Plum Breeding Worldwide

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ADDITIONAL INDEX WORDS. *Prunus domestica, Prunus salicina*

SUMMARY. The status of plum breeding around the world is reviewed. Two distinct types of plums are grown: Japanese-type shipping plums (mostly diploid hybrids of *Prunus salicina* Lindl. with other species) such as are grown in California, and hexaploid or "domestica" plums (*P. domestica* L.), which have a long history in Europe. In recent years there has been a resurgence of plum breeding outside the United States.

Plums are native across much of the temperate area of the world. In most areas early inhabitants long ago selected superior individuals of their local species. As *Prunus* breeders have made progress in improving plum quality and productivity, this native germplasm has been replaced by hybrid clones more suited to modern agriculture. Most plums in commercial production today are classified as Japanese (diploid) or European (mostly hexaploid) types.

Japanese plums

The ancestors of what we call Japanese plums actually originated in China. The term Japanese plum originally was applied to *Prunus salicina* (formerly *P. triflora* Roxb.) but now includes all the fresh-market plums developed by intercrossing various diploid species with the original species. These plums were initially improved in Japan and later, to a much greater extent, in the United States. Production in the United States is concentrated in California.

Historical background

Fortunately for the breeder, there are vast plum genetic resources although often they are not readily available (Okie and Weinberger, 1996; Ramming and Cociu, 1990). *Prunus salicina* cultivation goes back several thousand years in China (Yoshida, 1987) but plum has never been as commercially or culturally important in China as peach [*P. persica* (L.) Batsch.]. Plums in southern China are concentrated in Fujian and Zhejiang, with >20 million trees and ≈200 cultivars grown (Zhang et al., 1990).

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Plum culture in Japan and Korea is also very ancient, such that it is not possible to tell if they were ever part of the native range for plums. Trees of improved *P. salicina* cultivars 'Kelsey' and 'Abundance' were introduced into the United States from Japan over 100 years ago. Luther Burbank intercrossed these and other imports with *P. simonii* Carr. and North American species, resulting in 'Beauty', 'Burbank', 'Duarte', 'Eldorado', 'Formosa', 'Gaviota', 'Santa Rosa', 'Satsuma', 'Shiro', and 'Wickson'. These plums formed the basis for the world's shipping plum industry, and some are still widely grown.

Pure *P. salicina* and related species have been little used as parents since Burbank's early hybridizations and few pure *P. salicina* clones are available outside of China. Most of Burbank's plums are thought to descend from *P. salicina*, *P. simonii* and *P. americana* Marsh. (Howard, 1945). In general, *P. salicina* contributed size, flavor, color and keeping ability; *P. simonii* contributed firmness and acidity (Gomez and Ledbetter, 1994); whereas the American species gave disease resistance, tough skin and aromatic quality. Burbank was fortunate in having available improved native material to supply these characters.

With the advent of Burbank's improved plums that were large and firm enough to ship long distances, a new industry developed in California and local industries in other states mostly died out. As local industries declined, breeding programs were closed (Fig. 1). California-bred plum cultivars were tried around the world, but with the exception of a few places like Chile and some parts of Italy, they did not thrive as well as they did in California. As a result they were crossed with the local plums of the particular area.

In the southeastern U.S., the Japanese plums were crossed with the local *P. angustifolia* Marsh. resulting in plums such as 'Bruce' and 'Six Weeks' (Wight, 1915). Although *P. cerasifera* Ehrh. is a progenitor of European plums, it is a diploid species cross-fertile with Asian and American diploid species. These cherry plums have not been much used in modern breeding although chance hybrids with *P. cerasifera* produced 'Methley' in South Africa and 'Wilson' in Australia. This species provides earliness, cold hardiness and probably self-fertility, but fruit size is small in currently available germplasm in North America.

Unfortunately for modern breeders, only a few of the improved native American selections are still available, since cultivation of native plums is obsolete. New efforts to revive these local plum industries are underway in Kansas with sandhill plum (*P. angustifolia*) by Bill Reid and also by Richard Uva at Cornell University and others in Massachusetts with beach plum (*P. maritima* Marsh.) for fruit and soil conservation. Adapted native species with poor fruit quality such as *P. alleghaniensis* Porter, *P. geniculata* Harper, *P. mexicana* S. Wats. and *P. umbellata* Ell., have apparently been unused by breeders until recently.

