Sweet Cherry Breeding Programmes in Europe and Asia

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Abstract

The strength of the sweet cherry industry throughout Europe and Asia is due to the breeding efforts of France, Germany, Hungary, Italy, Denmark, the UK, the Czech Republic, Romania, Estonia and Ukraine, Turkey, Japan, and China. The last decade has seen the release of more than 140 novel cultivars that have provided the major thrust in extending the crop's seasonal calendar and improving fruit quality traits such as size, flavour, flesh firmness and colour. Fruit crack resistance has been enhanced and there are now a dozen cultivars with only 5-10% of fruit affected by cracking due to rain-damages. Molecular studies have brought new light to bear upon the genetic control mechanisms of key tree and fruit traits and this should enhance future breeding efforts. The introduction of new self-fertile cultivars with mutated *S*-locus alleles, has been a key factor in upgrading crop yields, especially in Italy. Notable releases include very early-season 'Primulat' and 'Early Bigi' (France); the self-fertile 'Sweet Early' and 'Grace Star' (Italy); the mid-season ripeners 'Giorgia' (Italy) and 'Vera' (Hungary); the mid-to-late 'Kordia', 'Vanda', 'Techlovan' (Czech Republic) and 'Black Star' (Italy); and the late ripeners 'Regina' (Denmark) and 'Alex' (Hungary).

INTRODUCTION

The sweet cherry industry has been stable over the past few years. Europe is the leading producer with annual production of 886 thousand tonnes (t) and Asia is second with 635 thousand t, together accounting for over 80% of world production. The leading countries are Turkey (240 thousand t) Iran at (2220 thousand t), followed by Germany, Italy, Spain and Russian Fed. (Table 1). There is strong demand by a solid consumer base and there have been notable advances in production, management, handling, storage and marketing. However, the key factor underlying the industry's health has been the change in the assortment of available cultivars, which has upgraded fruit type and quality to meet demand throughout the pipeline from field to table. Within the stone fruits, the breeding of new cherry cultivars is only second to peach, with no fewer than 230 newly cultivars released from 1991-2004: 116 in Europe, 71 in North America and 33 in Asia (Fig. 1). Breeding methods include crossing selection methodology (62% of new cultivars), clonal selection from populations of existing cultivars (16%); selection from open pollination (17%) and induced mutations in clonal genotypes (4%). In order to obtain a snapshot of the cultivar situation today and to predict the future course of the cherry industry we have surveyed efforts at the main breeding stations in Europe and Asia.

SURVEY OF BREEDING PROGRAMMES AND OBJECTIVES

Our survey was conducted via a questionnaire sent to 27 leading public and private cherry breeding stations in Europe and Asia with 20 responses received (Fig. 2). The questionnaire was divided into three sections: (1) a general part focusing on programme set-up, start-up (and end) date, names of breeders, and source of funding; (2) a more specific section seeking data on average number of yearly crosses, main parents, number of seedlings produced, number of plants in selection phases 2 and 3, total number of cultivars released, date of release, and the main objectives pursued (*see* Table 2); (3) methods of cultivar release, (free release, patents, trademarks), and the kind of field performance tests and trial set-up.

Breeding Goals

Of the 25 objectives listed in Table 3, the common denominator across the board was enhancing fruit quality in terms of size, firmness, and flavour. The Japanese stations were prominently interested in developing new fruit types via different skin colour type. The other objectives common to most respondents included enhanced yield via self-fertile cultivars, a target shared by half of the stations; increased fertility; reduced susceptibility to environmental damage and diseases at bloom and post-bloom; extending seasonality, especially for early ripeners, and resistance to cracking.

The programmes breeding for tolerance/resistance to biotic stresses are mainly located in Germany and Eastern Europe where an interdisciplinary approach with highly specialised teamwork is well developed. This work includes resistance to bacterial diseases (Dresden and Jork, Germany), and to *Monilinia* (Budapest, Holouvosy, Plodvid and Babtai. Hungary); work on frost resistance (Lithuania and Estonia). The two Stations at Verona (Italy), and Budapest (Hungary), have initiated selection of genotypes for easy peduncle removal for mechanised harvesting. All the respondents employ intercultivar crossing and subsequent selection as their sole breeding tool and produce an average yearly number of seedlings that range from a few hundred to a thousand (Table. 3). Of the 600 seedlings selected from Stage 1 assessment, 150 were employed for further assessment (Stage 2). Of the 154 novel cherry cultivars released by these programmes, 140 have come from European and 14 from Asian sources; EU patents have been filed for an average of 16%, a far lower rate than for patent of pome fruits.

Enhanced Fruit Quality

Upgrading fruit quality—such as size, appearance, firmness, flavour, taste, shelf life—is the top priority for cherry breeders everywhere. While these traits are closely linked to genotype, it is heavily influenced by factors both environmental, such as soil and climate, and agronomic, such as rootstock choice, field management, and nutrition. A good example is colour distinction and, hence, traditional consumer preference between European and Asian cultivars: the former cherries are only red, the skin colour ranging from bright to very dark red, or the so-called "black," (with red flesh and juice), whereas the latter are more variegated in colour, ranging from pinkish-yellow, reddish-orange and light pink to very light, almost translucent flesh and juicy. The heritability of the black/red colour is dominant to the yellow/red colour (Schmidt, 1998).

1. Size. Fruit diameter is the main benchmark used in commercial cherry grading, is a large factor in consumer preference, and is a large determinant of both farmgate and, market price. Large-size cherries enable more efficient picking, cuts down on sorting time and reduces overall handling costs, especially when size is uniform. The parents most often employed in breeding programmes to achieve large fruit size, together with the main results achieved by breeding stations, are listed in Table 2. The parental cultivars most frequent are the 'Celeste' and 'Sunburst' (Canada), 'Big Lory', (France), 'Regina', (Germany), and 'Nanyo' (Japan).

