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Apricot (*Prunus armeniaca* L.) quality and breeding perspectives

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Abstract

Apricot production, about 2.6 million tonnes in 2005, is mainly based on traditional cultivars providing standard quality levels for this very popular and appreciated temperate fruit. However, while in many other fruit crops the aim is the standardization of the product, changes in apricot market features requires the introduction of new cultivars. A huge evolution of fruit traits has been already observed over time, with major modification of fruit quality attributes such as firmness and external colour. Breeding perspectives includes environmental adaptability, resistance to diseases and fruit quality. Apricot germplasm provides a wide choice of parental material for crossing which could offer excellent opportunities for breeding. A first important breeding tool is the development of molecular maps to tag genes and to find molecular markers associated with those genomic regions responsible of complex or polygenic traits as are those that define fruit quality. This allows the development of breeding programs based on the information about where genes/quantitative trait loci (QTLs) are located and on marker-assisted selection (MAS). The determination of intrinsic quality can be supported by the use of rapid and non-destructive methods such as gas chromatography–mass spectrometry coupled with olfactometry, e-nose, FT-MIR and NIR technologies. Apricot fruit quality is associated with attributes such as appearance, texture, taste and colour. Sensory evaluation coupled with consumer science can provide predictions in consumer preference trends and help breeder's decision-making in selection. This paper discusses how breeding and marketing should work more closely, developing projects based on up-to-date technologies and strategies, able to direct cultivar pursue toward the improvement of horticultural and market requirements, guarantying consumer satisfaction.

Key words: Consumers, fruits, genotypes, molecular markers, new cultivars, apricot, quality, sensory evaluation, e-nose, NIR.

Introduction

Apricot (*Prunus armeniaca* L.) is one of the most popular of the temperate tree fruit species, having a total world production of about 2.6 million tonnes (source FAO 2005), with Turkey (370.000 MT), Iran (285.000 MT) and Italy (244.000 MT) being the main producers. Despite industry relies on traditional cultivars providing standard quality levels, changes in market requirements requires the introduction of new genotypes which should be suitable for logistic needs and for attracting consumers with high quality expectation, especially in terms of flavour and nutritional quality [60]. Tricon *et al*. [76] describe a huge evolution observed over time in the newly released apricot cultivars, characterized by an improvement of the main fruit quality attributes, mainly due to the variability of the germplasm base used in breeding programmes. Authors refers to this variability in apricot fruit traits as a trend opposite to what observed in most of other fruit species, where the aim is the standardization of the product. Breeding and marketing should work together to release new cultivars able to face both horticultural and market requirements to get and maintain long term premium prices. In fact, market tends to split into two classes of produces: high-quality and commodity (low price) [64]. The risk for new cultivars, if they are not fully satisfactory in terms of the consumers' expected quality, is to drop to the commodity category. Therefore, special attention should be paid to trends in consumer preference and sensory profiles [26]; while breeding programmes should be based on up-to-date scientific approaches able to direct cultivar pursue toward high levels of product quality, as proposed by Abbott *et al*. [1]. A strong tendency is reported to exist in the market to assign an extra-value to "locally" and "safely" grown crops. This can be an important issue for apricot thanks to its image of a "healthy fruit commodity" [9].

Breeding

Origin and germplasm: Apricot species have a large genetic variability organized in phylum, with a strong interaction among cultivars and areas of cultivation [8, 76]. Apricots belong to the family Rosaceae, genus *Prunus* L., and section *Armeniaca* (Lam.), which includes eight different species: *P. ansu* Maxima; *P. armeniaca* L.; *P. brigantiaca* Vill. (Alpine apricot); *P. x dasycarpa* Ehrh.; *P. holosericea* (Batal) Kost.; *P. mandshurica* (Maxima.) Koehne; *P. mume* (Sieb.) Sieb. et Zucc. and *P. siberica* L. [47]. Germplasm provides a wide choice of parental material for crossing which could offer excellent opportunities for breeding [66]. Apricots have a recognised plasticity as a species, since they are capable of existing and producing in areas as unfavourable as the Sahara desert as well as surviving in Canada [23]. On the other hand, apricot cultivars are known to have low environmental plasticity and to its short fruiting cycle [9].

