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ADVANCES IN APPLE BREEDING FOR ENHANCED FRUIT QUALITY AND RESISTANCE TO BIOTIC STRESSES: NEW VARIETIES FOR THE EUROPEAN MARKET

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A B S T R A C T

The current trends and future prospects for apple breeding in the newly enlarged 25-member European Union (EU) are reported. The last twenty years have seen a marked rise in both the number of breeding programmes and of the cultivars they have released. The main objectives of these efforts have focused on resistance to diseases like scab, mildew and fire blight and on enhanced fruit quality in its broadest sense-appearance, sensory traits, storability and shelf-life. While there are many new scab-resistant apples, their appeal to mainstream consumers is notably restricted. Yet the future appears to hold much promise for these programmes. The use of new biotech tools should accelerate the development of novel varieties while saving time and reducing work loads. Indeed, several stations have already introduced marker-assisted selection (MAS) for monogenic traits and QTLs are increasingly important in segregating polygenic traits. Expectations are high that with efforts like the EU's new HiDRAS Project traits involved in fruit quality (ripening, softening, acids, sugars, flavour, polyphenols and other antioxidant compounds) can be controlled. Other molecular tools are employed for genotyping parental lines, and genetic mapping of functional gene markers. Genomics is an area that is increasingly important for studies of gene expression targeted to such traits as fruiting, abiotic and biotic stress resistance, tree and bearing habit. The main tree behaviour and fruit-quality traits of more than 30 novel European-bred varieties are reported.

Key words: novel apple varieties, scab and mildew resistance, molecular marker and MAS (Markers Assisted Selection), fruit high quality traits

INTRODUCTION

Apple's genetic heritage and the new cultivars of the species being grown today are going through radical changes in an industry with a total output of almost 10 million metric tones (MMT) (Tab. 1). Almost every member country of today's recently enlarged European Union can boast of one or more apple breeding programs, and the number of research stations involved far outstrips that of 20 and more years ago. Countries like Italy and Poland, which once were entirely dependent on foreign breeding sources, now have multi-year, publicly financed programmes; there are even private breeders who have established companies in the Netherlands, France, Belgium and the United Kingdom to produce commercial cultivars by exploiting exclusive patent rights.

Table 1. EU apple production by country (25 states) in 2003 (1,000 Metric Tonnes)

Country	Production	% production
Austria	152	1.5
Belgium	319	3.2
Czech Republic	149	1.5
France	1728	17.3
Germany	818	8.2
Great Britain	156	1.6
Greece	165	1.7
Hungary	488	4.9
Italy	1851	18.5
Netherlands	405	4.1
Poland	2428	24.3
Portugal	280	2.8
Spain	680	6.8
Other	373	3.8
Total	**9992**	**100**

Source: Prognosfruit Lublin (2004); Eurofel Data

Europe thus appears to be awakening from a long period of creative torpor that had seen it succumb first to the innovations from No rth America and then from Asia and Oceania. Indeed, less than 15% of the apple cultivars being grown today are of European origin and even in newly established orchards fewer than 10 polyclonal varieties dominate unchallenged. Not only are all of the latter non-European but, because of the effect of globalisation, they also dominate in the world's other apple-producing countries since everyone is competing for the same markets, especially those in the wealthy western European countries (Tab. 2).

T a b l e 2 . EU (25 States) Output by Cultivar, 2003 (1,000 MT)

Cultivar	Production (EU 15 states)		Production (EU 10 new states)		Total Production (EU 25 states)	
	1000 MT	[%]	1000 MT	[%]	1000 MT	[%]
Annurca	40	(0.6)	-	-	40	(0.4)
Boskoop	92	(1.3)	-	-	92	(0.9)
Braeburn (group)	239	(3.6)	1	(0.0)	240	(2.4)
Bramley	64	(1.0)	-	-	64	(0.6)
Cortland	-	-	200	(6.0)	200	(2.0)
Cox's Orange Pippin	104	(1.6)	2	(0.1)	106	(1.1)
Elstar (group)	338	(5.1)	55	(1.6)	393	(4.0)
Fuji (group)	85	(1.3)	-	-	85	(0.9)
Gala (group)	681	(10.3)	137	(4.1)	818	(8.2)
Gloster	55	(0.8)	112	(3.4)	167	(1.7)
Golden D. (group)	2339	(35.5)	299	(8.9)	2638	(26.6)
Granny Smith	315	(4.8)	1	(0.0)	316	(3.2)
Idared	106	(1.6)	728	(21.8)	834	(8.4)
Jonagold (group)	736	(11.2)	171	(5.1)	907	(9.1)
Lobo	-	-	220	(6.6)	220	(2.2)
Pink Lady	50	(0.8)	-	-	50	(0.5)
Red Delicious (group)	540	(8.2)	84	(2.5)	624	(6.3)
Renette (group)	41	(0.6)	-	-	41	(0.4)
Šampion	-	-	10	(0.3)	10	(0.1)
Stayman Winesap	25	(0.4)	-	-	25	(0.3)
Other	729	(11.1)	1322	(39.6)	2051	(20.7)
Total	**6580**	**(100)**	**3342**	**(100)**	**9922**	**(100)**

Source: Prognos fruit Lublin (2004); Eurofel Data

These cultivars belong essentially to the polyclonal groups 'Fuji', 'Gala', 'Golden Delicious', 'Red Delicious' and 'Jonagold', which offer a broad range of highly coloured mutants and even some spurs such as those derived from 'Red Delicious' (e.g. 'Red Chief'®) that have displaced the original varieties. They are followed by other, smaller groups of cultivars with heterogeneous traits whose importance is increasing, including ‘Braeburn’, ‘Pink Lady’® and ‘Pinova’; on the other hand the traditional ‘Elstar’, ‘Granny Smith’, ‘Cox’s Orange Pippin’, and ‘Idared’, and their mutants, are gradually losing industry favour. Even once widely grown varieties such as ‘Rome Beauty’, ‘McIntosh’, ‘Belle’ of ‘Boskoop’, ‘Gloster’, ‘Jonathan’ and the various ‘Renettes’ are either disappearing or have been relegated to the industry’s margins.

1. International Scenario

Although the apple industry’s new varieties must be in line with the expectations of today’s global marketplace, international supply and demand are notably skewed. This for two main reasons:

- While over the last three decades Europe’s total apple produce has risen by about 30% to 17.5 MMT, Asia, with a surging, has boosted output by almost ten times (300%) the latter rate to 31.6 MMT; and, although the increments in North America (5.5 MMT), South America (3.4 MMT), Africa (1.5 MMT) and Oceania (0.8 MMT) are far more modest, their crops are increasingly geared to export rather than domestic markets.
- Production costs differ enormously from country to country, even in the European Union, and hence even the novel cultivars being bred cannot by themselves gain a foothold in a market whose trade relations are so imbalanced.

There are several other factors also affecting this international scenario:

1a) The current upswing in European production is mitigated by the loss of orchard acreage in less favorable growing districts, including vast tracts in Eastern European countries over the last 15 years and, to a lesser extent, certain areas in the west hit by particularly critical years (Italy alone lost 15,000 ha). The alpine, foothill and mountain districts, which enhance fruit quality, are today making a come-back to the detriment of less environmentally favorable lowland orchards. Overall, while output in countries like Poland is expected to show a strong resurgence, Italy and France, which represent 60% of western European apple production, are projected to post a rise by a couple of percentage points at best. The main concern of Europe’s markets is the increasing flow of exports from China, South America, South Africa and New Zealand.

1b) The enormous number of novel cultivars offered every year by the nursery industry compels the leading apple producing countries to set up national testing networks for comparative field trials so that growers receive up-to-date information. All of this requires investments, high overhead costs and expert staff. Italy, for example, publishes annually an advisory list of new and old cultivars, including negative ratings registered by those varieties that do not perform to expectations, compiled by a working group coordinated and financed by its Ministry of Agriculture. Given the essential failure of the EU's Eurofrut programme of a few years ago under the management of grower associations, the "EUFRIN" network has established a non-funded comparative cultivar rating system by country based on common data sheets and descriptors to work up the resulting profiles.

1c) The acceptance and spread of novel cultivars is hindered by the discovery of spontaneous mutants of the main commercial varieties, which are the backbone of the nursery industry. A glance at almost any nursery catalogue shows that sports (mutant clones) make up at least 70-80% of the entire listing. These clones are propagated under exclusive rights, despite the fact that some are chimeras and, hence, unstable and prone to regression. Not to mention, in such cases, the subsequent disappointment of growers, the rejection of the marketplace, plummeting prices and even the legal consequences (see for example what happened in Europe to the mutants 'Royal'® and 'Mondial'®, 'Gala', 'Brookfield'® and 'Schnitzer'®, 'Pink Lad'® and 'Pink Kiss'®, or the various Braeburns and Jonagolds).

1d) Thus, the introduction of 'novel' cultivars, even when derived by fruit type from planned crosses, is no easy matter. Indeed, given that the marketplace is dominated by the most popular varieties, whence a certain commercial inertia of its own making, the task becomes even more difficult when consumers are not educated via blanket advertising campaigns that only grower associations and large-scale retailers (backed perhaps by official government policy) can afford. It is estimated that per year of any new planting no more than 10-15% of the chosen varieties include novel cultivars that differ from those already grown.

Efforts to redress this situation must thus be aimed in two directions. One should focus on the production-distribution pipeline, i.e. coordinating growers, marketing organizations and supermarkets, as is being attempted in the Netherlands, France and Italy, to ensure a minimum orchard acreage and subsequent steps to promote apple supplies. The other involves convincing consumers that the novel apples are a 'better buy' with respect to the competing varieties, a strategy similar to that developed for integrated and organic fruit produce. It is estimated that such a coordinated introduction of a cultivar in Italy requires, at the beginning, at least 150-200 ha of orchard and several million euros (over several years), outlays to be covered by the higher than average market prices commanded.