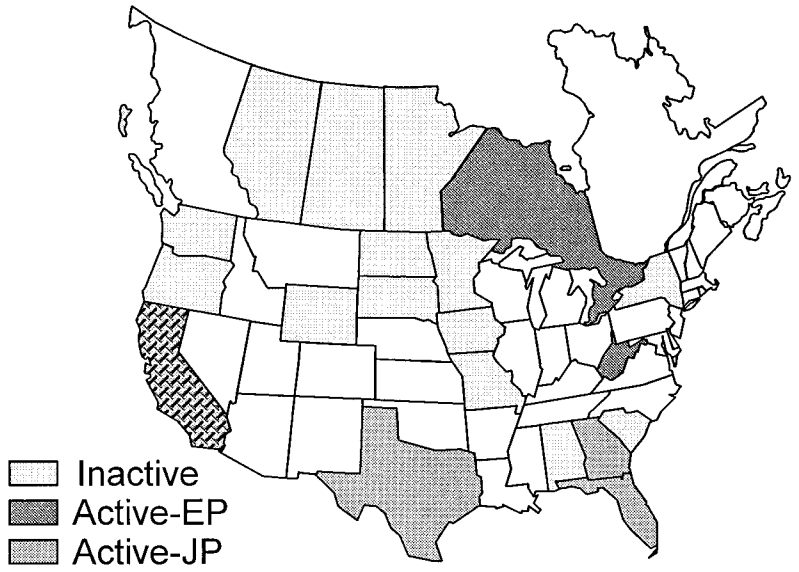

Fig. 1. Active and inactive Japanese plum (JP) or European plum (EP) breeding programs in the United States and Canada. California currently has both types of breeding programs.

Other underused resources include the Lithocerasus subgenus, which is more graft- and cross-compatible with plum than cherry (subgenus *Cerasus* (Adans.) Focke), where it was formerly classified. Fertile hybrids of *P. japonica* Thunb. x plum have been reported from Japan (Kataoka et al., 1988) and produced at Byron, Ga. The small-statured, pubescent-fruited species of the desert southwestern and western United States, are also little used by breeders (Okie and Weinberger, 1996). Plum interspecific hybridization is generally successful between diploids (Anderson and Weir, 1967; Okie and Weinberger, 1996). Plum–apricot (*P. armeniaca* L.) hybrids are easily made and carry flavor components and volatiles from both parents, plus some not found in either (Gomez et al., 1993). A few plumcots have been introduced (see Zaiger and Bradford below) but low productivity has been a problem. Peach–plum hybrids are easy to generate with bee pollination but are usually completely sterile.

Modern breeding objectives and programs

In most plum breeding programs, the principal objective is the development of plums that can be grown successfully in a particular locality and that can be marketed profitably. Trees must be productive, and must be resistant or tolerant to local problems, including hardiness in northern regions, low chilling requirements for buds in southern regions,

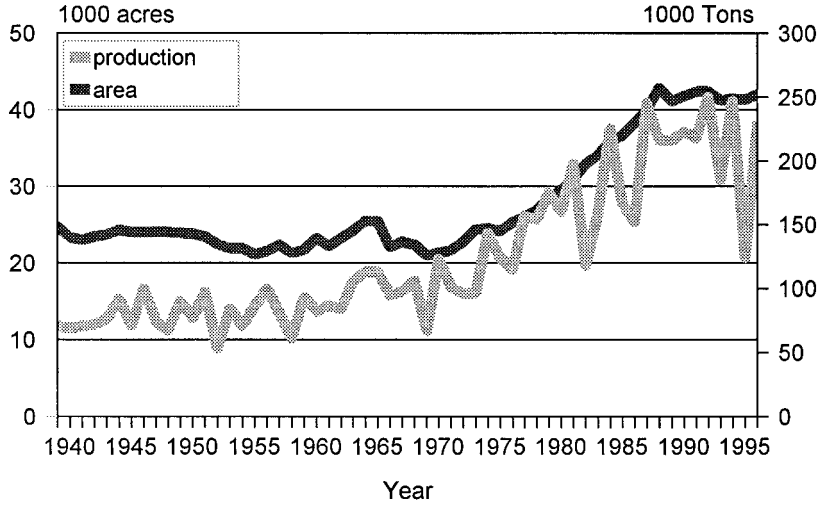

Fig. 2. Japanese plum industry in California. Area and total production 1939–96; 1000 acres = 405 ha, 1000 tons = 907 t.

and resistance to diseases and physiological problems. A saleable fruit must have an attractive appearance, adequate size and firmness, and acceptable flavor and texture.