Overview of apricot breeding: As reported by Egea [23] traditional varieties are different in each Country. Búlida, Canino and Moniquí in Spain, Bergerón, Polonais and Rouge de Rousillon in France, Portici and San Castrese in Italy, Thyrintos in Greece, and Castlebrite and Patterson in California. These cultivars are widely cultivated and also are the basic material for breeding. Breeding perspectives have been highlighted by Bassi and Audergon [9] and include environmental adaptability, resistance to diseases and fruit quality, with perspectives also in improving fruit for specific processing products such as juice, dry fruit and canning.

Differently from apple, in which varieties are well known by consumers, a survey conducted in France [51], showed that fresh apricots could be considered as a generic produce, with 81% of the interviewers unable to cite a single variety. Authors address the lack of product awareness as one weak point of perceived apricot quality; therefore, a market oriented breeding should improve communication with consumers. It should be remembered that apricots are available for fresh consumption in the market for a short period between the end of the spring and the beginning of the summer. In this sense, it is difficult to build up a strong image of the product and call for consumer's loyalty to a specific phenotype as occurs on apples. And different from other fruit, this situation cannot be overcome in the consumer markets by importing fruit, mainly due to the short postharvest life of this species.

Breeding is reported to have led to a vast modification of two major quality traits, i.e firmness and external colour [76]. Authors address this change to the contribution of Goldrich and Orangered® Bhart cov in breeding programs, recording a sugar content not significantly modified, while acidity content has increased, probably thanks to the contribution of Goldrich as frequently used parent. A recent publication highlights how information on apricot traits heritability is scarce [9]. Only for some basic fruit traits simple Mendelian heritability has already been described: flesh colour (white dominant), pit adhesion (free stone dominant) and skin fuzz (fuzzy dominant) [74].

Hybrids between plums and apricots have been produced recently which are said to be finer fruits than either parent. A "Plumcot" is constituted by 50% blood of plum and 50% of apricot; an "Aprium" is 75% apricot, 25% plum; and the most popular hybrid, the "Pluot" is 75% plum, 25% apricot. All these new genotypes have been licensed on last years by Californian private apricot and plum breeders, as Zaiger Genetics. However, there are ancient Italian reports that described hybrids between apricots and Mirabolan plum (*P. ceracifera*) even on the XVIII century, which were named as "Biricoccolo" [12].

Study of populations: One of the major diseases limiting apricot production is Sharka, caused by Plum pox virus (PPV). European apricot cultivars have shown high susceptibility to PPV, and the first cultivars showing resistance came from North America [48]. The development of new PPV resistant cultivars is an important objective in breeding programmes. However, the cultivation in traditional European areas of the Mediterranean basin of North American cultivars is not feasible due to their high chilling requirement and self incompatibility, both traits that preclude a consistent production of high quality fruits.

Central Asian apricot germplasm was used in hybridizations with Californian adapted apricots in order to increase sugar content levels and improve fresh eating quality [43]. *Prunus mandshurica* [(Maxim.) Koehne] from Central Asia has been used in apricot breeding as a source of frost resistance. In addition, on the bases of an isoenzymatic study, it has been suggested to be the ancestor of some North American apricot cultivars resistant to Sharka [7]. The transmission of Sharka resistance from *P. mandshurica* to the susceptible Spanish apricot cultivar Currot by crossing both progenitors was studied and the role of this related species as a source of resistance in apricot-breeding programmes was elucidated [63]. Unfortunately the study have shown *P. mandshurica* to be not a good progenitor in breeding apricot for PPV resistance, being not a reliable source of resistance. The majority of the apricot genotypes could be classified by their genetic origin and geographic distribution; nevertheless, there are some groups that are not easily grouped due to the every day most frequent trend of freely exchange of germplasm among breeding programs around the world [20].

The search for biochemical and molecular markers associated with resistance to the disease would be of a great interest. A detailed investigation of biochemical parameters, such as catalase (CAT), peroxidase (POX), ascorbate peroxidase (APX), monodehydroascorbate reductase (MDHAR), dehydroascorbate reductase (DHAR), glutathione reductase (GR) and superoxide dismutase (SOD) and of their correlation with Sharka resistance was conducted [34]. Results suggest that activity level of some antioxidant enzymes as CAT, APX and DHAR could be used as biochemical markers of PPV resistance in apricots.