1e) Patents. We think it only correct to safeguard the efforts of breeders and, hence, avoid the risk of their cultivars being unlawfully copied. It will be recalled that the European Union's (EU) decade-old 'Regulation 2100', a measure largely copied from the US system, was designed to introduce additional measures for the protection of novel plant material. The office is located at Angers and the approval procedure is under the supervision of M. Le Lezec. This legislation, called 'Community Plant Variety Rights', is replacing the individual patent regimes of member-states by extending intellectual property rights to breeders who, whether directly or through licensing agreements, now retain the rights not only to nursery plants but even to the produce and the varieties derived from these plants by mutation or crossing (both being similar). Indeed, 'clubs' (about ten so far but only a few are actually operational) and other kinds of marketing arms have been established to control the trade in the high-profile varieties, although such operations could just as well run counter to, rather than to the benefit of, growers' interests. This because if the market price fails to cover the greater outlays incurred by these clubs-advertising, marketing, inspection, potential legal expenses-these costs will be added as surcharges at the source. It is thus to be hoped that the current EU regulatory regime can be simplified if not actually revised (as one might rightly expect).

1f) Breeding: state of the art. The broadest analysis of the genetics and heritability of all know apple traits is reported by Janick et al. (1996) and Janick and Sansavini (1997). There are today more than 40 apple breeding programs throughout Europe: with Italy and Czech Republic being both the most productive and most numerous (Sansavini et al., 2004).

After that of Laurens (1999) who undertook a survey of the work being carried out in about fifty apple breeding programs throughout the world, we tried to interview a number of apple research stations in Europe through a questionnaire.

Respondents were asked to list their breeding objectives and where their efforts are focused. Here are the most frequently cited (Tab. 3).

- Enhance fruit quality, by which is meant improving the combined typological traits of fruit appearance like colour, shape, size, those intrinsic to the fruit itself like taste, firmness, crispiness, juiciness, flavour, and post-harvest potential like shelf-life and storability. The extension of calendar seasonality is also becoming more and more important.
- Introduce one or more forms of resistance (e.g. to scab and other pathogens and pests) or tolerance to the bio-stresses in general.
- Enhance environmental adaptability and resistance to abiotic stress, i.e. hardiness of cultivars and rootstocks, high yield, fertility and bearing stability (promote compact and spur habits), avoid yield biodiversity.
- Modify, where possible, bearing habit so as to boost tree yield efficiency and make trees suitable for dwarfing rootstocks in high-density plantings.

T a b l e 3 . Main objectives of apple breeding programmes in Europe

(a)	Country	Institution		Objectives (b)						
				1	2	3	4	5	6	7
*	B	B3F:	Bett.3Fruit – Heverlee	X	X			X		
#	B	CRA-W:	Walloon Agric. Res. Cent. – Gembloux	X	X		X			
*	CH	FAW:	Agrosc.FAW – Wädenswil	X	X			X		
*	CZ	RBIP:	Res. Breed. Inst. Pomol. – Holovousy	X	X	X	X			X
#	CZ	IEB:	Inst. Exper. Bot. – Prague	X	X	X				
#	D	IOZ:	Fruit Breed. Inst. – Dresden – Pillnitz	X	X					
*	F	INRA:	I. Nat. Res. Agr. – Angers	X	X	X				
#	F		French Nurseries groups	X	X					
#	H	CU:	Corvinus University – Budapest	X	X					
*	I	CReSO:	Centro Rirc. e Sper. Ortof. – Cuneo	X	X		X			
*	I	CSAF:	Centro Sper. Agr. For. – Laimburg (BZ)	X	X		X	X		
*	I	ISF-TN:	Ist. Sper. Fruttic. – sez. Trento	X	X	X				
*	I	ISMAA:	Ist Agr. S. Michele all'Adige (TN)	X	X	X		X		
*	I	DCA:	Dip. Colt. Arb. – Univ. Bologna	X	X	X				
*	I	CIV:	Consor. Ital. Viv. – Ferrara	X	X					
*	I	ISF-FO:	Ist. Sper. Frutt. Sez. Forlì	X	X	X				
#	LT	LIH:	Lithuanian Inst. Hort – Babtai	X	X				X	
#	LV	HPBES:	Hort. Plant Breed. Exper. Stat. – Dobele	X	X	X	X		X	
#	N	NCRI:	Norwegian Crop Res. Inst. – Leikanger	X	X		X		X	X
*	NL	PRI:	Plant Res. Int – Wageningen	X	X		X			
*	PL	WAU:	Warsaw Agr.Univ.	X	X			X	X	
*	PL	RIPF.	Res. Inst. Pom. Flor. – Skierniewice	X	X				X	
#	RO	AAFSRH:	Acad Agr. For. Sci. Rom. Hort. Soc. – Pitesti. Voinesti	X	X					
#	SCG	IVF:	Inst. Vitic. Fruitbreed. – Novi Sad	X	X	X				X
*	UK	EMR:	East Malling Res.	X	X		X			

(a) * = Direct information from the questionnaire answers (DCA University of Bologna, July 2004); # = Published Data (Braniste, 2000; Fisher et al., 2003; Gelvonauskis et al., 2000; Ikase, 1999; Lateur et al., 1999; Ognjanov et al., 1999; Røen, 1999; Toth, 2003; Tupy, 1999).
b) Objectives: 1 = Fruit quality; 2 = Disease and pest resistance; 3 = Tree Habit; 4 = Storability; 5 = Productivity; 6 = Climatic adaptation; 7 = Harvest.

Fig. 1

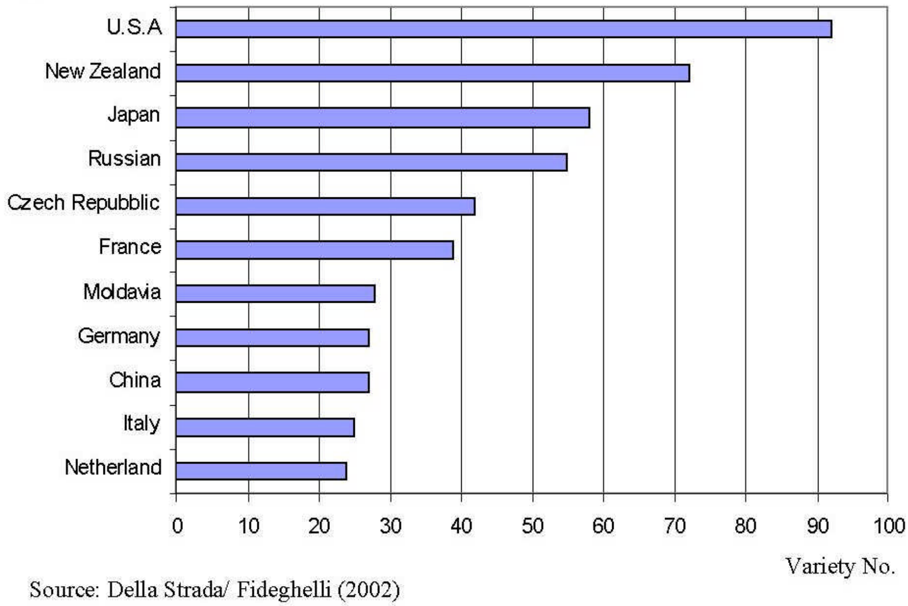


Figure 1. New varieties released by main countries from 1991 to 2001 (total 586)

Together with our survey responses, we report over 1000 novel cultivars released over the last 20 years; of these, 77 in the first and 146 in the second decade are scab resistant. It should be noted that in the later decade, Europe taken as a whole is now the world leader, followed by the USA, New Zealand and Japan (Fig. 1).

2. New molecular breeding approaches in apple

In the past few years the traditional breeding programmes of fruit tree species have been updated by the use of new molecular tools so as to cut as much as possible the time needed for the selection of plants carrying desirable traits. This can be simply accomplished by looking directly into the plant's DNA sequences without waiting for the expression of the trait itself. This type of indirect selection can be pursued only by the development of molecular markers capable of discriminating between plants carrying favourable and unfavourable alleles for a specific trait. Therefore, in the last decade much effort has been expended in basic research to explore the genetic basis of a given trait and to identify markers genetically linked to it. After this preliminary development phase, the new molecular methods were tested for their applicability and some protocols for marker-assisted selection (MAS) have been proposed for a limited number of traits. The subsequent step is final testing and cost-benefit analysis before these new tools are ready for routine application in public and private apple breeding programmes (Sansavini and Barbieri, 1998).

As recently reviewed by Tartarini and Sansavini (2002), a lot of markers linked to monogenic traits, mainly resistance to pathogens and pests, have been identified in apple. Most of these have been determined by "bulked segregant analysis, BSA" (i.e. markers for *Vf* and *Vm* genes for scab resistance and various genes for mildew resistance) and by the genome-wide approach of developing molecular maps and subsequent linkage analysis (e.g. markers for the *Sd1* gene, self-incompatibility gene, fruit acidity).

To date, most of these efforts have used the standard molecular markers like RFLPs, RAPDs, SSRs and AFLPs. An effective marker for a specific trait must be very close to the gene under investigation so that no recombination will occur even when analysing very large progenies. In such a case, indirect selection via molecular markers is highly efficient as phenotype assessment, at least for traits easy to score. It is even more powerful for traits that are difficult to score (e.g. mildew resistance) or for 'masked' genes (i.e. genotypes carrying two different resistance mechanisms against the same pathogen: the phenotype will be 'resistant' because of the presence of one or two genes). The advantage for early selection, i.e. at the seedling stage, for a trait that is be expressed after the juvenile phase is thus enormous.