CALIFORNIA. A shipping plum cultivar is needed for each week of a ripening season, which may continue for as long as six months, although the north–south length of the San Joaquin Valley extends the ripening season of a given cultivar. Production has been stable the last 10 years, after a 50% increase that occurred 1965–1985 (Fig. 2).

The California Tree Fruit Agreement (CTFA) lists 56 cultivars shipped for the fresh market that are regulated by specific rules and an additional 127 minor cultivars have general regulations (CTFA, 1996). Cultivars are given specific regulations when their production surpasses 10,000 packages (28 lb, 12.7 kg), and are removed from specific regulations when production falls under 5,000 packages. The top three cultivars, 'Friar', 'Angeleno' and 'Blackamber' are black and produce ≈40% of the total production (Fig. 3).

The top 10 cultivars have produced 75% of the total production in recent years. The second 10 cultivars add 15% more, but are essentially derived from the same germplasm. Production is predominated by cultivars 20–30 years old or older (Table 1). All 10 cultivars except 'French Prune' (*P. domestica*) and 'Simka' (parentage unknown but probably related to the others) trace back to just five parents, all released by Luther Burbank: 'Santa Rosa', 'Eldorado', 'Gaviota', 'Formosa' and 'Burbank' (Fig. 4).

The degree of consanguinity between the founding clones is not known because of Burbank's sketchy records. 'Kelsey' and 'Burbank' came directly from Japan. The others are hybrids, but could be closely related if only a limited number of parents were used from *P. salicina* and *P. americana* (Howard, 1945). Byrne (1989) reported the average coancestry of California plums to be 0.08, about half that of eastern U.S. freestone peaches (Scorza et al., 1985).

Despite the limited number of founding clones in California plums, remarkable progress has been made in developing a series of large and firm plums suitable for long-distance shipping. Of the new plums in Table 2, only 'Showtime' and 'First Beaut' appear to be making a significant impact on the commercial industry. It is clear from the parentages that many introductions are either mutations or chance seedlings, rather than the result of planned hybridizations.

Breeding by USDA at Fresno, Calif., was begun by John S. Weinberger in the 1950s and is now under the supervision of David Ramming. Over 67,000 seedlings have been grown in that time with six releases. This program released 'Frontier' (1967); 'Friar' (1968), the predominant plum in the industry; 'Calita' (1968), for use in Italy; 'Queen Rosa' (1972); 'Blackamber' (1980), another widely grown plum; and 'Fortune' (1990), a red plum. Black skin color became very popular with the introduction of 'Friar' because it did not show bruises and was very productive with large fruit.

Overproduction and low prices of black plums have increased the interest in red plums. 'Fortune' was selected when black plums were gaining in popularity, and was not desired by the market until recently. Current breeding objectives include ripening from early to late in the season, and large, firm fruit with good shipping ability and eating quality. Red or black skin color and yellow or red flesh color appear to be the most acceptable, al-

Fig. 3. Japanese plum industry in California: top 20 cultivars showing their share of 1996 production. Total 1996 production = 228,000 tons (207,000 t).