Fruit Quality Evaluation

Physicochemical parameters: The knowledge of physical and chemical parameters determining thresholds of quality standard is a basic requisite for fruit industry. Intrinsic apricot quality can be investigated through several physical and chemical parameters. Sucrose is generally indicated as the predominant sugar present in apricots. Other sugars such as glucose, fructose, maltose, sorbitol and raffinose are also present at lower concentrations than sucrose and varying among cultivars and production areas [2, 22, 80].

Fruit volatiles production is determined genetically and is affected by pre-and post-harvest conditions. Volatiles can be analysed by several techniques [59]. The formation of aroma compounds is a dynamic process connected to fruit ripening, with changes in volatiles profile both qualitatively and quantitatively. Volatile constituents of apricots have been firstly identified by Takeoka *et al*. [75] with lactones involved in the typical and basic apricot flavour, and several other substances (including terpene alcohols, 2-phenylethanol, β-ionone and hexyl acetate, benzaldehyde) contributing to the flower and fruity notes. In a research conducted in France, hexyl acetate, γ-octalactone and γ-decalactone resulted to be key compounds for the apricot flavour. Benzaldehyde showed a potential negative impact on the aroma of the less aromatic cultivars, while favourably completing the typical aroma of cultivar Rouge du Roussillon [30].

Studies conducted with aroma extract dilution analysis applied on an aroma distillate prepared from fresh apricots identified 26 odor-active compounds. Among them, (R)-γ-decalactone, (E)-β-damascenone, δ-decalactone, and (R/S)-linalool with the highest flavor dilution. Quantitative measurements were also performed by application of stable isotope dilution assays and calculation of odor activity values (OAVs): β-ionone, (Z)-1,5-octadien-3-one, γ-decalactone, (E, Z)-2,6-nonadienal, linalool, and acetaldehyde appeared with OAVs > 100. Other lactones, generally associated with an apricot aroma note, such as γ-undecalactone, γ-nonalactone, and δ-decalactone, showed very low OAVs (< 5). On the other hand, experiments found two new constituents of apricots aroma: (E, Z)-2,6-nonadienal or (Z)-1,5-octadien-3-one.

An investigation on aroma of apricot, cultivar Castlebrite, was conducted by Defilippi *et al.* [16]. Fruits at different stages of initial maturity were analyzed by three approaches: gas chromatography–mass spectrometry (GC–MS), electronic nose (e-nose) and a sensory panel. Among the volatiles identified by GC–MS, aldehydes and esters were the primary constituents of Castlebrite apricot aroma, and differences in volatile aroma profiles were observed between intact and ground fruit. Maturity stages affected the concentrations of aldehyde compounds, in particular hexanal. The e-nose sorted the two different stages of fruit maturity under investigation when they were subjected to simulated shelf-life storage. However, the detected differences were not perceived by a sensory panel.

Free aroma compounds from eight apricot varieties were discriminated by an e-nose [73]. Aroma compounds were obtained by liquid–liquid extraction (LLE) and solid phase microextraction (SPME), and identified by GC–MS. Aroma compounds concentrations were statistically analyzed by principal component analysis (PCA) and factorial discriminate analysis (FDA). An array was obtained with eight aroma compounds in SPME (hexanol, limonene, 2-hexenal, 6-methyl-5-hepten-2-one, linalool, 3,7-dimethyl-1,6-octadiene, β-ionone, γ-decalactone, and with five aroma compounds in LLE (limonene, linalool, 1,3-dimethylcyclohexanol, cyclohexylisotiocyanate, β-ionone). All the analyzed cultivars were classified on the basis of these aroma compounds. The influence of extraction method on aroma profile is highlighted by Solis-Solis and coworkers [72].