Recently, a high-quality SSR-enriched molecular map has been developed in apple (Liebhard et al., 2002). This map may well represent a very good starting point for readily developing new maps because of the high transferability of SSR markers within a certain species and even in related species (e.g. apple and pear; Pierantoni et al., 2004, in press; Yamamoto et al., 2001). Molecular maps of apple have already been used to identify genome regions controlling some quantitative traits, e.g. QTLs for fruit firmness (King et al., 1998) and polygenic scab resistance (Liebhard et al., 2003).

Since the adoption of molecular tools in apple breeding and genetics, much has been achieved with 'standard' markers and the available information is increasing very rapidly and continuously. In the meantime, a lot of apple gene sequences, mainly ESTs, have now found their way into public DNA databases: about 150,000 apple sequences are available (August 2004). Of course, 'a priori' knowledge of the gene sequence controlling a specific trait can be used to develop a very efficient marker because it can be directly related to a gene's function. Given this general knowledge, a new category of 'functional' markers has been developed. These 'functional' markers can be identified with various techniques (e.g. from the simple SCARs and CAPS to the more complex SSCP and SNP analysis), which make it possible to look even at differences of single nucleotide in specific DNA coding sequences and these differences may be linked to a specific gene function (Costa et al., 2004a, in press).

The genetic mapping of all these functional markers will make it possible to move to more useful and highly informative ‘functional’ maps. Functional markers target the coding part of the genome and, hence, an allelic variation will more likely associated with a phenotype variation of which it is the main cause. In this case, the functional marker is directly involved in the phenotype. The ‘standard’ markers like SSRs and AFLPs thus cover the genome and enable genetic map designing. One follow-up to this work is the ‘candidate-gene’ mapping approach being employed in the ongoing multi-partner EU HiDRAS Project, where it is being used to characterise genes involved in fruit firmness and sugar and acid metabolism in fruits.

3. Main objectives in improving apple traits

3.1. Fruit quality

While there are many traits defining fruit quality, for commercial reasons those regarding fruit appearance have often held sway over intrinsic sensorial traits. Today, however, markets are taking a second look, and quality as perceived by consumers has recently climbed to the top of the agenda -a sort of ‘consumer-strikes-back’ if you like- against a market thoughtlessness derived at least in part from dissatisfied demand and/or poor judgment in past supply. Given, too, that there has been a surplus supply in Europe for many years, the supply-side of the market equation has had to reorganize to deal with the downturn and has put the emphasis on quality, i.e. educating consumers to recognize and value apples of excellent quality, with quality stickers and process trademarks playing a signal role. In Italy, for example, consumers have learned to distinguish upland- from lowland-grown apples (the former are firmer, crispier, more coloured and store longer although they are smaller and not as sweet as the latter). These mountain apples, with the help of compulsory labels and ‘stickers’ on individual fruits, can be stored longer and are of higher value (up 30-60% more per kg in price). It is thus necessary to take into account the environmental factors interacting with the cultivars so as to improve the varieties themselves, which should be grown only in those districts yielding the best phenotypes (fruit and rootstock response). Indeed, even before releasing a novel cultivar, breeders should have it tested in performance trials at the Stage 3 selection process with outside institutions in various (potential) districts. Let us now look at apple types (Fig. 2):

Fig. 2

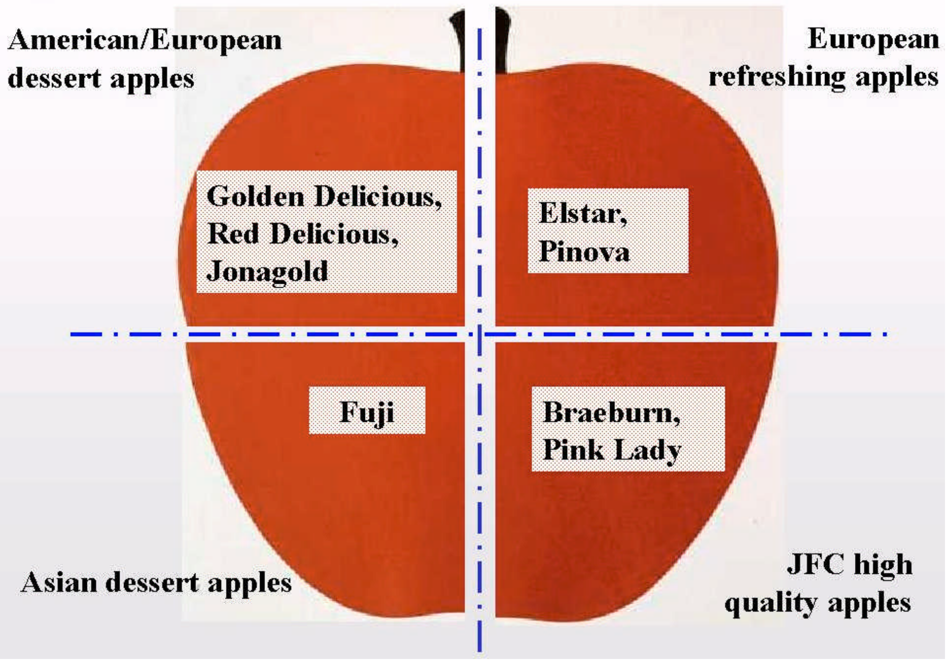


Figure 2. Apple ideotypes: four approximate consumer preference profiles

● **American/European *dessert apples***: *nice shape, appearance and colour (monocrhome preferred), large size, fine-textured and juicy flesh, sweet-and-tart-aromatic content, well balanced taste, good shelf life*. The Italian, French and Spanish markets have for decades been supplied with 'Golden Delicious' (accounting for almost 40% of industry production in the 12-member EU and over 50% in Italy alone), 'Red Delicious' (currently about 15%) and other dessert apples. This typology can also include 'Jonagold' and the latest derivates of 'Gala' (e.g. 'Galaxy'*****, the latter also being marked by good firmness and long storability although they are summer-autumn fruits. This type of apple is still successful in Europe, and there should in future be room for Golden-like and 'Red Delicious'-like types that are attractive in appearance with better flavour and shelf-life than the two original cultivars (see varieties like 'Cameo'®, 'Gold Chief'®, and others).

● ***European refreshing apples*** *marked by juiciness, tartness, good appearance, size and shape, solid or two-tone skin colour, compact or soft flesh with good storability*. These apples, such as 'Elstar' and its derivates, 'Cox's Orange Pippin', 'Boskoop', 'Gloster' the green 'Granny Smith', have been, and still are, a standard feature of the central and northern European markets. This type has undergone further development. Today a tart apple has to have a better taste and, hence, a higher sugar content, improved flesh firmness and evident crispiness. 'Pinova' and 'Rubens'® can improve this group.

● ***Asian dessert apples*** *marked by sweetness, low tartness, high firmness, juiciness and long storability*. This apple type is preferred by the influential Japanese, Chinese and Korean markets and is represented by 'Fuji' and its derivates (e.g. Naga Fu 12). Like sub-acid, sweet peaches, they have achieved wide appeal with consumers in western Europe and North America; while they may not have a good appearance (little colouration or tri-coloured skin), they are large-sized, very firm, crispy, juicy and flavorful, and have high storability even without refrigeration.

● ***JFC, high-quality apples****, with good attractiveness as to shape and colour (bi- or tri-color) and excellent combination of juicy firm and crispy flesh (JFC), sweetness and high acid content*. Several new apples have been selected for this high-quality profile in an original combination, so that they will immediately appeal to and be instantly recognized by consumers. The best known in this category are 'Braeburn', despite its drawbacks in some districts, and 'Pink Lady'® (while this variety has very nice traits like intense blush, good shape, high sugar and acid content, its drawbacks include long vegetative growth period, 2-4 runs to pick, overly firm flesh and a complicated postharvest storage if the ripening indices for starch/firmness/ethylene emission are not accurately observed). Other outstanding original varieties include the 'American Honeycrisp'® and 'Ambrosia'® (there are plans to release these varieties under the 'club' formula).

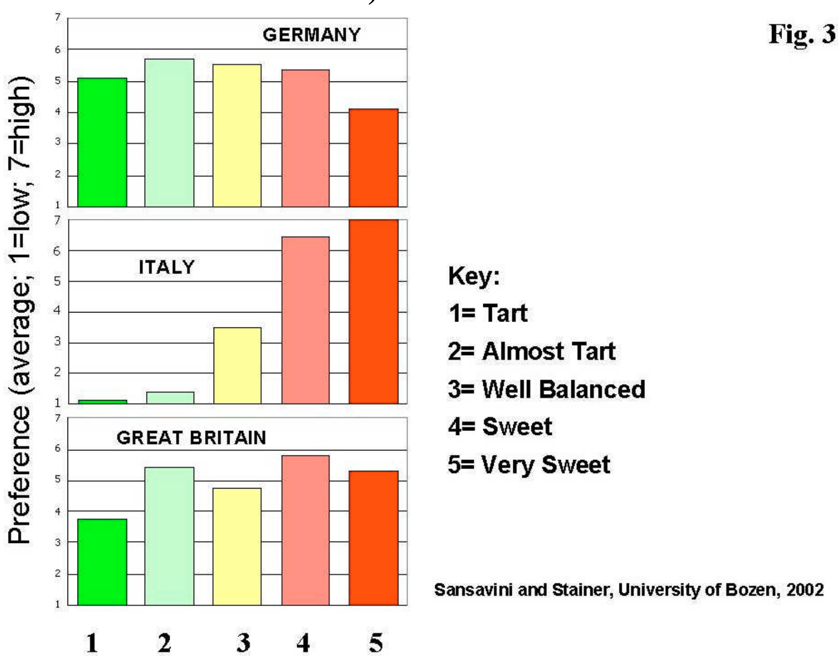


Figure 3. Market preferences for apple taste (sugar/acid ratio) in three countries

Although a rough approximation of typology, this over simplified list provides a starting point to gain a better understanding of consumer trends in Europe. Figure 3 shows certain trend differences in the U.K., Italy and Germany. We can see, for example, that German consumers have a marked preference for the refreshingly tart apples with respect to their Italian counterparts' taste for sweet dessert types.