2. Firmness. One of the traits most prized by marketers, consumers, and growers is fruit firmness, involving better on-tree ripening, increased resistance to handling and transport, better adaptability to cold storage, longer shelf-life and, hence, fruit better suited to export. However, the parameters used to measure firmness can differ from country to country depending on the instrument employed (durometer, pressometer, penetrometer). As a result values from different countries are difficult to compare and prevent developing a uniform system of classification. Breeders sometimes enhance flesh firmness using of local germplasm (Table. 2); examples include the Duroni series of cultivars and 'Corniola' an old cultivar (Italy) and 'Kordia' a new cultivar (Czech Republic and Germany).

3. Flavour. Quality factors affecting flavor are the same for all cherries, whether European or Asian. It includes sugar content, higher by 16-18% in cherry as compared to other stone fruits, titratable acids, which can vary a good deal and is usually higher in the red cultivars (even up to 10-20%), and aromas and volatile compounds, which are usually overshadowed by the sugar-acid ratio that tends to determine the taste of each variety. Phenolic content, compounds that give cherries their aftertaste, are also of some importance. Given sweet cherry's notably short growing season, it follows that the large, earlier-ripening cultivars are rather poor in sugar and acid content, as well as flavour. This means that only the mid-season and late ripeners whose growing cycle exceeds 50 days, attain full and very satisfying flavour. Table 2 lists the most sought-after cultivars in breeding for this trait.

4. Extending Seasonality. Lengthening the harvest season and, hence, the marketing calendar is a primary goal in species such as cherry, where supply is concentrated in a brief period and a circumspect geographical area, often no longer than five-to six weeks in a given district. The idea is to add one week at the beginning of the season and two and more weeks at the end in order to lengthen the overall season.

Early Ripening. Many European programmes have set their sights on breeding early genotypes of good fruit quality that ripen before the benchmark cultivars 'Burlat' and 'Moreau'. Early ripeners usually command notably higher farmgate and market prices, although they entail higher orchard costs linked to a low uniformity of ripening, which can involve 3-4 pickings, greater susceptibility to cracking, smaller fruit size on average and often poorer flesh firmness, all of which make them normally suitable for local markets only. While it is possible to force ripening in protected growing regimes to gain an extra 10 to 20 days, this practice is economically viable only in a few districts of southern Europe and, in Japan and other wealthy Asian districts where the high management costs are offset by the very high and selected market prices these "élite products" command. The most popular European parents are 'Burlat', followed by the recently released 'Rita' and 'Primulat'.

*Late Ripening***.** Extending the end-of-season calendar with extra-late ripeners has proved more successful, especially in the mountain and in the cold summer areas. Indeed, today's genotypes make it possible to grow cherries for 7-8 weeks depending on district. This is especially true of the northernmost European areas with August ripeners, the main limiting factor here being late summer or early autumn frost. Unlike the early and mid-season cultivars, the late ripeners usually contain better pomological traits such as size, firmness, colour and taste, and lower susceptibility to biotic stresses such as cracking (e.g. 'Regina' and 'Staccato').

5. Easy Fruit-Stem Abscission. The aptitude for easy picking is a trait located either between petiole and branch or fruit and petiole, although the latter is of interest only if the fruit's scar tissue hardens to a suberificated (cork-like) abscission so as to prevent juice loss, oxidation, and pathogen attack in shaked fruits. This trait has figured in the experimental work at the Verona, Italy, and Budapest, Hungary, stations, which have bred several novel varieties adapted to both the processing industry and to fresh market. Indeed, this trait has returned to the fore after the recent changes in the cherry quality regulations of the European Union (EU) that now list these produces as suitable for fresh market without the stem. Parents most often used are 'Vittoria' (Italy) and 'Linda' (Hungary).

Tree Traits

The major goals here are to reduce tree size and improve yield and fertility and resistance to abiotic and biotic stresses.

1. Compact Habit. In the past the lack of dwarfing rootstocks for cherry capable of controlling tree growth to meet the needs of an intensive orchard industry fueled the search for low-vigour genotypes, a situation that spurred breeders to pursue mutagenesis and subsequent selection for trees of reduced vigour (1960-1980). In our experience, the major problem with these mutants was the lack of stability of the selected traits, including the distinctive short-internode tree growth of the compact habit. Indeed, these traits are of a chimerical nature and, hence, can regress or be lost altogether in subsequent propagation cycles. Related problems include smaller fruit size with respect to that of the original cultivar, as with 'Durone di Vignola II', and lower yield, as with. 'Durone Nero II C1', both associated with the mutagenesis-induced growth habit change (Sansavini et al., 1998). The upshot was the elimination of this goal from the recent breeding programmes, which then turned to the more readily achievable development of dwarfing stocks, which could also control scion growth.

The spur habit was another trait that had been pursued both by crossing and mutagenesis-plus-selection to enhance tree yield potential of the most popular cultivars. Yet this too dropped from the breeding agenda with the advent of self-fertile cultivars and new stocks to control canopy shape and growth. Nevertheless this is still an important trait for selection, because of its favourable relationship with fruiting.

2. Self-fertility. The development of self-fertile (SF) cultivars has became a primary goal of many breeders, not least because the own-fertile trait can be readily transmitted via mutagenesis-selection and then crossing-selection again, as shown by the John Innes Institute (UK) in 1954. Indeed, this is a dominant trait controlled by several mutated alleles at the *S* locus. Almost all the SF cultivars grown today are derived from 'Stella', bred in Canada by K.O. Lapins via a cross of 'Emperor Francis' with the self-fertile English selection JI 2420. Save a few exceptions, SF genotypes usually offer better guarantees of steady and higher yields, as well as easier adaptation to a wider range of environmental conditions, than self-incompatible genotypes. They can also be used as universal pollinators when planted with the latter genotypes. The most popular SFs today are the Canadian 'Sunburst', 'Lapins' and 'Sweet Heart'. In years when climate is favourable to fruit set, SF cultivars can have excessive fruit load and, hence, prone to greater risk of reduced quality, especially as to fruit size. SF genotypes thus need rather thorough and, in certain situations, severe pruning that is proportional to their flower bud load. Due to the closest fruits, the SF cultivars are also prone to biotic adversities like *Monilinia*-inducing brown rot, and they are to be monitored in the long term for overall growth and bearing performance, especially in terms of steady cropping and fruit quality when they are grafted to dwarfing stocks in intensive orchards.