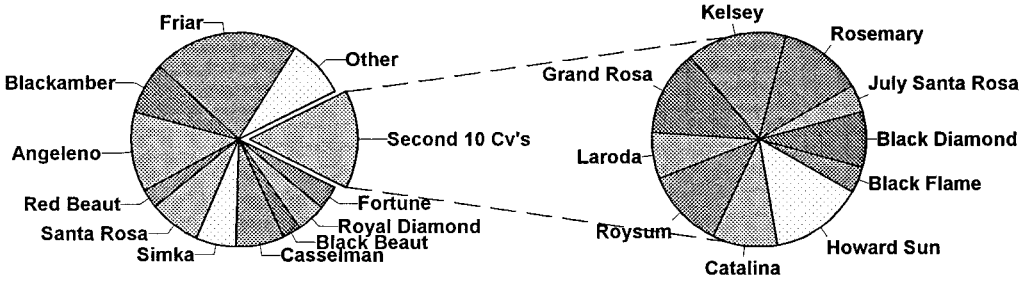

Table 1. Major California Japanese plums, ranked by 1996 production. Origin, release date, and percentage of each is of the total trees planted in the last 6 years. Total trees planted (based on nursery sales) 1991–96 is 676,000 (from California Tree Fruit Agreement, 1990–96). Total production is 228,000 tons (207,000 t).

Cultivar	Nursery sales 1991–96 (%)	Production (%)	Release date	Originator
Friar	3.9	21.8	1968	USDA–Fresno
Angeleno	9.4	11.8	1967	Garabadien
Blackamber	1.5	7.9	1980	USDA–Fresno
Santa Rosa	3.5	7.9	1906	Burbank
Simka	2.4	5.9	1959	Kazarian
Casselman	7.1	4.5	1959	Casselman
Royal Diamond	0.0	4.5	1989	Kitahara
Black Beaut	0.0	2.9	1975	Anderson
Fortune	15.3	3.6	1990	USDA–Fresno
Red Beaut	1.2	3.0	1965	Anderson
Kelsey	6.3	2.2	1870	Japan
Howard Sun	9.0	2.1	1982	Chamberlin
Grand Rosa	1.9	1.9	1959	Anderson
Rosemary	0.0	1.9	1975	Anderson
Roysum	0.1	1.8	1966	Sumruld
Catalina	2.2	1.4	1982	Krause
Black Diamond	1.5	1.2	1982	Superior
Laroda	0.0	1.0	1954	UCD
July Santa Rosa	0.0	0.6	1962	Friesen
Black Flame	0.0	0.6	1985	Superior
Wickson	0.0	0.6	1892	Burbank
Autumn Beaut	0.0	0.5	1993	Zaiger
Prima Rosa	0.0	0.4	1982	Gerawan
Freedom	0.1	0.4	1980	USDA–Fresno
Autumn Giant	0.0	0.4	1986	Zaiger
Queen Rosa	0.0	0.3	1972	USDA–Fresno
Eldorado	0.0	0.3	1904	Burbank
Show Time	8.7	0.0	1992	Wuhl
First Beaut	3.7	0.0	1990	Neufeld
Other cultivars	22.1	8.6		

though green-skinned plums are shipped to Asian markets. Yellow-skinned types will need to be nonbrowning, to slow skin discoloration when bruised. Early ripening cultivars without bitter or acid skin and late season cultivars with desirable storage characteristics and that resist skin cracking are needed. Higher sugar levels at early maturity stages would likely increase consumer preference for Japanese-type plums.

The University of California at Davis (UCD) began plum breeding in 1932 jointly with the USDA. Released were 'Burmosa' (1950), 'Redheart' (1950), 'Laroda' (1954), 'Redroy' (1954) and 'Queen Ann' (1954). 'Durado' was released by UCD alone in 1976. All except 'Redheart' and 'Redroy' have been important commercially. This program is no longer active in Japanese plum breeding.

Private breeders and growers in California have bred or selected (mostly) many important commercial plums. Fred Anderson released 'Red Beaut', 'Black Beaut', and 'Grand Rosa', (Table 1, Fig. 4) in addition to 'Amazon' (1960), 'Ebony' (1961), 'Grandoro' (1964), 'Andy's Pride' (1965), and 'Royal Garnet' (1981). His work has been continued by Norman and Glen Bradford. Their newer plums include 'Black Noble', 'Early Beaut', 'June Beaut', 'Purple Majesty', and 'Red Noble' (Table 2). They also developed plumcots 'Red Velvet' and 'Royal Velvet'.

John Garabedian selected 'Angeleno' (Table 1), which is still increasing in importance. Selections from open-pollinated populations include 'Black Jewel' (1987), 'Gar Jumbo' (1987), 'Santa Rosa-2' (1987), 'Rancho 9-Golden' (1987), 'Gar Red' (1989), 'Rancho Cinco' (1989), and 'Rancho Ocho' (1989).