Thus, the current debate about apple quality traits should take account of all these differences and, while some argue that crispiness is to be valued above all else, this trait should not be confused with firmness, which if too pronounced leads to a harder chew that can alienate a large segment of elderly consumers. Another key quality feature is dietary health, which includes such fruit components as organic acids, types of sugar, flavours, vitamins, antocyanins, polyphenols, flavonoids, other antioxidants and so forth. Indeed, there is a conviction that the apple of the future may take on neutraceutical functions proper to foods that can improve health as well as prevent illness and even enhance cell metabolism by trapping free radicals so as to delay cell ageing.

3.2. Disease resistance

a) Scab (Fig. 4)

Figure 4. Scab symptoms on apple fruits

Solving this problem is a chief concern of the worldwide apple industry. Yet none of the more than 200 scab-resistant (SR) cultivars released over the last 20 years has had enough success to carve out a recognised market niche. A recent survey in Europe (Kelderer et al., 2004) has revealed that even in countries like Switzerland and Germany, where ecological awareness is most notable and integrated and organic production systems are well developed, SR apples account for no more than 5-6% of the market; overall in Italy they stand at less than 1%, although they have climbed to 3-4% at least of the new plantings in the country's South Tyrol district. What is the problem with these apples? First of all, they are not well known, their diversity has not been appropriately advertised and their sensory qualities are neither equal to nor better than the most popular cultivars. The upshot is that the organic apple industry continues to rely on 'Golden Delicious' and other scab susceptible varieties (which require more than 15 treatments/yrs) and not on those more suitable to such a market because of their reduced need for disease and pest-control sprays.

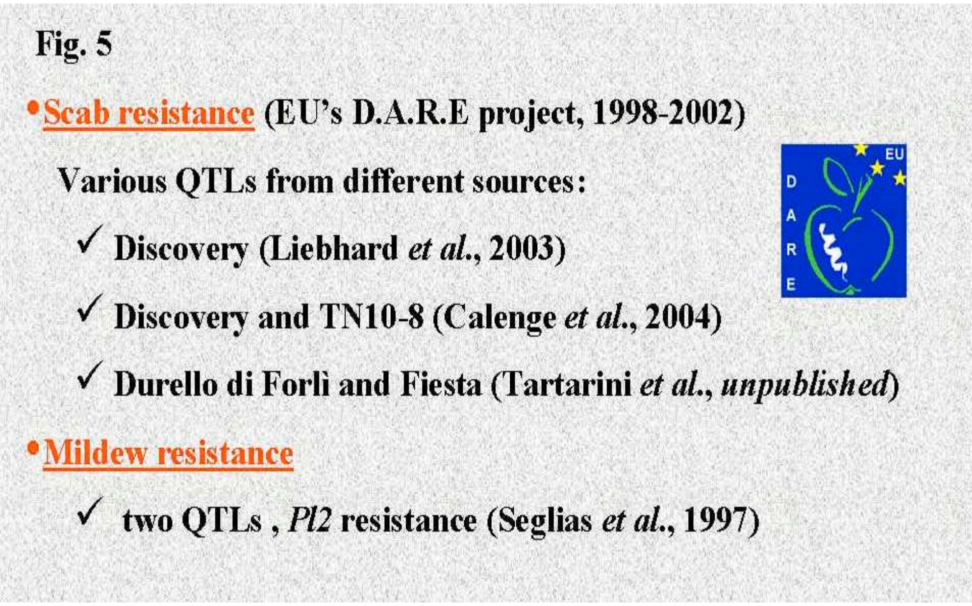


Figure 5. QTLs for polygenic scab and mildew resistance

The EU's DARE project was instrumental in gaining notable insight into polygenic scab resistance. The recent discovery that the *Vf*'s resistance can be overcome by races 6 and 7 of *Venturia inaequalis*–mutants for greater pathogenicity–has pointed research in the direction of a 'pyramidised' kind of resistance, i.e. induced by combining the vertical resistance of the *Vf* gene with other monogenic resistance genes (*Va, Vm* and *Vr*) or with polygenic resistances, as yet undiscovered, conferred by other genes for scab tolerance found in local European and foreign apple germplasm (e.g. 'Durello di Forlì' in Italy, 'Discovery' in Switzerland and the Netherlands, TN10-8 in France, studied by the DARE project and others like 'Renette Champagne' in France, 'Pinova' in Germany, 'Sansa' in Japan, etc.) (Fig. 5).

While two different types of scab resistances were mapped in the linkage group 1 of apple, the *Vf* gene (King et al., l.c.) and a resistance putative *Va* gene derived from 'Antonovka' (clone of University of Bologna; Pancaldi et al., 1995), the QTLs for polygenic resistances are located on several chromosomes (Durel et al., 2004; Liebhard et al., l.c.).

Increasing of markers associated with resistance genes and other important apple traits is enabling a more targeted choice of parental lines and MAS of progenies (Tartarini and Sansavini, l.c.).

About the host-pathogen mechanism, one protein (*LRPKm1*) has been identified from apple leaves ('Florina', SR) inoculated with *Venturia inaequalis* or elicitated with salicylic acid (Komjanc et al., 1999). The sequence putatively present a kinase domain and show homology with receptor- like proteins and polygalacturonase- inhibiting proteins (PGIP) involved in several fungi resistance systems, as evidenced by previous paper (Cervone and Sansavini, 1999).

It has also been found that SR apples, when not protected by fungicide sprays, can succumb to other pathogen fungi like *Cladosporium* sp. and *Alternaria* sp., which appear on fruits as small, black, scab-like patches (similar to late scab). Thus, SR apple growers in France, the Netherlands and Germany have been advised to treat their orchards at least twice/yr with fungicides, even in districts where there has been no breakdown in resistance.

'Pyramidisation' must also be seen as an approach to intogress genes, as for example for resistance to mildew (*Pl1* and *Pl2*) and fireblight. Indeed, this has been accomplished at Wädenswil with 'Ariwa' and at Pillnitz with other poly-resistant varieties, especially to *Erwinia amylovora,* like 'Rewena', 'Rebella', 'Regine', etc. (Fisher and Fisher, 2002) (Figs 6,7).

On a purely informative level, it should also be noted that two approaches through genetic engineering have been devised and successfully employed in Europe to develop SR apples. One, which has been pursued at the Angers INRA Station in France, introduces heterologous genes of bacterial, viral or plant origin (e.g. endochitinase) that can lower the plant's susceptibility to a pathogen, and the other, which has been employed at Bologna's DCA introgresses the *HcrVf* gene (whose sequence is homologous to the *Cf* resistance gene of tomato, Belfanti et al., 2004; Sansavini et al., 2002). While the field resistance is still being tested, these trials have triggered political hostility, and even boycots in some countries, by environmentalists.

Fig. 6

Cultivar	Scab resist. gene	Resistance						
		Scab	Powdery	Fire blight	Backterial canker	Spide mite	Spring frost	Winter cold
Realka	*Vr*	x	#	x	o	o	#	o
Reanda	*Vf*	x	(x)	x	o	#	x	o
Rebella	*Vf*	x	x	x	x	x	x	x
Regine	*Vf*	x	(x)	x	(x)	x	x	x
Reglindis	*Va*	x	(x)	(x)	o	x	x	x
Rejka	*Vf*	x	(x)	o	x	#	#	(x)
Releika	*Vf*	x	o	(x)	x	x	x	#
Releta	*Vr*	x	#	o	x	o	o	o
Relinda	*Vf*	x	(x)	o	x	#	(x)	x
Remo	*Vf*	x	x	x	o	o	x	x
Remura	*Vr*	x	(x)	o	o	#	o	x
Rene	*Vf*	x	#	x	(x)	#	x	o
Renora	*Vf*	x	(x)	o	o	o	(x)	(x)
Resi	*Vf*	x	o	o	x	#	x	#
Retina	*Vf*	x	(x)	o	o	(x)	x	#
Rewena	*Vf*	x	x	x	xo	o	x	o

x= Resistant; (x)= poorly resistant; o= poorly susceptible; #= susceptible

Fisher and Fisher, 2002

Figure 6. Multiple-resistance cultivars from the Dresden-Pillnitz breeding centre

Fig. 7

Low	Medium		High	
75th P.* < 10% Max.** >30%	75th P.* < 20% Max.** >30%	75th P.* < 10% Max.**<50%	75th P.* < 20% Max.** >50%	75th P.* > 20% Max.** > 50%
Reanda Faw 7207 Retina Ariwa Baujade Prima Rewena Rubinola Topaz Otava Boskoop	Realka Costance	Resi Renora Florina Ecolette Delgollune	Angold Rosana Saturn	Delorina Codel Resista

The numbers in brackets indicate (75th percentile/ maximum value)
** 75th P.=75th percentile, **Max.=maximal value*

Goerre et al., 2000

Figure 7. Mildew susceptibility in scab-resistant varieties

Of course, broadening resistance in apple via conventional breeding and selection methods is still important and practically the only way to introduce new SR varieties. There are many known genes for resistance and identifying parental lines carrying the desired traits is now possible thanks to the apple germplasm database network, along with MAS approaches. The proceeding of the ISHS symposium on apple breeding for scab resistance has been published by Acta Hort. (n°595, 2002). In addition, given that new cultivars can be bred

sooner with greater chance of success. extending this latter approach to polygenic traits of fruit quality via projects like HiDRAS holds out hope that polymorphic markers and QTLs for such traits with complex segregation can be identified (Figs 8,9,10).