3. Abiotic Stress Resistance

*Environmental Adaptability. B*reeding cultivars that can adapt to a range of climatically differing districts in temperate areas is a factor in market globalization, the aim being to provide the same cultivar at all latitudes, although it is a target some consider difficult to achieve (Sherman and Beckman, 2003; Richards et al., 1995). This because we still do not know enough about the genetic mechanisms controlling environmental response and also because, we do not posses proper assessment and selection criteria. Indeed, good environmental adaptation of a given cultivar is the result of an array of factors, including response to winter chill and cold and heat requirements, whose interaction regulates such various tree growth stages as bloom and fruit ripening dates.

What distinguishes sweet cherry from the other temperate species is its marked hardiness to winter cold (especially as compared to peach) and its brief cropping season (40-60 days). This combination makes cherry suitable to the cold of high latitude such as Norway, even beyond the resistance of apple, and to the low warm latitudes of Chile, Turkey, and Iran. Thus, high-priority breeding goals in Europe are cold hardiness and late bloom; late bloom to prevent damage from spring frost in northern districts and low chill requirement in southern districts. Among the cultivars that have shown ample plasticity in terms of genetic-by-environmental interaction are 'Germersdorfer', 'Ferrovia', 'Lapins', 'Schneider Spate', 'Ziraat' (0900).

Cracking and Rain Damage. A prominent goal in many programmes is breeding cultivars resistant to rain-induced cracking, a notable problem in northern districts, as it can compromise the harvest of the more susceptible cultivars in especially high rainy seasons. Prevention measures today rely mostly on selecting the most resistant genotypes and plastic cover systems, since treatments with calcium salts and other active ingredients such as growth regulators have proved largely ineffectual. As a matter of fact, when properly designed and deployed, cover systems are, despite their relatively high costs, the only means capable of providing 80-100% protection, although in the end the input of genetics may prove to be the best solution of all if the cultivars are of fruit high quality.

Breeding is further complicated by the fact that there are marked differences in susceptibility to cracking among cultivars. European sultivars like 'Adriana' and 'Flemings Srim' in Italy have proven to be almost completely immune; others shown low susceptibility ('Regina' in Germany, 'Kordia' in Czech Republic and Romania, 'J-no-shizuku' in Japan) and, hence, are used as parents by many breeders. There are several studies which screened more than 200 varieties. The main assessment was done by Vittrup Christensen in Denmark (1996). Noteworthy of the novel tolerant cultivars bred from these latter and having good quality traits 'Black Star', 'Fertard', 'Korvic', 'Regina' and 'Techlovan'

4. Biotic Stress Resistance

The diseases that breeders mostly key on include brown rot (*Monilinia laxa*), cilindrosporiosis (*Blumeriella jaapii*), root-crown rot (*Phytophthora* spp.), and those by bacteria-like canker (*Pseudomonas syringae*). The latter goal has high priority in

Germany (Dresden) and other central-north European countries where severity of bacterial attack is often boosted by wounds the plants suffer from winter frosts, hail, and pruning cuts, including root pruning (Fisher, 1996; Fischer and Hohlfeld, 1998; Lespinasse et al., 2003, Schuster and Tobutt, 2004). Evaluation of several bacterial and virus diseases in 12 cultivars and 6 rootstocks have been carried out in the Czech Rep. by Blazkowa (2004).

Biotechnology

1. In vitro Selection via Somaclonal Variation. new breeding tools involving biotechnology have been pursued (Schmidt and Ketwel, 1996; Stanys, 1998). Exploitation of stable somatic variants from cell and in vitro tissue culture have proved feasible but practical results have not been achieved. Protoplast cultures have not proved encouraging (Marino, 1986). Research successes to date include tissue culture for somaclonal variability in timber cherry (De Rogatis et al., 1994 and 1996); whole–plant regeneration from leaves and cotyledons (Yang et al., 1991; Cantoni et al., 1993; De Rogatis and Rossi, 1994); organogenesis, i.e. direct regeneration from disks of in vitro-grown leaves, to breed clones of 'Hedelfinger', which appear to exhibit reduced apical dominance (Piagnani et al., 2002); and somatic embryogenesis in 'Summit' from root explants of in-vitro-grown plantlets (Druart et al., 1998). In vitro technology has been pursued in Germany to evaluate self incompatibility status of cherry seedlings (Schmidt and Ketwel, 1996) and Stanys (1998) and to increase the output of seedlings from early maturing parents.

2. Molecular Markers and Marker Assisted Selection (MAS). Several molecular markers have been assessed in sweet cherry, especially AFLPs and SSRs, and used for genetic fingerprinting, estimation of genetic diversity, and mapping and in order to improve breeding efficiency (Boritzki et al., 2000; Downey and Jezzoni, 2000; Dirlewanger et al, 2002; Wunsch and Hormaza, 2002; Aranzana et al., 2003; Howard et al., 2005; Zhou et al., in press).

Several linkage maps have been developed for *Prunus* sp., including sweet cherry (Stockinger et al., 1996). Molecular markers associated with useful traits may soon be used for MAS (Martinez Gomez et al., 2003 and 2005). Boritzki at al. (2000) used AFLP and SSR primer combinations to separate almost 200 cherry cultivars, and important qualitative trait loci (QTL) have been investigated in stone fruit, including cherry (Wang et al., 2000; Testolin, 2003). New sources of resistance and adapted strategies of breeding are required as well as better knowledge of sinteny in the *Rosaceae* to increase breeding efficiency (Dosba, 2003).

