Evaluation and use of plant biodiversity for food and pharmaceuticals

Luigi Frusciante\textsuperscript{a,*}, Amalia Barone\textsuperscript{b}, Domenico Carputo\textsuperscript{b}, Maria R. Ercolano\textsuperscript{a}, Francesco della Rocca\textsuperscript{a}, Silvana Esposito\textsuperscript{a}

\textsuperscript{a}Department of Agronomy and Plant Genetics, University of Naples ‘Federico II’, Via Università 100, Portici, Napoli, Italy
\textsuperscript{b}CNR-IMOF, Research Institute for Vegetable and Ornamental Plant Breeding, Via Università 133, Portici, Napoli, Italy

Abstract

Many epidemiological studies have shown the importance of fruit and vegetables in the human diet so as to prevent the onset of cardiovascular disease and several forms of cancer. The use for food and pharmaceuticals of two of the most widely grown and genetically well-known species in the world, the tomato and the potato, is reviewed. Tomatoes are important sources of vitamin C, potassium, folic acid and carotenoids such as lycopene and β-carotene. It has been demonstrated that lycopene has anti-oxidant properties and interferes with the growth of cancerous cells. At the Department of Agronomy and Plant Genetics in Portici, interesting results have been obtained with the constitution of stable tomato hybrids having a high content of lycopene and vitamin C. Many of the parental lines used in constituting the hybrids come from interspecific crosses. Potato is also very important in the human diet for its content of high quality proteins, mineral salts and vitamins and it has many medicinal properties. The use of diploid wild species to transfer traits such as high content of vitamin C, mineral salts and high quality proteins into the cultivated potato through ploidy manipulation is discussed. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Tomato; Potato; Wild species; Plant breeding; Human diet; Lycopene

\textsuperscript{*}Corresponding author.
1. Introduction

The total number of the world's existing plant species is estimated at between 300,000 and 500,000. Of these, approximately 250,000 have been identified and classified [1,2]. There are approximately 30,000 edible species, of which 7000 are or have been cultivated as food crops [3]. Despite the enormous number of known species, the plants which contribute to mankind's food requirements concern a limited number of species, approximately 30 [4] of which four (rice, wheat, maize and potato) account for more than 75% of human calorie requirements.

The biological diversity found in the plant kingdom is the result of the long and continuous work of natural evolution which has allowed plants to adapt to living in different climatic conditions and to resist the attacks of parasites. Mankind has also intervened in this process of diversification, selecting the plant types most suited to field cultivation and/or its own food requirements. Mankind's intervention in plant breeding has always aimed to increase production, improve quality and protect plants from pests. The most noteworthy of such improvements have been achieved in the past century, progressing alongside genetic discoveries. Cereal production, for example, has risen in the past 40 years from 650 to 1900 million tonnes, an increase of approximately 300%. Such results have been achieved exclusively by increasing production per hectare. Indeed, the number of hectares sown with cereal crops in 1950 (1700 million) is virtually the same as that in 1990 (1730 million).

The results obtained in the past 50 years may be considered amazing if we think that the percentage increase in agricultural production has exceeded the percentage increase in population. The successes achieved in the field of plant production in the 1950s and 1960s gave rise to what is widely known as the 'green revolution'. The green revolution is above all associated with the Nobel prizewinner Norman Borlaug, who produced low wheat varieties able to make good use of factors of production (fertilisers, water, pesticides, etc.) and be indifferent to photoperiod, and hence to be adapted to cultivation in almost all areas of the world.

The green revolution has enabled some less developed countries, especially those in the Indian subcontinent, to change from being food importing countries to food exporters. Of particular note is Pakistan, where the yields per hectare of cereal farms have increased sevenfold in recent years.

Along with huge benefits, the green revolution has, however, produced negative effects, chiefly due to food surpluses generated in more developed countries, to the excessive energy costs of agricultural techniques, negative ecological impacts resulting from the use of chemicals and the cultivation of a limited number of genotypes. This last aspect is particularly serious since it leads to genetic erosion, that is, the reduction in the species gene pool.

Overall analysis of the above issues suggests the desirability of a new development model for crops which would tend towards a non-traditional use. The positive effects would be huge as there are no longer any cultivation problems for agrarian species (agricultural techniques are widely known and proven) and as genetic
knowledge, which is now very advanced, allows the performance of such species to be rapidly improved.

In this paper, we will consider the use for food and pharmaceuticals of two of the most widely grown and genetically well-known species in the world, the tomato and the potato.