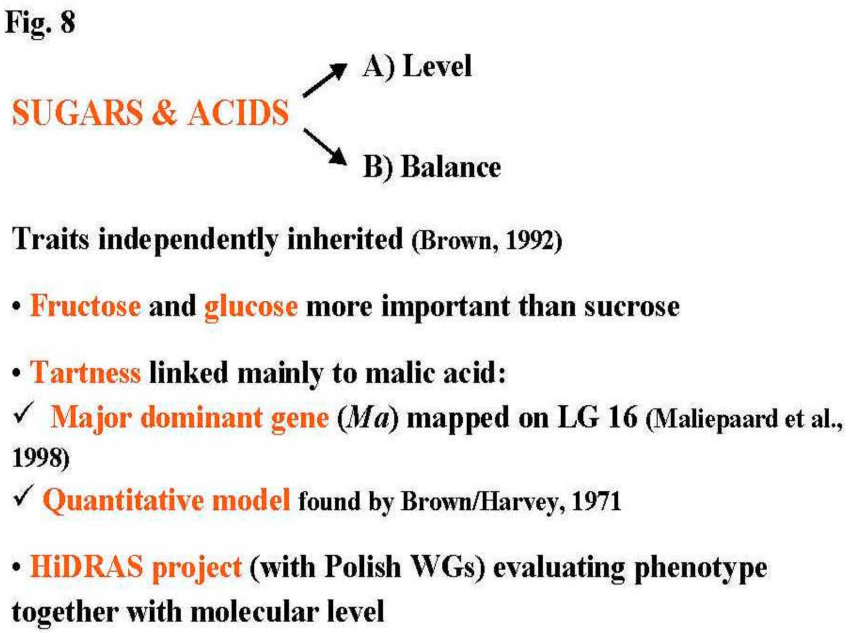


Figure 8. Genetics of taste: sugars and acids

b) Mildew

As with scab, even with mildew there is a broad range of susceptibility among cultivars, a fact that is especially true in regard to those that are also scab-resistant (Fig. 7). The main sources of resistance here in apple breeding are *Pl1* and *Pl2*, which were first identified by Knight and Alston (1969) after lengthy crossing that started with *M. robusta* (*Pl1*), *M. zumi* (*Pl2*), Crab Apple White Angels (*Plw*) and D12 genotype (*Pld*). Programmes to transfer resistance to *Malus x domestica* have also been set up at East Malling (Evans, 1997), Wädenswil and Dresden (Pillnitz) using *Pl1* and *Pl2*.

Fig. 9

1) QUALITY

- **Fruit ripening** (Costa et al., 2004a)
- **Fruit firmness** (King et al., 2000)
- **Fruit color** (Cheng *et al.*, 1996)
- **Fruit acidity, *Ma* gene** (Maliepaard *et al.*, 1998)
- **Fruit sweetnes**
- **Fruit flavour**
- **Other health contents (poliphenols, vitamins, etc.)**

2) OTHER TRAITS

- **Columnar habit, *Co* gene** (Hemmat *et al.*, 1997; Conner *et al.*, 1997)
- **Branching habit, root suckers, bloom date, vegetative and reproductive budbreak** (Lawson *et al.*, 1995)
- **Incompatibility, *S*-locus** (Maliepaard *et al.*, 1998)

Figure 9. Apple molecular markers linked to fruit quality and other traits

Fig. 10

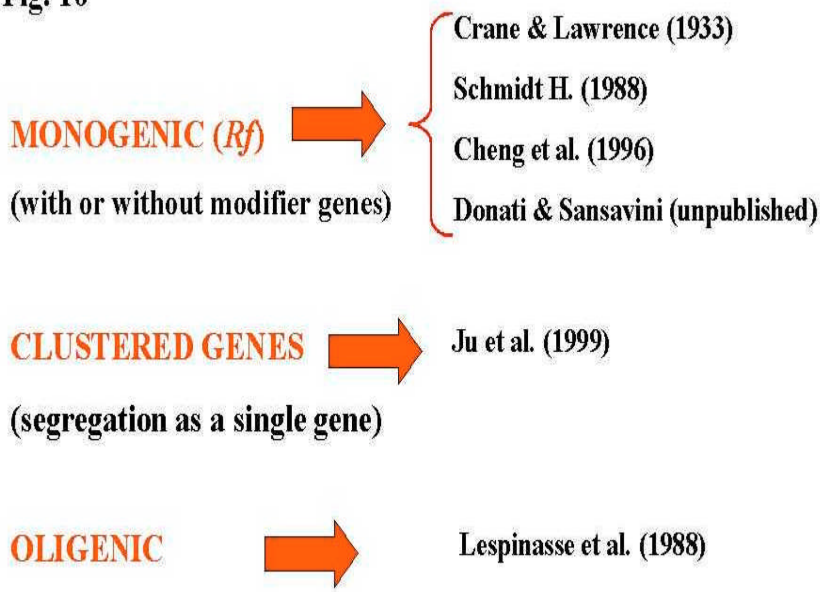


Figure 10. Different hypotheses about genetic control of red skin colour

This work has led to some signal achievements. The most noteworthy perhaps are the novel cultivars and selections like 'Ariwa' (Kellerhals et al., 2002), which carries the *Pl1* and *Vf* forms of resistance as well as tolerance to *Erwinia amylowora* and Nectria, FAW 8159 (*Pl1*) and FAW 8244 (*Pl2*), the latter used in subsequent backcrosses and with 'GoldRush' and 'Ariwa'.

Another important achievement has been reported at Pillnitz, where at least three mildew-resistant varieties, 'Rebella', 'Remo', 'Rewena', have been released. Noteworthy too is the support of several institutions which evaluated in the field a large suite of scab-resistant and scab-susceptible varieties scored as low, medium and high susceptibility to mildew (Borecki, 1987; Pitera, 1994).

The genetic and molecular studies of *Pl1* and *Pl2* are largely the product of the EU's DARE Project (Dunemann et al., 1999; Markussen et al., 1995; Seglias and Gessler, 1997). Indeed, the insights gained there have proved so valuable that today MAS can even be used for mildew. James and Evans (2004), employing BSA on crossing populations to achieve multiple forms of mildew resistance in apple, have recently identified several SSRs for *Plw* and other markers (including AFLPs and RAPDs) associated with *Pld*, resulting in a 'multiplexing *Pld* and *Plw* SCAR' system for simultaneous selection of plants with resistance from both genes.

3.3. Apples with low ethylene emission and delayed softening

Fig. 11

Ripening process	Genes	Identify by
Ethylene pathway	Md-ACS1; Md-ACO1; Md-ERS1	Castiglione at al., 1999; Costa et al., 2004b; Harada et al., 2000; Stella et al. (unpublished)
Fruit softening	Md-PG1; Md-Exp1	Atkinson et al., 1998; Costa et al., 2004a.

Figure 11. Main markers for ripening genes in apple

It is widely known that apples of high storability like Fuji emit low levels of ethylene. Indeed, it has also been shown that high release levels of endogenous ethylene is associated with a more pronounced flesh softening over ripening (Fig. 11). Knowledge of the markers for the genes determining the biosynthetic pathways of ethylene is thus especially important for MAS (our work in Bologna thus posits a 30 ppm emission limit in the climacteric period; *cf*, low storability cvs. like ‘Red Delicious’, ‘Braeburn’ and ‘Mondial Gala’ whose ethylene emisson range is > 30-100 $\mu l*kg^{-1}*h^{-1}$ and over).

The enzymes ACS (1-amino-cyclopropane-1-carbioxylate synthase) and ACO (1-amino-cyclopropane-1-carbioxylate oxidase) or EFE (ethylene-forming enzyme), preside over the last two stages of ethylene synthesis and are encoded by two gene families that have been widely studied. Several homologous and heterologous sequences of *ACO* found in the data banks have led to the identification of a functional marker, Md-ACO1 (Costa, 2004b, in press), specifically involved in ethylene biosynthesis. A specific allele of *ACC-synthase* (*Md-ACS1*) involved in apple ripening has also been reported (Harada et al., 2000).

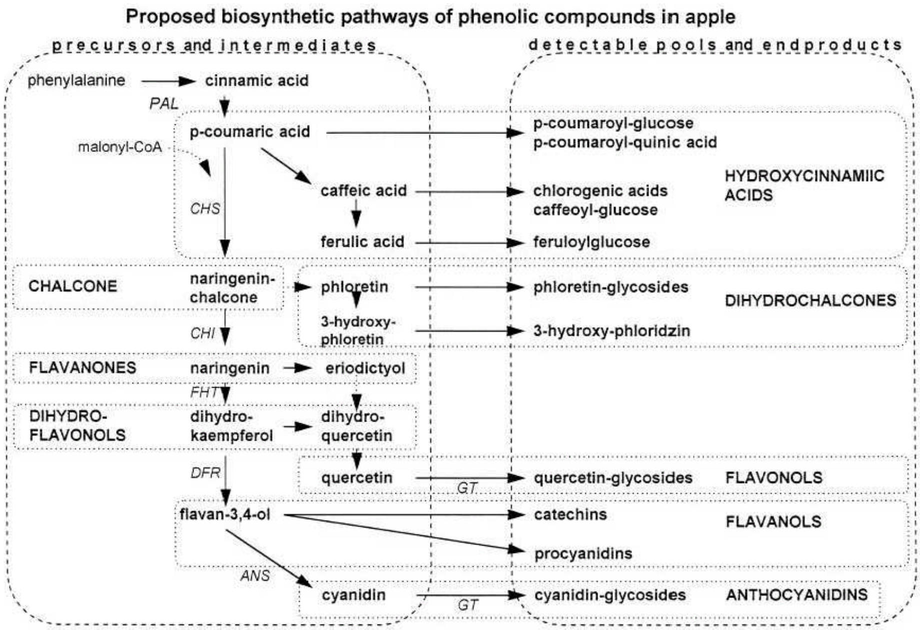
Efforts at the DCA in Bologna are currently focused in part on the allele variability of Md-ACO1 and Md-ACS1 in cultivars and seedling populations to determine any correlations with fruit ethylene emission. Another investigation is also under way to determine the associations between fruit ethylene emission and the flesh softening caused by the cell-wall enzymes expansin and polygalacturonase; the functional markers for these genes will also be investigated. This research has so far identified an SSR marker (Md-ExpDCA1) in a homologous sequence of expansin, which could prove to be highly significant in mapping firmness QTLs. We have also identified and mapped a SNP marker (Md-PG1) in the ‘Fuji’ x ‘Mondial Gala’ cross population upon aligning the specific sequences found in the parental varieties associated with flesh softening (Costa l.c., in press).