Floyd Zaiger released 'Autumn Giant' (Fig. 4) and 'Betty Ann' (Table 2), as well as

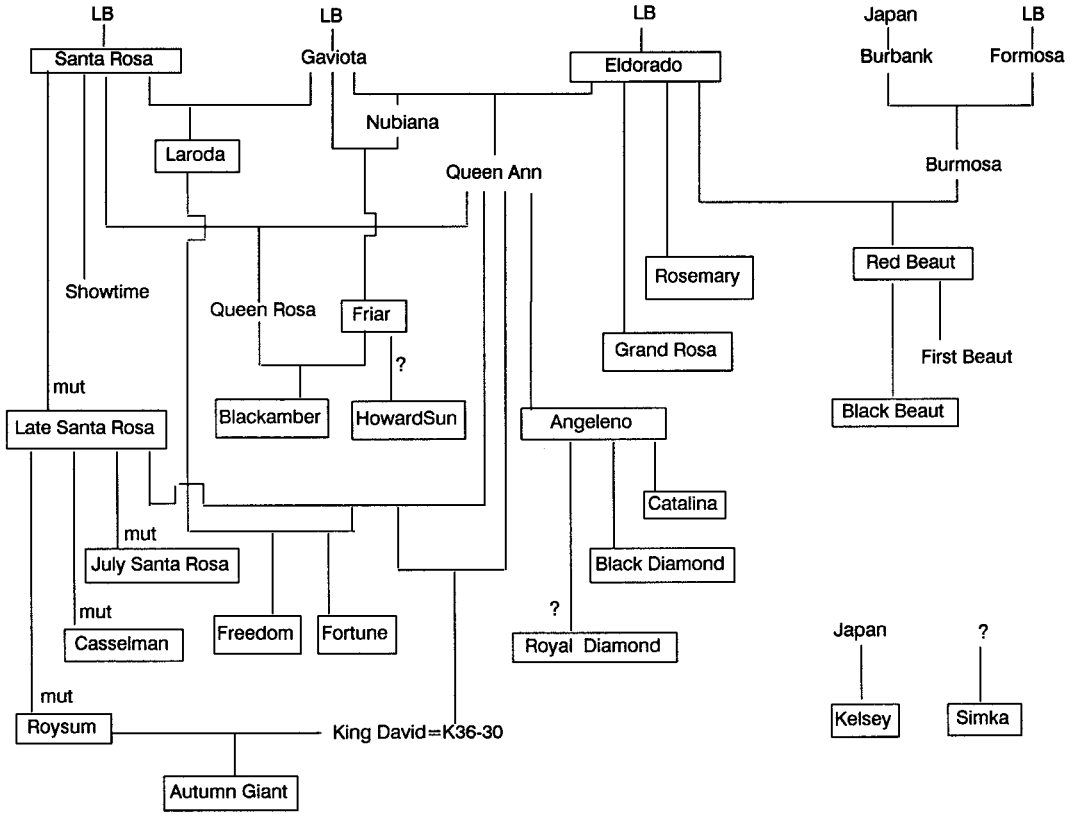

Fig. 4. Genetic relationships of important Japanese plum cultivars in California. Larger box denotes top 10 based on 1996 production; smaller box denotes second 10 ranking. LB = complex hybrid produced by Luther Burbank.

Table 2. Diploid plum and *plumcot* cultivars and selections since 1990. All from California except as indicated.