3. *S*-allele Variability of Self-incompatible Genotypes. A list of 17 incompatiblity groups is now available and specific PCR *S*-allele from *S1* to *S16* have been detected for cultivars including self-compatible ones (Tobutt et al., 2001; Sonneveld et al., 2003; Wunsch and Hormaza, 2004). The most advanced studies of the *S*-locus have demonstrated multiple codominant alleles such as $S4^{I}$ (Sonneveld et al., 2001; Tassinari, 2005) making it possible to recognize compatible cultivars for practical use (Sonneveld et al., 2003). The sweet cherry cDNA of the tagged *S* gene has been cloned and S-RNases sequenced by Tao et al. (1999). A pollen-expressed gene protein linked to S-RNase has been found by Yamane et al. (2003).

4. Genetic Transformation. Cherry is as one of the first tree species to consider genetic transformation. A number of research institutes have registered successes primarily with the transfer of reporter, selective, and other genes with agronomic interest, but, there has not been any commercial propagation. Employing the standard *Agrobacterium* spp. and less frequently the biolistic gun as vectors, these efforts have so far produced clones of the 'Colt' GM rootstock carrying the rice phytochrome A to induce more compact internodes (Negri et al., 1998) and plants of the rootstocks 'Damil' and 'Inmil have been transformed in Belgium using *GUS* and *rol* genes via *Agrobacterium* (Druart et al., 1998).

SURVEY RESPONSE DATA

The earliest breeding programmes were set up in the 1940s-1950s in Estonia, Hungary, Germany, Italy and Japan. These efforts were followed by programs in China (1990), Bordeaux, France (1980), Bologna, Italy (1983), and Japan (1990, 1997) (Table 3).

Promising Novel European Cultivars

The following brief descriptions of the most interesting European-bred novel cultivars in active programmes are listed in order of ripening date with respect to 'Burlat'. (According to the international professional nomenclature, the asterisk after the cultivar name means "trademark name" and ® means registered patented genotype name.) Each profile includes breeder data sheets integrated with, where available, original, local field performance observations (Zahn, 1985; Saunier, 1996; Saunier and Bargioni, 1997; Kask and Jänes, 1998; Rusterholz et al., 1998; Ruisa, 1998; Fisher and Fisher, 2004; Charlot et al., 2004; Zhivondov et al., 2004; Apostol 1999 and 2005; Sansavini and Lugli, 2005). Moreover, we added fruit analysis data recorded at Bologna's DCA laboratory in the last two cropping years (2004-2005) (Table 4).

It has taken each programme an average of 10 to 15 years to release a new cultivar. Given this lengthy time span, most stations have decided to enhance and speed up their selection process because of the high costs involved. This upgrading includes private and public cooperation and coordination to fund and/or evaluate the selected material at several test sites; the use of early selection techniques mainly based on inoculum of pathogens to determine the most resistant selections, and grafting to dwarfing rootstocks to screen for early bearing and spur habit, especially useful in high density plantings. MAS for early selection has yet to be introduced because there is not enough knowledge about the links between molecular markers and functional genes (Dirlewanger et al., 2004).

1. Very Early Ripeners (before-'Burlat').

'Rita'*, released at RIFO in Budapest, Hungary, ripens –5 to 7 days, high-yielding tree of average vigour, fruit of average size (24-26 mm Ø), semi-firm flesh, fairly good flavour, highly susceptible to cracking.

'Early Bigi® Bigisol'*, released by P. Argot (France), features a productive tree that is easily trained and pruned, staggered ripening –3 to 5 days, good-sized fruit (26-28 mm Ø), soft flesh, mediocre flavour, highly susceptible to cracking. Similar to 'Early Lory' and 'Earlise® Rivedel*'

*'Sweet Early® Panaro 1**', a self-fertile cultivar from the University of Bologna, features a vigorous tree that is high yielding on weak rootstocks; ripening date –2-4 days, large-size fruit (28-30 mm Ø), soft flesh, good flavour (low acid), cracking tolerant.

2. Early Ripeners (< 14 Days after 'Burlat').
'Folfer'*, released by INRA at Bordeaux, France, features a high-yielding tree of average and fruit that matures + 5-10 days, large size (28-32 mm ø), firm flesh, good quality; average susceptibility to cracking.
'Vera'*, released by RIFO in Budapest, Hungary, average-yielding, rather vigorous tree, large-sized fruit (28-30 mm Ø), optimum flavoured that ripen uniformly, ripens + 8-10 days, average-to-high susceptibility to cracking.
'Grace Star'*, self-fertile cultivar from the University of Bologna, features a vigorous and productive tree, ripening date +2 weeks, large fruit, uniform (28-30 mm Ø), semi-firm flesh, optimum quality and average susceptibility to cracking.
'Giorgia', released at Verona, features a vigorous, high-yielding tree with fruit that matures +2 weeks. medium-large fruit (26-28 mm Ø), firm flesh, mediocre, slightly acid taste, average susceptibility to cracking.

3. Mid-season Ripeners (16-24 Days after 'Burlat').
'Aida'*, released by RIFO, Budapest, Hungary, vigorous, productive tree, ripening date +16-18 days, and good sized fruit (26-28 mm Ø), firm, optimum quality (flavour), average susceptibility to cracking.
'Black Star'*, self-fertile cultivar from the University of Bologna, features a productive, vigorous tree, a ripening date +18-20 days, good size fruit, very firm, optimum quality (flavour) cracking resistant.
'Techlovan'*, released by RBIP at Holouvosy, Czech Republic, vigorous tree of average cropping, ripening date +3 weeks, large size fruit (28-30 mm Ø), average firmness, optimum flavour and low cracking susceptibility.