3.4. Enhancing the health value of apples

Several other apple traits determining fruit quality in a broad sense are catching the attention of consumers and even being considered by breeders. This kind of collective awareness may find concrete expression in the joint scientific efforts of pomologists, diet experts, clinical pharmacologists and biochemists. Indeed, because of their linkage with the constitutive self-resistance of plants to pathogens and because of the positive role that antioxidants play in cell metabolism and ageing, the polyphenols contained in apple fruits are being seen as potential traits for selection in several programs. Treutter showed (2001) how complex the pathways of these compounds are and how many chemicals need to be considered: quercitins (flavanols), catechins (flavonols), caffeic acids and so forth (Fig. 12).

The upshot is that enhancing fruit quality in apple also means investigating sensory traits via panel taste tests and careful collating of growing district and environment to ascertain their potential inputs. Yet perhaps what is most interesting from the standpoint of research is determining fruit health components so these can t hen be used as a selection tool in breeding. One such example is the program at Cornell University in Geneva New York (Brown, 2004). These efforts are aimed at selecting apples for ascorbic and other acids as well as sugar and antioxidant-polyphenol contents, i.e. the properties these compounds have to reduce flesh browning and enhance other aspects of quality in post-harvest.

Fig. 12



Biosynthetic pathways of phenolic compounds in apple. PAL, phenylalanine ammonia lyase; CHS, chalcone synthase; CHI, chalcone flavanone isomerase; DFR, dihydroflavanol reductase; ANS, anthocyanidin synthase; GT, glycosyl transferase (Treutter D., 2001)

Figure 12. Proposed biosynthetic pathways of phenolic compounds in apple

A good level of polyphenols like procyanidine also helps to strengthen the plant's self-defence system against pathogens, although too high an expression results in an adverse change of taste. Cultivars with a high level of this polyphenol include 'Granny Smith' and 'Braeburn' (over 2400 mg/kg), as compared to 'Golden Delicious' (1200 mg) (Guyot et al., 2002). Another study, this one employing ten apple cultivars, found a significant difference in procyanidine between one and the next, which ranged from 2.3-3.6 g/kg, and especially in the level of chlorogenic acid, from 30 to 430 mg/kg (Podsedek et al., 2000). Molecular assays have also been run to identify the genes (multi-gene family) involved in the biosynthesis of the antocyanins (Kim et al., 2003). It should be noted too that Treutter (l.c.) has emphasized the impact of biotic stress and other factors on the formation of these compounds in leaves and fruits.

Fruit	Hydrocarbons	Carbonilic compounds, aldeids and chetons	Alcohols	Organic acids and lactones	Esters	Bases	Other compounds	Sulfurous compounds	Terpens	Total
Apple	32	42	43	45	92	12	9		3	275+
Pear	1	17	18	11	79					129
Quince	3	34	23	9++	58		4		8	149
Apricot	4	6	12	10	7		6			45
Peach	4	7	12	8	31		3			55
Plum	27	46	39	12++	109		23		8	241++
Mirabelle	14	19	11	8	62		10	4		130
Cherry	3	6	16	11	15		2	2		56
Strawberry	36	47	46	36	101		11	4		285
Gooseberry	32	58	54	7	39		21	3		214
Currants	43	37	36	14	46		10	1		187
Raspberry	3	34	32	14	20		7			110
Grape	23	34	33	20	63	1	13	1		188

+ according to Berger et al. (1988) they are > 350; ++ without volatile acids (by Friedrich and Fisher, 2000)

Figure 13. Chemical classes and number of aromatic and other compounds on fruits of temperate species

Interest is also growing in the flavour-aromatic compounds. It is known that peak flavour occurs during the climacteric peak; their pathways are linked to those of acids and sugars; and the components-alcohols, aldehydes, esters and so on-change rapidly during ripening. Friedrich and Fisher (2000) showed in a comparative chemical evaluation of flavours how much they differ from species to species, as well as from variety to variety (Fig. 13). Indeed, except for blueberry, apple is the fruit with the highest content of total flavonoid compounds.

3.5. Managing cropping habit

The modern apple industry tends to eschew those cultivars marked by a growth habit with an ungovernable canopy or by onerous management practices due to canopy vigour, uprightness, expansion, alternate bearing and so forth. The idea is to come up with cultivars having a compact, moderately expansive habit like 'Braeburn', a spur habit resulting from natural, chance mutation like 'Red Chief'®, or even one derived from crossing like 'GoldRush', and better suited to high-density orchards. As shown in Figure 14, markers have been found for spur (PGM isozyme) and columnar habits.

The University of Bologna's DCA, for instance, has developed 'Gold Chief'®, which is ideal for training and has a markedly solid spur habit. INRA at Angers is now selecting genotypes that tend to set just one fruit per inflorescence to prevent alternate bearing and/or eliminate fruit thinning operations. Uniform ripening is also important to eliminate multiple picking runs and ensure that the entire crop goes to the desired market.

Fig. 14

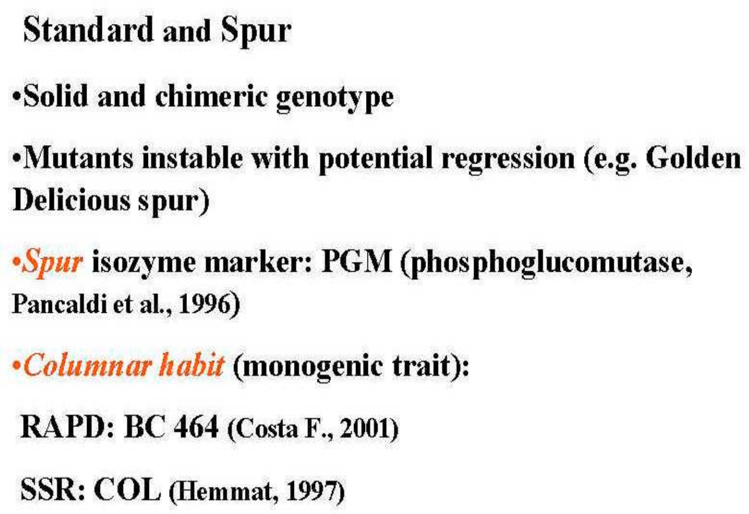


Figure 14. Genetic control of apple tree habit

4. Recently introduced apples in Europe

The breeding data in Table 4 show that Europe as a whole is now the world leader followed by North America, Asia, Oceania, each with more than 80 novel cultivars (1991-2001). Very active European countries in the breeding of new varieties are Russia, the Czech Republic, France, Moldavia, Germany and Italy (Fig. 3).

T a b l e 4 . Apple varieties released 1991-2001

Continent	N°	%
Europe	280	47.8
North America	106	18.1
Asia	91	15.5
Oceania	84	14.3
South America	12	2.1
Africa	3	0.5
Unknown	10	1.7
Total	**586**	**100**

Source: Della Strada/Fideghelli (2002)

T a b l e 5. Main parental lines used in European apple breeding programmes

Parents (a)	Institution (*)																				
	CRA-W (B)	FAW (CH)	RBIP (CZ)	IOZ (D)	INRA (F)	CU (H)	CReSO-CN (I)	CSAF-BZ (I)	ISF-TN (I)	ISMAA-TN (I)	DCA-BO (I)	CIV- FE (I)	ISF-FO (I)	LIH (LT)	NCRI (N)	PRI (NL)	WAU (PL)	RIPF (PL)	AAFSRHS (RO)	IVF (SCG)	EMR (UK)
Alkmene				X												X					
Antonovka	X														X						
Ariwa		X					X			X	X							X			
Braeburn (group)		X	X			X				X	X	X						X			X
Crimson Crisp							X				X										
Co-op (series)									X	X											
Cox's Orange.Pippin				X												X				X	
Discovery	X														X	X		X			X
Elise																X		X			
Elstar								X	X			X				X					
Enterprise													X					X			
FAW (selection)		X								X											
Florina						X				X		X	X		X			X	X	X	
Freedom						X												X		X	
Fuji (group)		X			X	X	X	X		X	X	X	X					X			
Gala (group)					X		X	X		X	X	X	X								X
Gloster																X	X				
GoldRush									X	X	X	X	X					X			
Golden Del. (group)	X								X	X	X		X			X			X	X	X
Golden Orange									X	X											
Granny Smith						X											X			X	

Parents (a)	Institution (*)																				
	CRA-W (B)	FAW (CH)	RBIP (CZ)	IOZ (D)	INRA (F)	CU (H)	CReSO-CN (I)	CSAF-BZ (I)	ISF-TN (I)	ISMAA-TN (I)	DCA-BO (I)	CIV- FE (I)	ISF-FO (I)	LIH (LT)	NCRI (N)	PRI (NL)	WAU (PL)	RIPF (PL)	AAFSRHS (RO)	IVF (SCG)	EMR (UK)
Harmonie							X			X											
Idared						X								X			X			X	
James Grieve				X												X				X	
Jonathan						X													X	X	
Liberty						X						X							X		
Ligol																	X	X			
Melrose																X	X			X	
Pink Lady					X						X	X	X								X
Pinova					X		X	X		X											X
Priam						X									X						
Prima						X			X					X	X	X			X	X	
Priscilla						X			X												
Re- Varieties				X														X			X
Red Delicious (group)							X		X	X			X								
Rubinola			X															X			
Saturn							X														X
Summerred															X					X	
Topaz		X	X		X													X			X
Wijcik										X			X							X	

