografía agraria. Instituto de Geografía de la Institución Alfonso el Magnánimo, Valencia.

CAPA. 2006. Dades bàsiques del sector agrari valencià. Conselleria d'Agricultura, Peixca i Alimentació (CAPA). Valencia.

Clark, M.F., Adams, A.N., 1977. Characteristics of the microplate method of enzyme-linked immunosorbent assay (ELISA) for the detection of plant viruses. J. Gen. Virol. 34, 475-483.

Cebolla Cornejo, J., Bartual, R., Soler, S., Nuez, F. 2000. Recuperación y conservación de variedades tradicionales de tomate. Actas de Horticultura 30, 81-88.

FAOSTAT., 2006. Food and Agriculture Organization of the United Nations Database. http://faostat.fao.org/default.aspx

Frese, L. Combining static and dynamic management pf PGR: a case study of *Beta* genetic resources. In: Engels, J.M.M., Ramanatha Rao, V. Brown, A.H.D., Jackson, M.T., (eds.). Managing plant genetic diversity. CAB International, Wallinford, pp. 133-148.

Glick, T.F., 1970. Irrigation and society in medieval Valencia. Belknap Press of Harvard University Press, Cambridge. 406 pp.

Granges, A., Leger, A., Produit, V., 1995. Quality of tomatoes: a comparison of traditional, mid-life and long-life types. Revue Suisse de Viticulture, d'Arboriculture et d'Horticulture 27, 277-283.

Guarino, L., 1995. Assessing the threat of genetic erosion. In: Guarino, L., Ramanatha Rao, V., Reid, R. (Eds.) Collecting plant genetic diversity, technical guideliness. CAB International Wallingford, pp. 67-74.

Hamilton, E.E., 1976. What the New World economy gave the Old. In: Chiappelli (ed.), First images of America: the impact of the New World on The Old, vol 2. University of California Press, Los Angeles, pp. 853-884

Hall, T.J., 1980. Resistance at the *Tm-2* locus in the tomato to tomato mosaic virus. Euphytica 29 (1), 189-197.

Hammer, K., Knüpffer, H., Xhuveli, L., Perrino, P., 1996. Estimating genetic erosion in landraces–two case studies. Genet. Resour. And Crop Ev. 43, 329-336.

Hawtin, G., Iwanaga, M., Hodgin, T., 1996. Genetic resources in breeding for adaptation. Euphytica 92, 255-266.

IPGRI, International Plant Genetic Resources Institute. 1997. Descriptors for tomato (*Lycopersicon* spp.). IPGRI, Rome.

Jenkins, J.A., 1948. The origin of cultivated tomato. Econ. Bot. 2, 379-392.

Jordá, C., Lázaro, A., Font, I., Lacasa, A., Guerrero, M., Cano, A. 2000. Nueva enfermedad en el tomate. Phytoma España 119, 23-28.

Jordá, C., Osca, J.M., 1991. Un nuevo virus en España, el TSWV. In: Consejería de Agricultura, Industria y Comercio de Extremadura (ed.). Estudios de Fitopatología. Consejería de Agricultura, Industria y Comercio de Extremadura, Mérida, pp. 35-40.

Laghetti, G., Perrino, P., Cifarelli, S., Bullitta, S., Hammer, K., 1999. Collecting crop genetic resources in Sardinia, Italy and its islands, 1998. Plant Genet. Resour. Nwsl. 120, 30-36.

MAPA, Ministerio de Agricultura, Pesca y Alimentación. 2006. Anuario de estadística Agroalimentaria. Ministerio de Agricultura, Pesca y Alimentación, Madrid. 706 pp.

Marco, J.B., Mateu, J.F., Romero, J., 1994. Regadíos históricos valencianos: propuestas de rehabilitación. Consellería d'Agricultura, Pesca i Alimentació, Valencia.

Martin, G.J., 1995. Anthropology. In: Martin, G.J. Ethnobotany: A methods manual. Chapman &Hall, London, pp. 95-116,

Matthioli, P. A., 1544-1554. Di pedanio Dioscoride anazarbeo libri cinque della historia et materia medicinale trodotti in lingua vulgare Italiana. Venezia.

Moriones, E., Arno, J., Accotto, GP., Noris, E., Cavallarin, L., 1993. First report of tomato yellow leaf curl virus in Spain. Plant Dis. 77 (9), 953.

Navas-Castillo, J., Sanchez-Campos, S., Diaz, J.A., Saez-Alonso, E., Moriones, E., 1997. First report of tomato yellow leaf curl virus-Is in Spain: coexistence of two different geminiviruses in the same epidemic outbreak. Plant Dis. 81 (12), 1461.

Nuez, F., Pico, B., 1999. Collections of vegetable crops and wild relatives in the Centre for Conservation and Breeding of the Agricultural Biodiversity (Spain). Plant Genet. Resour. Nwsl. 11, 68.

Picó, B., Díez, M.J., Nuez, F., 1996. Viral diseases causing the greatest economic losses to the tomato crop. II. The tomato yellow leaf curl virus - a review. Scientia Hort., 67 (3-4), 151-196.

Piergiovanni, A.R., 2000. The evolution of lentil (*Lens culinaris* Medik.) cultivation in Italy and its effects on the survival of autochthonous populations. Genet. Resour. and Crop Ev. 47, 305-314.

Pignone, D., Hammer, K., Gladis, T., Perrino, P., 1997. Collecting in southern Sardinia (Italy), 1995. Plant Genet. Res. Nwsl. 109, 7-10.

Gómez de Ortega, C., 1784. Flora española o Historia de las plantas que se crían en España, Tomo V. Ibarra, Madrid.

Rick, C. M., Fobes, J. F., 1975. Allozyme variation in the cultivated tomato and closely related species. Bul. Torrey Bot. Club 102, 376-384.

Roselló, S., Díez, M.J., Nuez, F. 1996. Viral diseases causing the greatest economic losses to the tomato crop. I. The tomato spotted wilt virus - a review. Scientia Hort. 67 (3-4), 117-150.

Soler-Aleixandre, S., Cebolla-Cornejo, J., Nuez, F., 2005. Sources of resistance to Pepino mosaic virus (PepMV) in tomato. Tomato Genetics Cooperative Reports, 55: 43-45.

Stevens, M.R., Scott, S.J., Gergerich, R.C., 1992. Inheritance of a gene for resistance to tomato spotted wilt virus (TSWV) from *Lycopersicon peruvianum* Mill. Euphytica 59 (1), 9-17.

Zamir, D., Ekstein-Michelson, I., Zakay, Y., Navot, N., Zeidan, M., Sarfatti, M., Eshed, Y., Harel, E., Pleban, T., Oss, H.v., Kedar, N., Rabinowitch, H.D., Czosnek, H., 1994. Mapping and introgression of a tomato yellow leaf curl virus tolerance gene, *Ty-1*. Theor. Appl. Gen. 88 (2), 141-146.

Zeven, A.C., 1999. The traditional inexplicable replacement of seed and seed ware of landraces and cultivars: A review. Euphytica 110, 181-191

Zeven, A.C., 2000. Traditional maintenance breeding of landraces: 1. Data by crop. Euphytica 116: 65-85.