4. Late-season Ripeners (25-34 Days post 'Burlat')
'Korvic', released by RBIP at Holouvosy, Czech Republic, vigorous tree of average cropping, ripening date + 28-30 days, good size fruit (26-28 mm Ø), very firm, optimum flavour and low cracking susceptibility.
'Regina', released at the Jork station in Germany, features a very vigorous tree that crops well only on dwarfing stocks, a ripening date 30-32 days after Burlat, and fruit of large size (28-30 mm.), very firm, low juiciness, average quality, tolerant to cracking.

5. Very late Season Ripeners (> 35 Dys post-'Burlat')
'Fertard', bred by INRA at Bordeaux, France, features a tree of average-to-high vigour and average cropping, a ripening date 35-40 days after Burlat, and fruit of good size (26-30 mm.), firm, average quality, poor juiciness, low susceptibility to cracking.
'Alex'*, a self-fertile cultivar bred by RIFO at Budapest, Hungary, features a vigorous tree of steady cropping, ripening date + 38-40 days, good size fruit (28-30 mm.), semi-firm, fairly good flavour quality, and of average cracking susceptibility.

6. Promising New Asian Cultivars. Except for the programme starter over 50 years ago in Japan's Yamagata Prefecture, all the other Asian breeding initiatives are of relatively recent date. The most noteworthy novel cultivars so far are Japanese releases.
'Benitemari', marketed in 2000 and released by the Yamagata station, a vigorous, high-yielding tree with fruit that ripens in early July of large size (28-30 mm) and good quality.

'J-no-shizuku', marketed in 2000 and released at the station in Aomori Prefecture, vigorous and high-yielding. fruit ripens 5 days after 'Satonishiki', average size with soft flesh and cracking tolerant.

CONCLUSIONS

The nearly 30 breeding programmes established in Europe and Asia over the last half century have provided a significant boost to the upgrading of yield and quality throughout the sweet cherry industry. In Europe efforts have extended the harvest season while markedly improving such fruit quality traits as size, colour, and flavor. Indeed, many of the novel cultivars that have been released so far are better adapted to the colder northern latitudes and upland growing districts and, hence, have enabled growers to both extend consumer expectations and seasonality from the standard 40-60 days to a market calendar that now runs as long as 90-100 days, and sometimes longer, in both hemispheres. With these exceptional results in hand, breeders are beginning to turn their attention to the new tool kit offered by biotechnology in their pursuit of further advances. The benefits that tools like functional markers and their mapping may deliver include the introduction of such novel traits as resistance to environmental, diseases and pests. Although MAS has yet to come on line in cherry breeding, the sinteny found for AFLP and SSR markers in the Rosaceae is encouraging. Another positive development is the diversification of fruit types based on colour, starting from the dark European reds and the light orange-yellowish Asian cultivars. Clearly breeding has all the potential to further expand the industry by meeting consumer preferences for large fruit, firmness, and high flavor (for both sugar and acids). Our survey indicates that the cherry industry of Turkey, which has just embarked on an ambitious breeding programme, has made the most marked improvement of any country in Europe or Asia. Indeed, given the high marks it gets in the international marketplace, and the fact that Europe is perhaps the world's most selective commercial arena, it may soon be able to harness the best releases from the world's breeding programmes so as to exert a determining influence on cultivar assortment and, hence, market supply.

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Tables

Table 1. Main sweet cherry producers in Europe & Asia (avg 2002/2004; 1000 t/yr). Cherry production decreased from 3% (Asia) to 5% (Europe) as compared to 1999-2001. Source: Faostat.

Europe		Asia	
Country	Production (000t)	Country	Production (000t)
Germany	112.7	Turkey	240.0
Italy	110.1	Iran	222.0
Spain	95.3	Syria	39.7
Russian Fed.	91.7	Lebanon	34.8
Ukraine	77.2	Japan	18.9
Romania	71.9	China	13.8
France	59.5	India	8.0
Greece	45.7	Azerbaijan	5.6
Other	222.7	Other	52.6
Total	886.8	Total	635.4

Table 2. Main cherry parents for breeding programmes in Europe and Asia.

		Main breeding objectives and countries						
		Ripening		Self	Fruit quality			Cracking
Main parents[1]	Origin[2]	Early	Late	fertility	Size	Firmness	Taste	resistance
Adriana	I							I, D
Benishohou*	J	J			J	J	J	
Burlat	F	BG, F, I, RO			CZ		I	
Carmen*	H				H	H	H	
Celeste® Sumpaca*	CDN			LT, I, J	I, LT			
Colney	UK		UK				UK	
Corniola	I		I			I	I	
Durone Nero II	I		I			I	I	
Fercer	F				F	F		
Ferrovia[3]	I, D, H		BG, D, I		BG, I, RO	BG, I	BG, I, RO	
Hongdeng	RC	RC			RC			
Honyan	RC	RC				RC	RC	
Jiahong	RC					RC	RC	
J-no-shizuku*	RC						J	J
Juhong	RC					RC	RC	
Kordia	CZ		RO			CZ, D, I	CZ, D, I	CZ, D
Krupnoplodnaja	RUS				D, H	H	H	
Lapins	CDN		I	CZ, F, I, J			F	
Nannyo*	J				J	J		
New Star	CDN			I, J, RO	I, RO		I	
Regina	D		I, D, F		D	D, I		D, I, F
Satonoishiki*	J				J	J	J	
Skeena*	CDN		I, D	I, D	I	I	I	
Staccato*	CDN		I, D	I, D		I, D	I, D	
Stella	CDN			BG, F, H, I, J				
Summit	CDN		J		D, F, J		F, J, RO	
Sunburst	CDN			H, I, J, LT, RO, UK	I, RO, UK			
Sweetheart® Sumtare*	CDN		I, J	I, J				
Techlovan*	CZ				CZ		CZ, D, I	
Tenkovnisiki*	J				J	J		
Van	CDN						BG, I, RO	

[1]Only parents used in two programmes or for at least two objectives are listed. (According to the international professional nomenclature, the asterisk after the cultivar name means "trademark name" and ® means registered patented genotype name.)