(a) Varieties in boldface have been used as parents at least 4 times
(*) See Table 3 for questionnaire respondents and published data

Table 6. Outstanding or promising new apple varieties in Europe

A) European-bred varieties

Variety	Public or private Breeder	Parental	Pick date (*)	SS/ SR(**)	Key variety traits
Ariane*	INRA (Angers) + Novadi nursery (F)	Complex hybrid (involving Florina. Prima. Golden D.)	+5	SR	Tree: medium vigour, regular bearing, productive, SR (*Vf* and *Vg* genes); tolerant to mildew and fire blight. Fruit: red colour, with apparent lenticels. Medium size, good quality, high sugar and acidity, crunchy. Long storage.
Ariwa	FAW Wadenswil (CH)	Golden Delicious x Sel. A849-5	-3/+3	SR	Tree: standard habit, picking in two or three runs. Resistance to scab & powdery mildew, tollerance to fire blight. Fruit: medium size, orange-red, very firm, slightly sweet.
Autento® Delcoros*	Delbard nursery (F)	Delgollune x Cox’s Orange Pippin	- 15	SS	Tree: vigour moderate, habit upright, compact. Fruit: roundish conical, solid blush (dark red. average 80%); flesh: sweet, with good firmness.
Brina	ISF-Trento (I)	Sel. PRI 2059-101 O.P.	+7	SR	Tree: medium vigour; high yield. Fruit: medium or medium-large; truncate-conical shape. Skin: uniformly red coloured on yellow background. Flesh: firm, crispy, juicy, with medium texture, sweet, sub-acid; with intensive & characteristic aroma.
Choupette*	INRA + Ligonniere nursery (F)	Sel. X4598 x Sel. X3174	+22	SR	Tree: medium vigour, good and regular productivity. Fruit: medium size, red overcolour (average 70%), flesh: sweet-tart, aromatic.
Corail® Pinova*	Instutut für Obst. Pillnitz- Dresda (D)	Clivia x Golden Delicious	-3/-1	SS	Tree: medium vigour, second bloom in summer (possible fire blight infection). Productivity: high. Fruit: two-tone color, ground yellow, overcolour bright red. Flesh: crisp, juicy, tart.

Variety	Public or private breeder	Parental	Pick date (*)	SS/ SR(**)	Key variety traits
Dalinco	INRA + Ligonniere nursery (F)	Elstar x Sel. X3191	+12	SR	Tree: marked vigour. Fruit: large size, flat conical, round shape, pinkish bright red, sometimes with slight tendency to dark red (average 60%). Flesh: coarse, somewhat crispy texture, juiciness. Taste sweet-acid, somewhat aromatic.
Diwa® FAW 5878	FAW Wadenswil (CH)	(Idared x Maigold) x Elstar	-7	SS	Tree: vigour moderate, habit spreading. Fruit: rather small, flat conical round uniform shape. Color striped/flecked, mainly with solid blush, dark red (average 75%). Juice, balanced sugar/acid ratio, good firmness. Good quality & storability.
Early Free Gold	Res. Inst. Pomol. – Skiernievice (PL)	Unknow		SR	Fruits are medium to large, oblong-conical, ground colour is greenish-yellow with pink blush. Fruit ripen in the first half of September in Poland.
Free Red Star	Res. Inst. Pomol. – Skiernievice (PL)	Unknow		SR	Fruits, formed mainly on spurs and shoot tips, are oblong-conical, with small ribbons around calyx. Their ground colour is green-yellow with intensive red over-colour covering almost the entire surface. It ripens just after Freedom.
Gold Chief® Gold Pink*	DCA-Bologna (I)	Starkrimson x Golden D.	+12/+15	SS	Tree: spur habit, moderate vigour (compact tree), early bearing, high & constant yielding. Fruit: size medium to large, roundish-conical (Red Delicious type); skin yellow, pink blush 10-40%, flesh firm, juicy, sweet-acid, flavored. Good storability.
Golden Orange	ISF-Trento (I)	Ed Gould Golden x Sel. PRI 1956	+7	SR	Tree: medium vigour, not subject to fruit drop. Fruit: medium-large, truncate-conical intermediate, skin: green-yellow, rose coloured on side exposed to sun (5-20%). Flesh: slightly crispy, juicy, thin texture, medium sweet, slightly acid.

Variety	Public or private breeder	Parental	Pick date (*)	SS/ SR(**)	Key variety traits
Green Star® Nicogreen*	B3F+KU Leuven + Nicolaï nursery (B)	Delcorf x Granny Smith	0	SS	Tree: medium-high yield; moderate to weak vigour. Fruit: large, regular shape. Skin: green colour with bright lenticells, tart taste, flesh: firm and juicy. Low scab sensibility, good shelf-life.
Harmonie® Delorina	Delbard nursery (F)	Grifer x Florina	+7/+10	SR	Tree marked vigour. Fruit: little-medium size, red colour (60-70% average), skin without russeting. Flesh: compact, good sweet/tart ratio. Picking in two runs.
Initial*	INRA. Angers (F)	Gala x Redfree	-34	SR	Tree: moderately vigourous, standard bearing habit. Triploid. Fruit: red color (75%), medium to big size. Flesh: crisp, taste midly tart.
Melfree	Res. Inst. Pomol. – Skiernievice (PL)	Melrose x Freedom		SR	Fruits are medium to large, soshape oblmewhat variable, the ong-conical. Skin is non-waxy, with red stripes overlaying green-yellow ground colour. Harvest in the second half of September a few days before Freedom.
Mairac® La Flamboyante	RAC Changins (CH)	Gala x Maigold	+7/+10	SS	Tree: medium vigour. Fruit: medium to large, globose conical shape, red-orange to red brown, lenticels visible, flesh crisp, juicy, high acid level.
Prime Red	DCA Bologna (I)	Prima x Summerred	-35	SR	Tree: vigourous, standard habit. Fruit: medium-large, regular, roundish; without russeting. Skin covered by 70-90% red; typical evident lenticels; fine, juicy, melting flesh. Good balanced taste, sugar, with pronounced acidity.
Rebella*	Instutut für Obst. Pillnitz- Dresda (D)	Golden Delicious x Remo	-20	SR	Tree: growth semi-vigourous. Fruit size: large, skin: fire red coloured (average 90%). Taste is tart-sweet with aromatic flavour, juicy and firm. SR (*Vf* gene), resistance to powdery mildew, fire blight, bacterial canker.

Variety	Public or private breeder	Parental	Pick date (*)	SS/ SR(**)	Key variety traits
Regine*	Instutut für Obst. Pillnitz- Dresda (D)	Kurzocox x SR clone	0	SR	Tree: growth low to medium vigourous. Fruit size: medium, dark red skin (100%). Taste: acid-sweet with good flavour, juicy and firm. SR (*Vf* gene), resistance to fire blight, red spider mite.
Rubens® Civni*	C.I.V. Ferrara (I)	Gala x Elsatar	-18	SS	Vigour moderate, tree habit spreading to upright. Fruit size: rather small, conical to long conical shape, deep calyx cavity. Color: striped, bright red to somewhat to dark red (70-80%). Juicy, crispy/brittle texture. Sweet/acid taste.
Rubinola	Inst. Exper. Botany – Strizovice (CZ)	Prima x Rubin	-16	SR	Tree: vigourous, spreading. crops well and regularly, resistant to powdery mildew. Fruit: medium-large, flat globose. Skin bright red over most of the surface, russet present in stem cavities. Flesh: firm, fine-textured, juicy, sweet, aromatic flavour.
Tentation® Delblush	Delbard nursery (F)	Golden Delicious x Grifer	+7	SS	Tree: medium vigour, good yield. Fruit size: medium, ground color: golden yellow with an orange blush. Flesh: with high tart level. Golden-like.
Topaz	Inst. Exper. Botany – Strizovice (CZ)	Rubin x Vanda	+8	SR	Tree: moderately vigourous, upright. Moderately tolerant to powdery mildew. Fruit: medium, flat globose, overcolour orange-red with strips. Flesh yellowish with fine texture, firm crisp, very juicy, sweet, sub-acid.
Wellant® CRPO 47	PRI Wageningen (NL)	Sel. CPRO x Elise		SS	Tree: vigour rather marked; spreading habit. Fruit rather big, conical, round, red stripe to solid blush, intensive to dark. Firm texture, juiciness, aromatic. Long storability.

B) Foreign-bred varieties

Variety	Public or private breeder	Parental	Pick date (*)	SS/ SR(**)	Key variety traits
	Mennell Cawston. British Columbia (Can.)	Ambrosia®	+8	SS	Tree: spur type, upright growth, not a tip bearer. Fruit size: medium to large, bright red blush, on creamy/yellow back-ground, flesh sub-acid, fine, crisp, juicy & aromatic.
Cameo® Caudle*	Smith e Caudle. Washington (USA)	Chance seedling	+15	SS	Tree: good vigour, high productivity. Fruit size: medium to large, conyc shape, very similar to Delicious, but without the “bumps” on the bottom. Skin colour: bright red stripe, quality firm, crisp, highly appearing sub-acid, aromatic flavour.
Crimson Crisp® Coop 39	PRI (USA)	Sel. 669.205 x Sel. PCF W2134	-10/-5	SR	Tree: moderately vigourous, upright tree, standard bearing habit. Moderate yield. Skin: very bright (75-100%), medium to dark red at sun-exposed side, attractive. Flesh: mildly tart, crisp, sweet, spicy, full rich flavour.
Honeycrunch® Honeycrisp*	Minnesota Univ. (USA)	Macoun x Honey Gold	-14	SS	Tree: low vigour, high precocity. Fruit: 60% orange/red over yellow color. Size: large. Exceptional texture and juiciness.
Jazz® Scifresh	Hort. and Food Research Havelock North (NZ)	Braeburn x Royal Gala	+15	SS	Tree: suitable to different environments, yield appears not high. Fruit: medium or small-to-medium size, with red bright colour (70%), flesh crispy, juicy, good sweet/tart ratio.
Pacific Rose® Sciros*	Hort. and Food Research Havelock North (NZ)	Gala x Splendour	+15	SS	Tree is compact, early bearing, but with tendency to biennal bearing. Fruit: medium size, 60-90% overcolor, bright red to pink tone. Flesh is crisp, firm, juicy, chewy, predominantly sweet with low acidity.