In terms of volatile biosynthesis, fruit aroma is considered a complex trait, especially in terms of the number of different pathways involved, the complexity of the final metabolites, and their regulation. In order to understand the biochemical processes involved in apricot aroma, few studies have been performed at the gene level, especially considering the genes, and the encoded enzymes participating in the last stages of volatile synthesis, such as alcohol acyl transferase (AAT), alcohol dehydrogenase (ADH), pyruvate decarboxylase (PDC), and lipoxygenase (LOX) [28].These authors isolated and characterized these genes at four stages of maturity in cv. Modesto, observing a reduction in aldehyde and alcohol production between early and late-harvested fruits, concomitant with an increase in ester production. The qPCR analyses showed that the expression levels of the adh gene and the lox gene stayed constant at all stages. Interestingly, AAT levels showed a sharp increase in the late harvest stages concurrent with the changes observed in ester levels. Key aroma compounds have been investigated also with the application of molecular sensory science concept [29].

Ripening stage at harvest is known to influence overall quality and particularly aroma [10], with different effects on high- or low-aromatic apricots. Effects on harvest time on quality parameters have also been studied by Dinnella *et al.* [18] following soluble solids content (SSC), polygalacturonase and carotenoid variation during storage. Similar to other fruit, it seems ethylene would also play a role in modulating volatile production. By affecting ethylene biosynthesis or action on Modesto and Patterson apricots, Valdés *et al.* [77] showed that among the volatile compounds identified, esters and aldehydes showed ethylene-dependent behavior in both varieties. On the other hand, alcohols and terpenes were not affected by ethylene inhibition, suggesting ethylene-independent behavior.

Nutritional Properties

Ledbetter *et al.* [43] suggest that the use of biochemical analyses should support apricot breeding by identifying accessions with specific sugar profiles of particular interest. The identification of low glucose: fructose ratio genotypes might be of interest since fructose provides a high level of perceived sweetness relative to other sugars at the same concentration [56].

Akin *et al.* [2] performed biochemical analyses, including phenolics, carotenoids, β-carotene, sugars, organic acids and mineral content on several Malatya (Turkey) apricots. All varieties were found to have high content of phenolic compounds (4233.70-8180.49 mg of gallic acid equiv $(100\ g)^{-1}$ of dry weight), carotenoids (14.83-91.89 mg of β-carotene equiv $(100\ g)^{-1}$ of dry weight), and β-carotene (5.74-48.69 mg $(100\ g)^{-1}$ of dry weight). Malic acid was the predominant organic acid in all apricot varieties analyzed. As related to mineral composition, potassium was significantly high and consistent concentrations of Mg, Zn, and Se were found.

The main carotenoids in apricots are β-carotene, β-cryptoxanthin, c-carotene, lycopene, and lutein [65, 69]. Other authors such as Munzuroglu *et al.* [53] studied nutritional value of apricots. Their study showed that, apricot fruits were rich in vitamins A, C and β-carotene and selenium, at levels sufficient to meet RDAs of almost all healthy individuals with adequate servings (50-260 g sulphur-dried weight per day), but poor in vitamin E.

Polyphenols and carotenoids vary with cultivar, stage of maturity and origin. Studies conducted on apricots grown in Croatia showed how the content of individual polyphenols during ripening was quite similar, whereas their amount significantly changes. Immature fruits showed the highest level of polyphenols, which decreased at semi-mature fruits while did not change remarkably on ripe fruits [21].

Non-destructive evaluation methods: In the last decades, the research of rapid and non-destructive methods to approach determination of food quality has provided consistent advances. Concerning apricot, non destructive evaluation of intrinsic quality is of particular importance for product standardization. In fact, physical and chemical quality parameters are established for every new variety [46] with measurements based on methods which are usually expensive, time consuming and scarcely representative due to a not large enough batch of sampling [13].

VIS-NIR has been used to measure SSC [14]. Fourier transform mid-infrared (FT-MIR) spectroscopy application of ATR-FTIR has been applied for the determination of sugars and organic acids in apricot fruit [11]. The method was calibrated and cross-validated on fruits of eight cultivars, to establish multiple-cultivar models. ATR-FTIR technique resulted able to determine SSC, titratable acidity, individual sugars (sucrose, glucose, and fructose) and organic acids (malic and citric acids).

Kantor *et al.* [41] evaluated the performance of an electronic tongue (ET) for classifying different apricot varieties, to reveal differences between control and 1-methylcyclopropene (1-MCP) treated samples and to detect the effect of post-harvest techniques on fruit taste and ripeness. The experimental approach was aimed to the determination of correlations between ET data and parameters such as pH, SSC and intensity of chosen sensory traits. Authors report positive results in terms of sorting apricot varieties and determination of correlations between ET, chemical properties and sensory analysis.