[2]BG=Bulgaria, CDN=Canada, CZ=Czechoslovakia, D=Denmark, F=France, H=Hungary, I=Italy, J=Japan, LT=Lithuania, RC=Rep. China, RO=Romania, RUS=Russian Fed., UK=Ukraine.

[3]Ferrovia group included Schneider, Spate, Noire de Meched, Badacsony

Table 3. Main objectives of the recorded cherry breeding programmes and update selection process at 2005.

Country[1]	Institution	Breeding start (year)	High priority objectives[2]	Total seedling/year	No. selections stage 1	No. selections stage 2	No. cultivar released	Latest released cultivars
Europe								
BG	FGI Plodvid	1987	3, 5, 6, 7, 9, 10, 11, 16, 17	200	49	25	9	Vassilena, Daneliya, Stefaniya
BG	IA Kustendil			250		5		
CZ	Holouvosy	1973	1, 2, 4, 10, 11, 16, 17	50-200	60	11	11	Aranca, Halka, Horka, Korvic, Marta, Silvana, Techlovan, Vanda, Vilma
D	BAZ Dresden	1956	1, 2, 4, 7, 9, 10, 11, 13, 16, 17	400-600	80		10	Nadino, Namare, Namati, Napruni
D	FRI York	1953	1, 2, 8, 9, 16, 17, 23, 24				8	Johanna, Karina, Regina
EST	PHI Karksi	1945	2, 7, 8, 16, 18	80	255	28	16	Kaspar, Polli 6-2 (Anu), Polli (Irma)
F	Private (Paul Argot)						14	Agoudel, Bellise, Big Lory, Coralise, Earlise, Early Bigi, Early Lory, Feu 5, Late Lory, Lory Strong, Lory Strong, Masdel
F	INRA Bordeaux	1980	1, 2, 9, 10, 11, 16	500	50	8	12	Ferdiva, Ferdelices, Ferdouces, Ferlizac, Fermina, Ferpin, Fertard, Folfer
H	RIFO Budapest	1950	1, 2, 5, 6, 8, 10, 11, 16, 17, 21	500		50	12	Alex, Aida, Anita, Carmen, Pal, Peter, Paulus, Petrus, Rita, Sandor, Vera
I	ISF Roma	1968	5				4	Ferrovia Spur
I	DCA Bologna	1983	1, 2, 3, 7, 9, 10, 11, 16	300-800	75	12	6	Black Star, Blaze Star, Early Star, Grace Star, LaLa Star, Sweet Early
I	ISF Verona	1956	7, 8, 9, 11, 13, 16, 23, 25	150	50	1	16	Bargioni 137, Enrica, Giulietta, Isabella
LT	LIH Babtai	1965	1, 3, 5, 7, 10, 12, 13, 16, 17	1000	28	2	7	Auste, Meda, Jurgita, Vasare, Vytenu rozine, Vytenu juodoji, Vytenu geltonoji
RO	RIFG Iasi and Pitesti	1968	3, 6, 7, 10, 16	400		6	18	Ana, Cetatuia, Catalina, Golia, Maria, Marina, Superb, Splendid, Tentant
UK	EMR E. Malling	1982	1,2,3,4,7,8,9, 11,16,17, 18	1000	20		1	Penny

Asia								
J	YARC Yamagata	1957	1, 2, 4, 7, 10, 12, 14, 23	300	4	6	4	Benisayaka, Benihuhou, Benitemari
J	HCAES Hokkaido	1990	1, 2, 3, 4, 7, 11, 16	100			1	HC1
J	KFTRC Aomori	1997	1, 2, 3, 4, 6, 7, 8, 9, 10, 16	200	6	4	1	J-no-shizuku
J	YP Yamanashi		1, 3, 4, 7, 10				1	Fujiakane
RC	FPI Beijing	1960	1, 3, 7, 8, 9, 10, 11, 16, 22	500-1000	10	4	2	
RC	DAI Dalian	1990	1, 3, 8, 9, 10, 11, 16	500-1000	10	5	5	Hongdeng, Hongyan, Hongmi, Jiohong, Johong
RC	Shanddong & Henan	1990	1, 3, 8, 9, 10, 11, 16	500-1000		9		
TR	HRI Yalowa	2004	1, 2, 3, 5, 7	250-2000				

[1]BG=Bulgaria, CZ=Czechoslovakia, D=Denmark, EST=Estonia, F=France, H=Hungary, I=Italy, J=Japan, LT=Lithuania, RC=Rep. China, RO=Romania, TR=Turkey, UK=Ukraine.

[2]FRUIT: 1 Size; 2, Firmness; 3 Flavour; 4 Colour - TREE: 5 Compact habit; 6 Spur Habit; 7 Self-Fertility; 8 Early cropping; 9 Yield
PHENOLOGY: 10 Early ripening; 11 Late ripening; 12 Uniform ripening; 13 Late bloom; 14 Low chill requirement; 15 High chill requirement
RESISTANCE/TOLLERANCE: 16 Cracking; 17 Brown Rot; 18 Black Fly; 19 Cilindrosporium; 20 Cytospora; 21 Leaf Spot;
22 Spring frost; 23 Bacterial Canker; 24 Valsa - OTHER: 25 Easy fruit abscission.

Table 4. Traits of traditional and new cherry cultivars in Europe. Source: Lab CMVF-DCA University of Bologna (Technical assistance: Dott. A. Gaiani and M. Grandi; Mr. R. Correale).