Variety	Public or private breeder	Parental	Pick date (*)	SS/ SR(**)	Key variety traits
Pink Lady® Cripps Pink*	JE Cripps (AUS)	Golden Delicious x Lady Williams	+45	SS	Tree: vigourous, upright growing. Fruit small-to-medium size, oblong-cylindrically shaped. Pink blush over a green ground color. Very firm flesh, somewhat tough and often dry. Flavor is tart yet balanced by high sugar content.
Sonja	J. Mc Laren (NZ)	Red Delicious x Gala	-7	SS	Tree: vigourous, productive. Fruit shape: conical with restriction in calyx. Fruit overcolor: red (in low percentage). Flesh: crunchy.

C) Main sports of popular varieties

Origin variety	Public or private experim. station	Variety	Pick date (*)	SS/ SR(**)	Key variety traits
Braeburn	D. Easton, Nelson (NZ)	Eve® Mariri Red*	+15	SS	Growing characteristics are similar to standard Braeburn but may be slightly later in maturity. Fruit: full (90-100%) red blush at maturity. Flesh is firm & crisp, with an acid-to-sweetness ratio like standard Braeburn.
Braeburn	J. Hillwell, Hastings (NZ)	Hillwell® Hidala*	+15	SS	Tree: like Braeburn. Fruit: better skin colour than standard. Flesh: like Braeburn.
Fuji	Japan. license Braun (ITA)	Kiku® 8	+22	SS	Vigour medium-strong, high fruit bearing. Fruit medium-large. Color: shiny red blush, with stripe all over fruit, even on the shaded side. Round shape, flesh crunchy aromatic and sweet.
Fuji	Exper. Stat. – Nagano (JPN)	Naga Fu 12	+22	SS	Tree: like Fuji standard. Fruit colour: solid/striped type, a pinkish-red color. Sweet flesh, firm, and crisp texture. Fruit is large, excellent quality & stores very well.

Origin variety	Public or private experim. station	Variety	Pick date (*)	SS/ SR(**)	Key variety traits
Fuji		Raku Raku	+22	SS	Vigour medium-strong, highly fruit bearing. Fruit medium-large. Color: shiny red blush, with stripe all over fruit, even on the shaded side. Round shape, flesh crunchy aromatic and sweet.
Fuji	Austin orchards, Nelson (NZ)	Zhen® Aztec	+22	SS	Tree: medium-high yielding. Fruit red solid overcolour 100%. Flesh: like Fuji.
Gala (Royal Gala)	Brookfield, Hawkes Bay (NZ)	Brookfield® Baigent	-25	SS	Tree: like Gala. Fruit color: markedly striped color. Flesh: like Gala.
Gala (Royal Gala)	Schnitzer (I)	Schnitzer® Schniga*	-25	SS	Characteristics similar to Brookfield Gala®.
Golden Delicious	Kerschbaumer (I)	Goldrosìo®	0	SS	Tree vigour: medium to strong. Fruit color: completely yellow at maturity, pronounced red blush. Flesh: firm crisp and juicy.
Golden Delicious	Lerat s.n.c., Elaris (FRA)	Pink Gold® Leratess	-5	SS	Golden-like, with pink face.
Pinova	Feno (D) excl. admin. var. rights	Evelina® RoHo 3615*	-3/-1	SS	Fruit: better skin colour than standard.
Pink Lady®	Bowden. N.S. Wales (AUS)	Rosy Glow*	+40	SS	Mutant with noticeably better and earlier coloring (only two runs necessary). More colour (% and tonality) than Pink Lady®.
Red Delicious (Early Red One®)	Valois nursery (F)	Jeromine	-10	SS	Tree: medium vigour, standard habit. Fruit size: medium to large, colur: uniform dark red (100%) that appears before others. Flesh: juicy, sweet.
Red Delicious (Top Red)	Feno (Europ. PVR appl. owner)	Redkan*	-5	SS	Tree: typical spur character, a little bit weaker than Red Chief®, 'Camspur'. Fruit color: intensive red (100%). Flesh: firm, crispy, with high sugar contenent, low acid, aromatic.

Origin variety	Public or private experim. station	Variety	Pick Date (*)	SS/ SR(**)	Key variety traits
Red Delicious (Red Chief® Campbell)	Ray Sandidge, Entiat, Washington (USA)	Superchief® Sandidge*	-5	SS	Tree has same compact growth habit as Red Chief®. Good % and intensity of colour.
Šampion Red*	Res & Breed. Inst Pom. – Holovousy (CZ)	Mutation of Sampion.	-6	SS	Tree: medium vigour, upright spreading canopy. Fruits have medium size, ground color: green yellow, over color: crimson red, flesh: creamy colour, medium firmness, juicy, full flavored, sweet.

(*) Days before (-) or after (+) Golden Delicious (in Italy 2nd decade of September)
(**) SR = Scab Resistant; SS = Scab Susceptible

Using the data reported in literature as well as personal communications in response to our queries, we have put together a summary survey of the cultivars released by the main public and private breeders in Europe over the last 10-15 years, starting from the breeding objectives (Tab. 3) and including their parentals (Tab. 5), ripening date and most salient traits (Tab. 6).

The cultivars shown in Table 6 represent the bountiful fruits breeding has to offer. Noteworthy in this connection is the fact that most of the European-bred varieties released in the last decade are scab-resistant (almost all because of the *Vf* gene). Although extensive field-performance data for them in various countries and growing districts are not yet available, we can probably assume that the breeding stations released them after thorough testing to make sure that their key traits, especially as to overall flavour and quality, are on a par with or better than consumers now demand from the most popular cultivars on the market.

Despite these efforts, the marketplace has yet to respond adequately to these novel cultivars. Indeed, this weak response should serve as a wake-up call to grower associations, which with the help of common market organisations, and perhaps even EU-member governments, should initiate a blanket advertising campaign based on the requisites for integrated (IFP) and organic fruit production.

While most of these novel cultivars have been brought on-line by public breeding stations. France and Italy head the list of countries in which private nursery groups, whether alone or jointly with public institutions, have also been a source of novelty. This kind of public-private partnership can be taken as a model for future teamwork, especially given the paucity of public-sector research and breeding budgets. As a matter of fact, such collaborations could even be extended to cultivar field tests and market release schedules (Sansavini et al., 2003).

Almost all breeding is done under separate in-house programmes. Perhaps the time has come to encourage and promote a coordinated networking among stations and even countries to establish a more streamlined and efficient selection procedure. Such a system could start off with exchanges of markers for MAS, or by concerting certain selection stages to benefit more than one programme, so as to promote international field testing and release of novel cultivars. Indeed, it's reach could even be extended to include less costly marketing schemes for both growers and nurserymen, as well as one that provides better stewardship of trademarks and propagation rights. It can be hoped that with its own networked breeding programme each EU member-state will soon have the chance to upgrade its range of assorted cultivars so as to supply high-quality apples to meet the markedly variegated consumer demands in the European marketplace, which are quite well differentiated in and between country

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POSTĘPY W HODOWLI SZANSĄ NA POPRAWĘ JAKOŚCI OWOCÓW I OTRZYMANIE ODMIAN ODPORNYCH NA STRESY ŚRODOWISKOWE: NOWE ODMIANY DLA RYNKU EUROPEJSKIEGO

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STRESZCZENIE

Istniejące tendencje i przewidywania na przyszłość w hodowli jabłoni w poszerzonej UE o 25 państw zostały przedstawione w niniejszej publikacji. W ostatnich dwudziestu latach widoczny był postęp w programach hodowlanych realizowanych w Europie i na świecie. Główny wysiłek w hodowli kierowano na otrzymanie form odpornych na choroby, w tym na parcha, mączniaka, zarazę ogniową oraz na poprawę jakości owoców, jak na smak i zdolność przechowalniczą. W wyniku tych prac otrzymano wiele nowych odmian jabłoni odpornych na parcha. W przyszłości będą one odgrywać na rynku bardzo ważną rolę. Nowe technologie w hodowli pozwolą uzyskać odmiany, przy uprawie których będą potrzebne stosunkowo małe nakłady pracy. Niektóre ośrodki naukowe wdrażają do prac hodowlanych markery molekularne w celu selekcji monogamicznych cech i segregacji cech poligamicznych. Są duże oczekiwania w stosunku do projektu badawczego HiDRAS realizowanego przez kraje UE. Projekt ten obejmuje ocenę jakości owoców (dojrzewanie, soczystość, kwasowość, cukier, aromat, polifenole i inne antyoksydanty). Inne metody z wykorzystaniem markerów są stosowane do ustalania linii rodzicielskich, mapowania genów. Genom jest polem, w obszarze którego bada się ekspresję genów dla wyjaśnienia spraw związanych z owocowaniem, wrażliwością drzewa na stresy biotyczne i abiotyczne oraz charakterem owocowania drzewa. Badania nad wpływem różnych czynników na zachowanie się drzew i ich planowanie prowadzone są w ponad 30 europejskich programach hodowlanych.

Słowa kluczowe: nowe odmiany jabłoni, odporność na parcha i mączniaka, markery molekularne i MAS (Markery Uczestniczące w Selekcji), wysoka jakość owoców