Flesh firmness is a key parameter for apricot quality and shelf-life determination. It can be measured with a common penetrometer or with a durofel device equipped with a 0.1 cm^2 diameter probe, expressed in DI10 (Durofel Index) [13]. A non-destructive study of apricot firmness was performed with a laser air-puff method [49]. Results suggest the method suitable only for coarse screening of fruit into two penetrometer-determined flesh firmness categories.

Guillot *et al.* [31] studied apricot volatiles through headspace-SPME combined with GC-MS and gas chromatography-olfactometry (GC-O). Ten compounds, i.e. ethyl acetate, hexyl acetate, limonene, β-cyclocitral, γ-decalactone, 6-methyl-5-hepten-2-one, linalool, β-ionone, menthone and (E)-hexen-2-al were recognized by HS–SPME–GCO as responsible of apricot aroma. Authors indicate them as molecular tracers of apricot aromatic quality, which could be utilized for apricot cultivar discrimination. E-nose technology can be of help in finding out correlation between intrinsic and perceived quality [16, 17, 55].

Some reports refer to the use of Near Infrared Spectroscopy (NIR) for predicting apricot quality [14]. More recently portable NIR was used to determine apricot fruit quality as related to measuring SSC, acidity and flesh firmness [13]. Reasonably correct predictions were obtained for SSC; however, the model appears robust enough only if based on individual cultivars and not for the apricot as a group. Flesh firmness provided predictions unsuitable for the development of global models. Results related to acidity were unsatisfactory. Interesting results were obtained also by Ruiz *et al.* [67], with NIR models allowing a good prediction for both SSC and titratable acidity.

Sensory evaluation: Apricot fruit quality is associated with attributes such as appearance, texture, taste and colour, and all of these attributes vary during ripening. Sensory evaluation should also consider that ripening process in apricots is climacteric; thus, eating quality evaluation should be performed when the sugar increases, the acidity decreases and, an optimal texture is reached. In fact, apricot suffers a rapid quality loss, both sensorial and nutritional, once harvested due to the fact that it displays a pronounced and very short ethylene crisis [25]. Therefore, the best period for sensory evaluation must be established within the span from commercial ripening to senescence. For avoiding over-ripe fruits, which are unsuitable for consumption and depending on pre- and post-harvest factors such as cultivar, maturity at harvest or postharvest treatments, the time to reach commercial ripening ranges from 3 to 5 days [3, 77]. Azodanlou *et al.* [6] performed sensory evaluation of apricots having a panel rating the following sensory attributes: odour, aroma, sweetness, acidity, skin hardness, flesh firmness, juiciness, mealiness and overall appreciation. Sensory evaluation was performed also by Infante *et al.* [40] and Defilippi *et al.* [16]. Robini *et al.* [61] investigated the possibility to correlate physical and chemical measurements with sensory attributes. Fruits of 14 cultivars were analyzed considering 13 sensory tastes and texture attributes 9 chemical and 2 physical parameters. The relationship between analyzed attributes and the projected ones showed that sensory attributes such as sweetness, firmness were foreseeable by instrument measures. For other parameters such as taste, fibrousness, and mealiness were assessable only through sensory analysis.

Studies were conducted also in Spain for the evaluation of the sensory quality of two apricot genotypes at three different ripening stages. The panel evaluated the intensity of eight sensory attributes related to aroma, flavour, colour, and texture. On equivalent fruits, instrumental analyses of physical and chemical parameters were carried out in order to compare both methodologies. Assessors could distinguish between apricots at different maturity states contributing to identify the best ripening stage for consumption [24].