	Ripening date[1]	Weight (g)		Firmness (g)[2]		Soluble solids (%)		Acidity (g/L)[3]	
Cultivar		2004	2005	2004	2005	2004	2005	2004	2005
Rita*	-8		7.9		230		14.9		5.32
Primulat® Ferprime*	-6	6.9	7.4	450	350	16.7	16.1	7.33	6.52
Early Bigi ® Bigisol*	-4	10.0	8.8	340	320	14.4	15.7	5.31	6.48
Sweet Early® Panaro 1*	-2	9.4	9.7	350	280	15.0	14.5	4.50	4.75
Burlat	0	7.4	7.6	360	280	18.0	17.2	5.60	6.03
Ferpin*	+4		8.9		350		16.5		6.13
Vera*	+8	9.5	9.9	480	600	18.0	16.5	7.65	8.13
Grace star*	+10	9.5	10.3	510	460	17.5	19.8	8.52	9.64
Giorgia	+12	8.7	8.9		510	16.7	17.2	8.81	9.93
Celeste® Sumpaca*	+12	8.9	10.3	440	520	14.4	14.6	6.92	8.71
Black Star*	+16	10.1	10.4	470	480	18.4	22.0	7.42	6.03
Aida*	+18	8.8	9.9	830	710	19.4	21.9	7.64	8.31
Techlovan*	+20	10.1	8.4	440	450	20.8	19.9	6.25	7.60
Kordia	+22	8.6	8.7	580	500	19.8	19.9	6.35	6.91
Ferrovia	+24	9.9	10.5	450	460	16.9	16.8	8.04	6.54
Lapins	+26	9.2	9.5	410	440		21.5	6.91	7.45
Regina	+30	10.1	9.7	550	690	18.7	19.2	6.59	7.33
Germersdorfer	+30	10.1	10.6	390	390	16.9	17.4	7.11	6.64
Sweet Heart® Sumtare*	+35	8.5	8.9	580	550	18.6	20.2	8.85	9.05
Alex*	+38	8.5	9.1	480	600	22.7	22.0	9.90	9.75

[1]Days +/- relative to Burlat (May 25, Vignola, Italy)
[2]Penetrometer (6 mm diameter)
[3]Malic acid

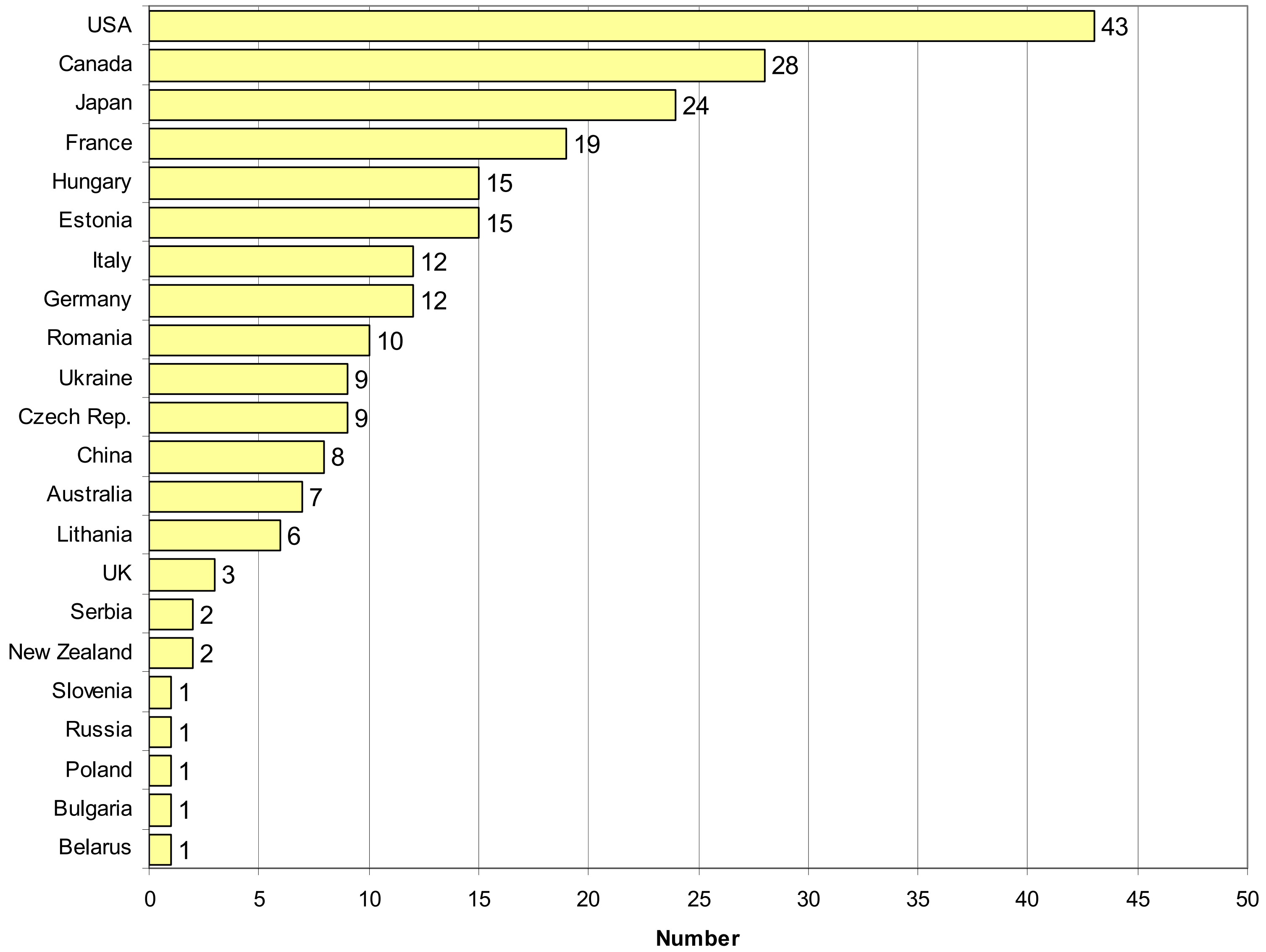
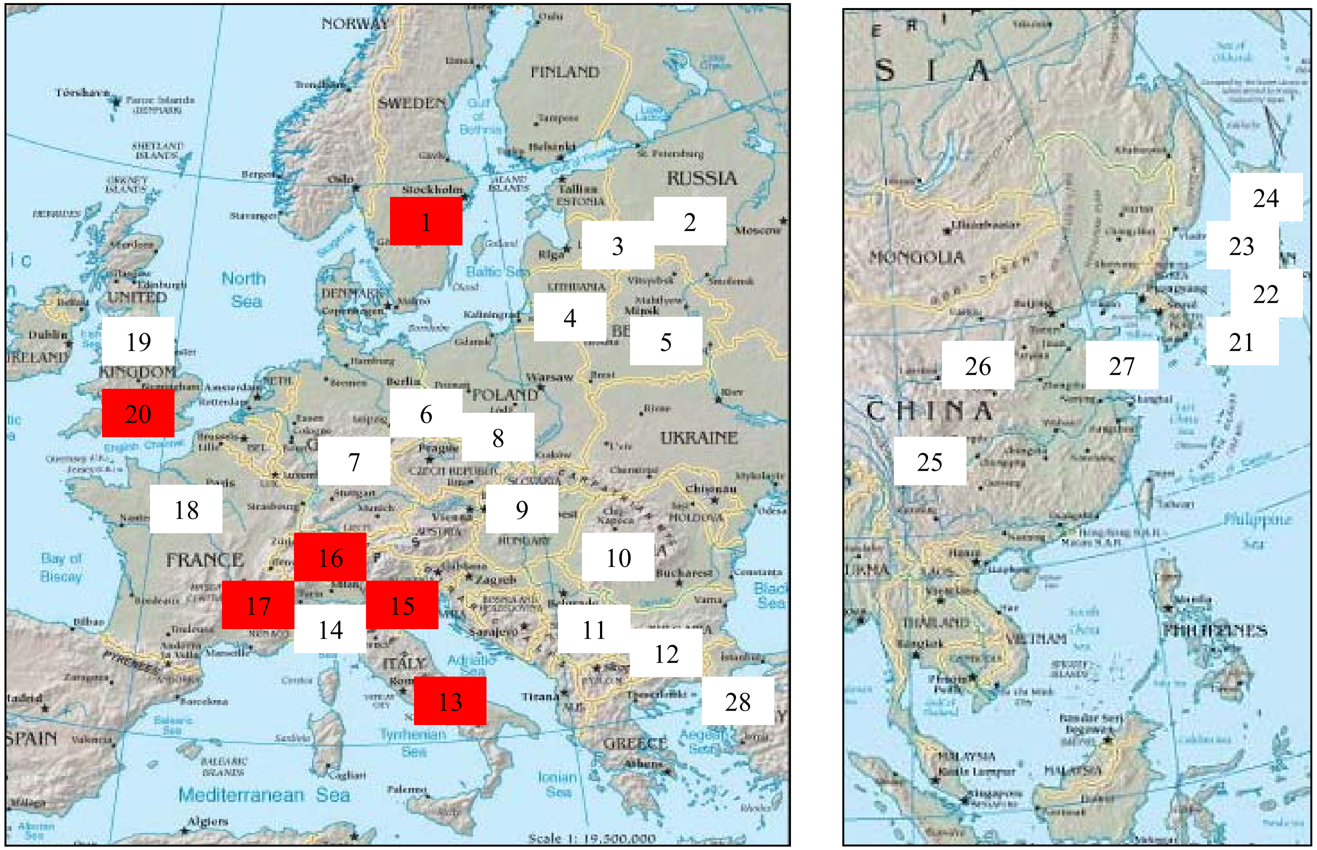