2. Tomato

The tomato is a native of the Americas, originating probably in Peru. It was introduced into Italy at the beginning of the 16th century and used only as an ornamental plant, owing to its coloured berries. Only in the mid-16th century did it begin to be grown as a vegetable for food. In subsequent decades its cultivation became more widespread, and now the tomato is one of the world’s major food crops.

All tomato cultivars belong to the self-compatible diploid species *Lycopersicon esculentum* (2n = 2x = 24). The *Lycopersicon* genus includes a few other wild species, namely *L. pimpinellifolium*, *L. cheesmani*, *L. hirsutum*, *L. chmielewskii*, *L. peruvianum* and *L. pennellii*, which are also diploid. While *L. peruvianum* is isolated from *L. esculentum* because of severe incompatibility barriers, all the other species may be crossed with *L. esculentum*.

Many epidemiological studies have shown the importance of fruit and vegetables in the human diet so as to prevent the onset of cardiovascular disease and several forms of cancer. Recently, particular attention has been devoted to tomato products. Some authors report that the consumption of tomato and its products (sauces, pizza, ketchup) is inversely correlated with the risk of the onset of tumours in the digestive apparatus and the prostate. Moreover, tomato is also one of the basic constituents of the Mediterranean diet, associated for some time with the reduced occurrence of cardiovascular diseases. Given that the greatest and perhaps only contribution of lycopene in the diet comes from tomato, the same authors believe that this molecule is responsible for the protective action cited. Experimental studies report that lycopene is also an excellent anti-oxidant and interferes with the growth of cancerous cells.

Tomatoes are also important sources of vitamin C, potassium and folic acid as well as carotenoids which may strengthen the preventive action reported. The composition in carotenoids differs greatly with varieties. Lycopene is prevalent in red-berry cultivars, while β-carotene is chiefly found in yellow-berry cultivars. Wide genetic variability is found in wild species, where germplasm may be found which have a lycopene content five to six times higher than in cultivated varieties. Interesting results have been obtained in Portici with the constitution of stable tomato hybrids (‘cherry’, round and smooth, ‘San Marzano’) which have a high content of lycopene and vitamin C. Many of the parental lines used in constituting the hybrids come from interspecific crosses. Table 1 reports carotenoid composition of superior F1 tomato hybrids selected within the breeding program carried out at the Department of Agronomy and Plant Genetics. Most of hybrids tested
Table 1
Carotenoid composition (µg/g fresh wt.) of F1 tomato hybrids with different genetic background

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>Lycopene</th>
<th>β-Carotene</th>
<th>Phytofluene</th>
<th>Phytoene</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>148</td>
<td>6.4</td>
<td>3.5</td>
<td>6.3</td>
<td>164</td>
</tr>
<tr>
<td>41</td>
<td>25</td>
<td>6.6</td>
<td>1.8</td>
<td>2.8</td>
<td>36</td>
</tr>
<tr>
<td>38</td>
<td>57</td>
<td>6.8</td>
<td>1.5</td>
<td>3.1</td>
<td>68</td>
</tr>
<tr>
<td>26</td>
<td>126</td>
<td>6.6</td>
<td>2.1</td>
<td>4.6</td>
<td>139</td>
</tr>
<tr>
<td>35</td>
<td>95</td>
<td>7</td>
<td>2.4</td>
<td>4.1</td>
<td>109</td>
</tr>
<tr>
<td>5</td>
<td>124</td>
<td>4.1</td>
<td>3.1</td>
<td>6.8</td>
<td>138</td>
</tr>
<tr>
<td>30</td>
<td>116</td>
<td>3.2</td>
<td>3.5</td>
<td>7.9</td>
<td>131</td>
</tr>
<tr>
<td>4</td>
<td>120</td>
<td>9.3</td>
<td>3.4</td>
<td>4.9</td>
<td>138</td>
</tr>
</tbody>
</table>

had a lycopene content much higher than that of control cultivars Arletta and Rita (75 and 55 µg/g fresh wt., respectively). The genotypes with the highest lycopene content were hybrid 19, hybrid 26 and hybrid 5 (148, 126 and 124 µg of lycopene/g fresh wt., respectively).

Identification of such genotypes and their use in breeding programmes would allow us to obtain tomato cultivars with a very high lycopene content. Knowledge of the genes involved in synthesising lycopene facilitates the breeder’s task, who thus has the possibility to transfer only genes capable of increasing the lycopene content (Fig. 1).

