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Phenotypic and genetic diversity of Spanish tomato landraces

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ABSTRACT

The structure of Spanish landraces of tomato (*Solanum lycopersicum* L.) has been analyzed. This diversity has been evaluated using agro-morphological characteristics (43 descriptors), quality parameters (solid soluble contents and individual sugars and organic acids) and DNA markers (amplified fragment length polymorphisms, AFLP). A wide range of variation was found for all traits but in the DNA marker level. Certain common characteristics could be identified in populations of the same landrace in several of the dimensions analyzed, but generally, an overlap of the spectrum of variation of different landraces was found. The results indicate that in each landrace the populations are strongly selected using very basic morphological characteristics such as fruit shape, colour or ribbing, while other traits vary depending on each farmer preferences. Seed mixing and pollen contamination might introduce variation which would be purged by farmers at the morphological level, but would be maintained in quality and yield traits. Despite the introduction of spurious variation it would be still possible to identify certain relations between quality attributes and the morphological traits defining specific landraces. The existence of a wide level of variation in plant yield and quality profiles enables the development of selection programmes targeted to provide farmers with materials with economically viable yield and excellent organoleptic quality. The results also highlight the necessity to stress the efforts in morpho-agronomical and quality characterization over molecular characterization in the ex situ management of these resources, as well as not to underestimate the importance of intra-varietal variability.

1. Introduction

It is commonly accepted that the tomato (*Solanum lycopersicum* L.) was domesticated in México (Bai and Lindhout, 2007). With the arrival of the Spaniards in America, the tomato participated in the exchange of crops between the New and the Old World. And it reached Europe though Spain probably in the first half of the 16th century, though the exact date remains unknown. From Spain it spread to the Viceroyalty of Naples and to the rest of Italy (Dondarini, 2010). Considering that Spain played a major role in the spread of tomato and the fact that Spain and Italy were the first countries cultivating this crop in Europe, it seems logical that both countries would represent an important secondary centre of diversity.

Over these five centuries 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 tomato landraces existed in the main horticultural areas of Spain.

The term landrace has received numerous definitions and several synonyms refer to the same concept, including local variety, local population, traditional cultivar, farmer variety and farmer population (Zeven, 1998) or traditional variety and primitive variety (Negri et al., 2009). Harlan (1975) described them as follows: “Landraces have a certain genetic integrity. They are recognizable morphologically; farmers have names for them and different landraces are understood to differ in adaptation to soil type, time of seeding, date of maturity, height, nutritive value, use and other properties. Most important, they are genetically diverse.” In the same text Harlan stated that landraces “consist of mixtures of genotypes or genetic lines”. Louette (2000) in the context of maize cultivation defined a local variety or landrace as the set of farmers’ seed lots that bear the same name and are considered as a homogeneous set, and seed lots as the set of kernels of a specific variety selected by one farmer. Again the idea of a landrace or local variety as composed of different selections appears. The different selections of the same landrace made by farmers can be considered as populations of the landrace or as subpopulations (being in this case the landrace a single population). Considering that during germplasm collections the term

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population is usually used to define the sample obtained at a specific site (Brown and Marshall, 2000; Hawkes et al., 2000), it could be proposed that a landrace maybe formed by different populations that, despite sharing common characteristics typical of the landrace to which they belong, have suffered different selections by different farmers and have evolved in different environments.

In Spain several different tomato landraces 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 1 kg). Their origins remain unclear, as in the case of other crops it is difficult to find varietal designations, other than the name of the crop, until the first half of the 20th century. Nowadays it is still difficult to differentiate in some cases between real landraces, selected by farmers, and old obsolete commercial varieties selected by breeders, as only their designations and not their origins are conserved in the spoken tradition.

In this context, the evaluation of Spanish landraces seems to be a good model in order to analyze the structure of variation in tomato landraces. Several studies regarding Spanish landraces of tomato have been previously published, but usually they include data on a specific group of characteristics (morphological or quality traits or DNA) and usually including a very limited set of landraces and accessions per landrace (Garcia-Martinez et al., 2006, 2013; Casals et al., 2011a, 2011b; Cebolla-Cornejo et al., 2011).

These landraces constitute the main source of variation in the cultivated species and usually show outstanding organoleptic quality. In fact, this last reason has enabled the development of quality markets where consumers are eager to pay a differential of 4.7 over the price of commercial modern varieties (Cebolla-Cornejo et al., 2007). The information obtained in the analysis of wide collections of landraces would be of great interest in the management of ex situ collections, for their utilization in breeding programmes or for their direct use in quality markets, as the cultivation of these materials could represent a 'true pearl' as defined by Meerburg et al. (2009): the one that satisfies societal demands while providing a reasonable income to the farmer.

In this context, this work includes the evaluation of agronomical and morphological traits, chemical composition related to organoleptic quality and DNA variation in a wide collection of Spanish landraces, including a wide representation of farmers' selections or populations of several key landraces.