U.S. plant patent no.	Cultivar	Origin	Ripe date[z]	Skin flesh color[y]	Parentage[x]
			1995 (or later)		
PP10385	Joanna Red	Zaiger	?	r/?	?
PP10277	Teak Gold	Yates	?	p/y	Chance sdlg
PP10116	7-B	Gerawan	20 May	r/y	?
PP09858	Hiromi Red	Zaiger	?	r/?	?
PP09568	Muriettato	Zaiger	?	?	?
PP09513	September King	Chamberlin	15 Sept.	r/?	?
PP09331	Blue Gusto	Zaiger	Late	bl/?	?
PP09254	Dapple Dandy	Zaiger	25 July	bz/dr	(Laroda x Queen Ann) x plumcot
PP09162	Emerald Beaut	Zaiger	2 Aug.	yg/y	Wickson x (Red Beaut op)
PBR-SA[w]	Pioneer?	INFRUITEC-S.A.	5 May	r/y	17-24-185 op (=Laroda op)
PBR-SA	Atlantic?	INFRUITEC-S.A.	10 May	r/y	Laetitia op
PBR-SA	Lady Red?	INFRUITEC-S.A.	18 May	r/y	7-36-168 op (=Songold op)
	#377290	EPAGRI-Brazil	?	ry	Amarelinha x Kelsey
	#	EPAGRI-Brazil	?	r	Amarelinha x Harry Pickstone
	IAPAR 48-Irati	IAPAR-Brazil	6 June	r/y	FS89 x Amarelinha
	Gulfbeauty	Sherman-Florida	19 May	r/r	Fla85-1=complex polycross
	Gulfblaze	Sherman-Florida	3 June	r/y	Fla87-7=complex polycross
	GB92-26	Topp-Australia	10 June	r/yr	Wade x Santa Rosa
GB83-74	Topp-Australia	20 July		r/y	Doris op x GB2-46
			1994		
PP09022	Primetime	Wuhl	7 July	pr/yr	Challenger x Showtime?
PP08969	Bradprune	Bradford	4 Aug.	dr/y	unnamed selection op
PP08955	Early Rosa	Wilson	14 June	dr/y	Late Santa Rosa mut
PP08922	*Flavorglo*	Zaiger	22 May	y/y	Red Beaut op op
PP08913	Atlas	Zaiger	Aug 22	y/y	Nemaguard x (Jordanolo alm x P.blireiana)
PP08912	Viking	Zaiger	Aug 20	w/w	Nemaguard x (Jordanolo alm x P.blireiana)
PP08864	Melrose	Kamada	1 June	pr/y	Ambra mut

Table 2. (Continued) Diploid plum and *plumcot* cultivars and selections since 1990. All from California except as indicated.