Fig. 1. Number of releases of new sweet cherry cultivars from 1991-2004 (Source: Della Strada and Fideghelli, 2004).

1. Sweeden – Department of horticultural Plant Breeding, Balsquard
2. Latvia – Horticultural Plant Breeding Experimental Station, Dobele
3. Estonia – Polli Research Centre of Horticulture, Karksi
4. Lithuania – Lithuanian Institute of Horticulture, Babtai
5. Belarus – Research Institute for Fruit Growing, Minsk
6. Germany – BAZ, Institute for Fruit Breeding, Dresden
7. Germany – Fruit Research Station, York
8. Czech Republic – Research and Breeding Institute of Pomology, Holovousy
9. Hungary – Research Institute for Fruitgrowing and Ornamentals, Budapest
10. Romania – Research Institute for Fruitgrowing, Pitesti, Iasi, Bistrita
11. Serbia – Fruit and Grape Research Centre, Čačak
12. Bulgaria – Fruit Growing Institute, Plovdiv; Institute of Agricolture, Kyustendil
13. Italy – CRA – Istituto Sperimentale Frutticoltura, Ministry of Agriculture, Roma
14. Italy – Dipartimento Colture Arboree, University of Bologna
15. Italy – Istituto Sperimentale Frutticoltura, Verona Province
16. Switzerland – Swiss Federal Research Station for Fruit-Growing, Vadensvill
17. France – P. Argot and Delbard Pepinières, Commentry
18. France – INRA, Station de Recherches Fruitières, Bordeaux UK – John Innes Institute, Norwich
19. UK – East Malling Research Station, East Malling
20. Japan – Yamagata Agricultural Research Center



21. Horticultural Experiment Station
22. Japan – Hokkaido Central Agricultural Experiment Station
23. Japan – Kennan Fruit Tree Research Center, Aomori Prefectural Agriculture
24. Japan – Yamanashi Prefecture
25. China – Dalian Agriculture Institure, Dalian
26. Forestry and Pomology Institute, Beijing
27. National Hortitucultural Research Institute, RDA, Korea
28. Horticultural research Institute, Yalova

Operating

Ceased

Fig. 2. Site of the main sweet cherry breeding programs in Europe and Asia