To which point are farmers' selections of the same landrace similar? Are different landraces really differentiable? Is this variation clearly structure is separated groups? Landraces are usually distinguished morphologically, but do they have a clear chemical profile defining a characteristic taste? Several authors have analyzed a discrete set of Spanish landraces using DNA markers, but are the results consistent when a wide collection of landraces and farmer's selections are considered? These are the questions that this work tries to answer.

2. Materials and methods

A collection of several accessions or populations of different landraces was analyzed considering different traits: morpho-agronomical traits, quality-related traits and DNA. The variation in fruit weight and yield (accumulated fruit weights) variation was analyzed in depth considering the importance of these traits. The number of accessions evaluated was reduced for plant yield, quality and DNA variation, considering the costs of each characterization. In each case, the populations were selected depending on the socio-economic importance of each landrace.

2.1. Analysis of morpho-agronomical variation

For the analysis of morpho-agronomical variation 75 populations of 29 landraces were included (Table 1). Although several landraces were included in this study, it was centred in the analysis of four especially important landraces or landraces: 'Valenciano', a heart shape tomato, 'Muchamiel', a flat and ribbed tomato, 'Pimiento' a long landrace resembling an Italian pepper and 'Penjar' a small fruited landrace with long shelf-life. All the accessions were provided by seedbank of the Instituto Universitario de Conservación y Mejora de la Agrodiversidad Valenciana, COMAV (Valencia, Spain). These populations were evaluated using morphological and agronomical descriptors.

A selection of IPGRI (1997) descriptors (marked I-) was used with some additions (marked A-), including 21 qualitative morphological descriptors, 4 qualitative agronomical descriptors, 17 morphological quantitative descriptors and 5 agronomical quantitative descriptors. Some agronomical descriptors can also be considered as morphological. Nevertheless, they have been studied together as morpho-agronomical variation.

Qualitative descriptors were classified in scales from 1 to 9, generally 1 corresponding to extremely low intensity and 9 to extremely high intensity. Morphological descriptors included were: I-unripe external fruit colour, I-green stripes, I-green shoulder intensity, I-fruit pubescence, I-fruit shape, I-fruit size, I-fruit size homogeneity, I-external ripe fruit colour, I-intensity of ripe external fruit colour, I-secondary fruit shape, I-intensity of fruit ribbing, I-easiness of fruit to detach from pedicel, I-easiness of fruit wall (skin) to be peeled, I-skin colour of ripe fruit, I-flesh colour of pericarp, I-flesh colour intensity, A-core colour, I-intensity of core colour, I-fruit cross-sectional shape, I-shape of pistil scar, I-fruit blossom end shape and I-blossom end scar condition. Qualitative agronomical descriptors were: I-sensorial fruit firmness, I-radial cracking, I-concentric cracking and A-seed yield. Quantitative morphological descriptors and the corresponding units used in the evaluation were: I-fruit length (mm), I-fruit width (mm), A-fruit width/fruit length ratio, I-pedicel length (mm), I-pedicel length from abscission layer (mm), I-width of pedicel scar (mm), I-size of corky area around pedicel scar (mm), I-thickness of pericarp (mm), A-fruit section length (mm), I-size of core (mm), A-minimum number of locules, A-maximum number of locules, I-mean number of locules, A-mean locule size (mm), A-size of hollow area between pericarp and core (mm), A-fruit firmness (measured with a Bertoluzzi FT327 penetrometer with a 8 mm probe, kg/mm), A-size of the internal fibrous area associated to pedicel scar (mm). Agronomical quantitative descriptors included: I-mean fruit weight (g), A-mean plant yield (g/plant), A-minimum plant yield (g/plant), A-maximum plant yield (g/plant) and A-percentage of commercial fruits.

Cultivation was carried out in the open air in Turis (39° 20′ 54″N, 0°, 43′ 19″ W), in an area with low populations of tomato virus vectors, during one growing cycle. Four blocks were utilized with three plants per accession randomly distributed in each block. Plants of the hybrid 'Royesta' were used as borders in order to provide similar growing conditions in the experiment. All the landraces had the same indeterminate growing habit and similar vegetation. Thus, neighbour effects were considered to affect uniformly to all the plants. Plants were staked with a separation of 0.4 m between plants and 1.2 m between rows. A basal dressing of 30,000 kg/ha of manure and 1500 kg/ha of 15/15/15 NPK was applied. A total top dressing of 2500 kg/ha of ammonium nitrate, 1.500 kg/ha of mono-ammonium phosphate, 3.500 kg/ha of kalium sulphate and 500 kg/ha of magnesium sulphate was applied gradually using drip irrigation. Plants were pruned on a weekly basis.

The variation was analyzed statistically using multivariate tests. A principal component analysis (PCA) was carried out using the