3. Potato

The cultivated potato is believed to have originated in the Andes, in particular in the south of Peru and north of Bolivia. The introduction of the potato into Europe dates back to the 16th–17th century. There were presumably two introductions, the first into Spain in 1570, and the second into England in 1590. It is worth noting that the first genotypes introduced were adapted to develop tubers under short-day conditions typical of the Andes. This is clearly attested in historical evidence from Spanish archives, which also state that these genotypes tuberised from December to January in southern Spain and southern Italy. The first genotypes introduced, belonging to the species *Solanum tuberosum* Group Andigena, required several centuries of selection in Europe to adapt to the long summer day in northern Europe. This slow adaptation was completed between the 18th and 19th centuries, such that the potato spread to central and eastern Europe. Thus the potato, which until the 16th century was a crop confined geographically to the Americas, became one of the world’s most important crops in less than 300 years.

Unlike the *Lycopersicon* genus, the *Solanum* genus includes many wild species, most of which are able to tuberise. Wild potatoes typical of the American continent have been found in many different types of habitat, which is why they have adapted to environmental stresses and have developed strong resistance to a huge range of pests and diseases. By contrast, cultivated potatoes have evolved in far more
limited environmental conditions, which is why they are unable to withstand pests and diseases. Cultivated potatoes belong to the Tuberosa series which, in turn, includes 68 wild species and 8 cultivated species. These species are classified according to ploidy level, i.e., according to the number of basic chromosomes (12) found in the somatic cells. Cultivated potatoes may be diploid ($2n = 2x = 24$), triploid ($2n = 3x = 36$), tetraploid ($2n = 4x = 48$) and pentaploid ($2n = 5x = 60$). Tetraploids are the most important and widespread, with noteworthy varieties being *Solanum tuberosum* Group Andigena, grown in the Andes regions and *Solanum tuberosum* Group Tuberosum, adapted to long day conditions and cultivated everywhere.

The potato is well-known to be important in the human diet: its content of high quality proteins, mineral salts and vitamins make it a foodstuff with high nutritive value. Indeed, the potato is the crop which produces the highest quantity of proteins/hectare and per day. This is due to its biological value, i.e., the fraction of absolute nitrogen allocated by the plant organism for growth and maintenance (73 vs. 54 for maize and 53 for wheat flour).

In the last few decades the acquisition of knowledge regarding the physiological and hereditary mechanisms of adaptation to climatic factors, resistance and tolerance to biotic and abiotic stresses (low temperatures, salinity, drought), the
Table 2
Some *Solanum* species used as medicinal plants

<table>
<thead>
<tr>
<th>Species</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>S. siparunoides</em></td>
<td>Contraceptive</td>
</tr>
<tr>
<td><em>S. sisymbriifolium</em></td>
<td>Antifebrile</td>
</tr>
<tr>
<td><em>S. stenotomum</em></td>
<td>Source of vitamin C</td>
</tr>
<tr>
<td><em>S. stramonifolium</em></td>
<td>Treatment for skin infections and herpes</td>
</tr>
<tr>
<td><em>S. tuberosum</em></td>
<td>Antispasmodic, haemostat, sedative</td>
</tr>
</tbody>
</table>

application of modern biotechnologies (in vitro tissue culture, molecular genetics, expansion in the use of true potato seed), together with the use of suitable breeding strategies, have lent decisive momentum to potato-growing and to its expansion into areas previously considered impracticable, thereby contributing to supporting human populations with high food deficits.

As already stated, potato is an irreplaceable food crop. However, it is also a plant with surprising medicinal properties. The medicinal properties of some wild and cultivated species are listed in Table 2. This characteristic of *Solanum* species was acknowledged right from its original introduction into Europe, and 18th century writings highlight its therapeutic powers, the best known being its anti-scurvy properties. It is worth reporting the conclusions of a study conducted by a group of researchers on behalf of the Medical Faculty of the University of Paris, who recommended that poor breastfeeding women should eat potatoes since they had a beneficial effect both on milk quantity and quality. They also advised their direct use in children’s diets. Even today, especially in villages in the Andes in central South America, the potato is the main foodstuff for children and in many cases is the remedy for several diseases.

Wild *Solanum* species have been and are currently widely used by breeders to transfer to cultivated potatoes resistance genes to biotic and/or abiotic stresses, good tuber characteristics and high yields for industrial processing. However, they have been little used for transferring traits such as high content of vitamin C, mineral salts and high quality proteins. The most efficient strategy for using wild *Solanum* species, most of which are diploid, is tied to the use of: (a) parthenogenetic haploids (2$n$ = 2$x$ = 24) of cultivated potato to ‘capture’ interesting genes through 2$x$ × 2$x$ crosses with diploid species; and (b) 2$n$ gametes, which are very common in potato, to recover the tetraploid condition of the cultivated potato *S. tuberosum* Group Tuberosum by means of 4$x$–2$x$ crosses [10].

References