Eight apricot cultivars (Orangered, Laycot, Sungiant, San Castrese, Tonda di Costigliole, Valeria Gottero, Bergeron and Tardif de Bordaneille), grown North-western Italy, were evaluated for fruit quality through physical-chemical and sensory analyses. A total of 11 descriptors were used to evaluate: appearance, odour, texture, taste and flavour. A continuous scale ranging from 0 to 15 (0 = absent and 15 = very strong). An overall quality judgement was also requested. The sensory evaluation indicated the overall quality to be positively correlated with flavour, sweetness and juiciness [78]. A detailed sensory evaluation was performed by Lespinasse *et al.* [44]. Sensory parameters to be evaluated by assessor included external and internal odour, firmness, mealiness, juiciness, stringy, melting, skin's persistence in mouth, sweetness, harsh taste, aroma, flesh's and skin's acidity. Good correlations with intrinsic parameters such as firmness and SSC (but only up to 14 °Brix). To evaluate other variables, including melting, juiciness and floury texture, sensory evaluation resulted as the only suitable method. Sensorial postharvest quality was studied on cultivars Palsteyn and Grandir [37] and descriptors included visual and taste attributes such as shape, colour, aroma, sweetness, acidity, juiciness, texture and flavour. Evaluation was completed with some more hedonic judgments such as appreciation, attractiveness and harmony. Simplified sensory approach could provide preliminary data to be validated by a trained panel. An easy sensory evaluation method was used in studies on the effect of ripening inhibitors. A non-trained sensory panel of 10 assessors was request to determine the taste differences between control and 1-MCP treated samples through a generic evaluation of "sweet flavour", "sour flavour' and 'overall impression' [42].

Consumer Preferences

Consumer science allows observing the quality from the point of view of the consumer, providing opportunities for successful marketing decisions [54, 70]. Appearance of fresh fruit (visible quality) is a primary criterion in purchase making decision [42], and is often a major factor for marketing/placement choices. However, it is not correlated to consumer satisfaction, since it is heavily driven by eating quality.

Surveys conducted on consumer appreciation indicate that apricots have the image of a tasty fruit, but with gustatory and market quality not always up to the consumers' expectations [51]. The low sweetness is among the most common consumer complaints [52]. Fruit quality is a fundamental aspect for the acceptance of apricot cultivars by consumers due to a definite situation of high competition in the markets with the presence of numerous new cultivars, other fruit and other foods. The concept "quality" includes sensory properties (appearance, texture, taste and aroma), nutritional value, chemical compounds, mechanical properties and functional properties [1]. As already mentioned, apricots are particularly appreciated for their fruit appearance, for their aroma and sweetness. However, in a recent survey conducted in France [51], apricot quality resulted only 'moderately' satisfactory according to most of the interviewed persons, with ripeness deficiencies addressed as a critical point. Consumers indicate that fruit were often "too hard". This situation is produced by early harvesting, which in many cases, do not allow the fruit to acquire the optimum sensorial characteristics demanded by consumers [25]. Early harvest is commonly executed when fruit should be kept on cold storage or be transported to far markets, because this kind of fruit would be more tolerant to handling [5]. However, as in most countries, fresh apricots are packaged by hand; the risk of mechanical damage is minimized. A careful fruit handling could allow the use of more mature fruit to attain its full flavour potential, either for fruit oriented to a near market or after cold storage [40]. Improvements of storage capacity can provide opportunity to reach distant markets as shown for peaches and nectarines [39].

Another major trait indicated by French consumers as a negative characteristic of apricots was flesh mealiness [51]. On the other hand, the prevailing positive characters of apricots were pointed out as 'easy to eat' and 'attractive'. The most desired characteristics were 'sweet' and 'aromatic', considered far more important (63%) than 'juicy' and 'melting' (27%). While traits as 'crispy flesh' and 'acidulous' resulted not quite relevant for French consumers. As related to visual traits consumers indicated to be attracted by brightly coloured apricots. Furthermore, the most appreciated fruit shape is the fairly rounded, but not excessively, being roundness particularly appreciated by young consumers. The majority of consumers prefer medium-sized fruit, although elder people prefer large apricots.

Azodanlou *et al.* [6] had consumers participating in a hedonic test performed in supermarkets in different Swiss cities. Consumers were asked to give an overall appreciation of apricots on a 1–9 liking scale: (1=extremely bad to 9=extremely good), with the overall appreciation being the only attribute supporting the quality of the product. A modified procedure was also adopted, where each fruit was divided into halves; one half was used to assess for the sensory quality, while the other half was assigned to different baskets according to the score obtained (1–9). The pooled samples were homogenized as described above and used for instrumental analyses. This way of classifying samples is hereafter called "hedonic classification". Combined panel-consumer tests indicated interesting correlations between analytical values such as are sugar content, flesh firmness and some flavours with consumer appreciation [62].

Molecular Approaches

Molecular markers application: Apricot present a high number of cultivars often with different synonyms [47]; therefore, fast and reliable techniques for molecular fingerprinting may provide opportunities for correct identification, supporting classic approach based on pomological, morphological and horticultural traits shown to have some limitations.

Among available genetic markers for population studies and genetic diversity assessment markers, nuclear simple sequence repeats (SSRs or microsatellites) are widely used. SSR markers identified in *Prunus* [15, 32] have been used for the molecular characterization and cultivar identification [35, 81]. SSRs have been isolated from apricots and made available to be tested on European accessions [32, 45, 50, 57]. Cultivar identity and phylogenetic origin in apricot was studied also using amplified fragment length polymorphisms (AFLPs) [27, 33, 36]. Apricot cultivars and related species, for a total of 136 accessions, originating from different geographical regions have been studied with 10 polymorphic SSR markers developed in apricot [47]. Molecular characterization of apricot cultivars and breeding lines of different origins (Spain, North America, France, and Greece) was approached with the use of 17 peach SSR markers to establish the genetic relatedness among genotypes. Amplification of SSR loci was obtained for all 17 primer pairs and 14 of them produced polymorphic amplification [68].

Genetic linkage maps and QTL analysis: The first apricot map was based on an F1 progeny (Goldrich × Valenciano) segregating for resistance to Sharka [36]. The second apricot map based on an F2 population (Lito selfed) was constructed using amplification fragment length polymorphism and SSR markers [79]. Recently, a linkage map based on the cross between the apricot Lito and the genotype 'BO 81604311' were constructed using a total of 185 SSR markers sampled from those isolated in peach, almond, apricot and cherry; 74 were derived from a new apricot genomic library enriched for AG/CT microsatellite repeats (UDAp series), and 98 had never been mapped in *Prunus* [19].

Candidate gene analysis: Candidate genes that mapped in the region of the apricot PPV resistance locus were transformed into polymerase chain reaction markers and tested for their co-localization with the major PPV resistance locus [71]. The study was based on populations of F1 and F2 individuals derived from crosses between PPV-resistant cultivars (Stark Early Orange or Goldrich) and susceptible parents. Linkage relationship between the PPV resistance locus in apricots and markers that target candidate disease-resistance genes were investigated. SSR markers linked to resistance-gene candidates were also mapped to positions flanking the PPV resistance locus in different apricot populations. Authors highlight how this strategy could be useful for saturating the major genomic region controlling in apricot resistance to PPV with important co-dominant markers. SSR markers derived from candidate genes can find application in co-segregation studies and tested for marker-assisted selection.

Conclusive remarks and future prospects: It is highly accepted that *P. armeniaca*, thank to the wide variability of its germplasm offers clear opportunities for the generation of cultivars gathering all the commercial, horticultural and quality traits in a single genotype [9]. However, only well planned breeding programs can reach this objective. Bureau *et al.* [11] define apricot fruit quality as a multi component concept defined by physical, physiological and biochemical attributes such as flesh firmness, skin and flesh colour, ethylene production, respiration rate, sugars, organic acids, pigments, phenolic compounds and volatiles. This definition gives an idea of the complexity of the topic, which should be faced with a multidisciplinary approach and a number of competence able to fulfill quality requirements, sometimes conflicting, of market needs and consumer expectations. Only an approach to quality including a combined use of chemical-physical measures, panel and consumer test, such as that developed for pear, in Italy [58] can provide a comprehensive appreciation of fruit quality. A more detailed knowledge of the genetics of apricot would support breeding programs based on the information about where genes/ quantitative trait loci (QTLs) are located and on marker-assisted selection (MAS). A first important step in this direction is the development of molecular maps to tag genes and to find molecular markers associated with those genomic regions responsible of complex or polygenic traits as are those that define fruit quality. Apricot is addressed as a species still strongly susceptible to genetic improvement [9]. A quality based approach, as proposed by Infante *et al.* [38], could provide opportunities for the obtaining of new cultivar suitable for market objectives and satisfactory for consumers.

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