U.S. plant patent no.	Cultivar	Origin	Ripe date[z]	Skin flesh color[y]	Parentage[x]
			1994		
PP08693	Summer Treat	Nilsson	14 July	dr / yr	Santa Rosa mut?
PP08583	Earliqueen	Zaiger	25 May	dr / y	Zaiger 61EC540 op(=unknown)
PP08557	Sweet Queen	Vart	1 July	g / yg	Queen Ann mut
PP08546	*Flavorich*	Zaiger	15 Sept.	rp / o	Friar x ((Autumn Giant x Queen Ann) x plumcot)
	Black Ruby	USDA–Byron	15 June	rb / y	(Queen Ann x Santa Rosa) op
	Cirena-1	Rodriguez-Mex		r / y	Cirena (=Fla85-1) x Santa Rosa
	Corazon Rojo	Rodriguez-Mex		r / r	Fla.86-4 (=F4 of polycross)
			1993		
PP09488	Bradgreen (Greensweet)	Bradford	3 Aug.	g / g	Black Beaut op op
PP08471	Betty Anne	Zaiger	24 Aug.	r / y	(Friar x (Mariposa x Ebony)) x Autumn Giant
PP08470	*Flavorella*	Zaiger	5 June	y / y	Red Beaut op op
PP08393	*Tri-Lite*	Zaiger	20 June	lr / w	O'Henry op x (Red Beaut x peach)
PP08363	Suplumtwenty	SunWorld	14 June	rb / y	Suplumeleven x Queen Rosa
PP08189	Autumn Beaut	Zaiger	10 Sept.	rb / y	Roysum op x Eldorado
PP08103	Compact Friar	Wong	20 July	b / y	Friar mut
PBR-SA	Souvenir	INFRUITEC-SA	20 June	p / y	Songold op
	Sui Li 3	Wu-China	?	?	?
			1992		
PP08069	Green Jade	Taylor	25 May	yg / y	Wickson op
PP08068	Prima Black Plum 8-15	Gerawan	7 Aug.	pr / y	Chance sdlg
PP08067	Prima Black Plum 5-25	Gerawan	1 June	p / y	Chance sdlg
PP08057	Prima Red Plum 9-1	Gerawan	10 Sept.	dr / y	Chance sdlg
PP08038	Crimson Nugget	Matoba	18 May	dr / y	Red Beaut op
PP08037	Showtime	Wuhl	18 June	pr / r	Santa Rosa op
PP08026	Flavor King	Zaiger	5 Aug.	r / y	(Mariposa x (Red Beaut op)) x (Red Beaut op)
PP07975	Red Noble	Bradford	26 May	dr / y	unnamed selection op
PP07896	Black Jack	Zaiger	18 June	b / y	Friar op
PP07858	Akihime	Kojima-Japan	15 July	pr / y	chance sdlg
PP07843	Autumn Pride	Zaiger	27 Sept.	p / y	Friar x (Mariposa x Ebony)
PP07827	October Sun	Chamberlin	20 Sept.	yr / y	chance sdlg
PP07765	Red Nugget	Matoba	10 May	r / r	Red Beaut op
PBR-SA	Sapphire	INFRUITEC-SA	6 June	p / y	Laroda irradiated op
	Changli #15	Li-China	Early	r	Sueilinghong x Meiguoli
	Changli #84	Li-China	Mid	r	Liuhaoli x Siguolii
	Changli #109	Li-China	Mid	r	Liuhaoli x Siguolii
			1991		
PP07574	Black Premium	SunWorld	20 June	rb / y	Queen Rosa x Eldorado
PP07504	Black Noble	Bradford	8 June	pr / r	Red Beaut x?
PP07503	Purple Majesty	Bradford	19 June	pr / y	Red Beaut x ?
PP07474	Golden Globe	Zaiger	31 Aug.	y / y	Laroda x Queen Ann
PP07443	Red Giant	SunWorld	28 May	pr / r	Queen Rosa op
PP07431	*Royal Velvet Plum-cot*	Bradford	24 May	pr / yo	chance sdlg
PP07420	*Flavor Queen*	Zaiger	20 July	y / y	Mariposa x (Red Beaut x cot)
			1990		
PP07355	Tokay Red	SunWorld	11 June	b / y	Queen Rosa op
PP07348	Bill Hengst October Gem	Hengst	1 Oct.	r / y	Chance sdlg
PP07335	First Beaut	Neufeld	15 May	rp / y	Red Beaut mut
PP07192	Royal Star	Kitahara	15 Aug.	db / lr	Chance sdlg
PP07159	Gar-Belmont	Garabedian	1 June	dr / y	chance sdlg
PP07148	Jake's Best	Garabedian	27 May	dr / r	Chance sdlg
PP07119	Gypsy Red	Taylor	5 Aug.	pr / r	Elephant heart op

[z]Ripe date for Santa Rosa on ≈31 May in Fresno, Calif., area.
[y]Colors (skin and flesh): b = black, bz = bronze, d = dark, g = green, l = light, o = orange, p = purple, r = red, w = white, y = yellow.
[x]Seedling = sdlg, open-pollinated = op, mutation = mut.
[w]PBR–SA = Plant Breeders Rights in South Africa.

'Rosemary' (1975), 'Rose Zee' (1984), 'Dolly' (1987), 'Royal Zee' (1985), 'Mid Red' (1986), 'Blue Giant' (1989), 'Golden Globe' (1991) and others. He has been a leader in development of complex interspecific hybrid rootstocks, such as 'Citation', 'Viking', and 'Atlas'. He also has been very active in the development of plum–apricot hybrids and back crosses, such as 'Flavor Delight' and 'Flavor Supreme' and newer ones listed in Table 2, which are marketed using his trademarked terms "Aprium" and "Pluot". Improved taste is a current goal of their breeding. 'Flavorich', with black skin and firm, flavorful, fine-textured orange flesh, is quite promising for fruit quality.

Breeders John Weinberger, Carlos Fear, Bruce Mowrey, and David Cain at Sunworld International (formerly Superior Farms) have patented 'Black Gold' (1980), 'Black Diamond' (1982), 'Black Torch' (1984), 'Sweet Rosa' (1984), 'Black Flame' (1985), and some newer ones (Table 2). Their program has been the largest of the private breeders, but recent reorganizations make future plum breeding uncertain (D. Cain, personal communication). As with most private programs, the releases are patented and often exclusively grown as well.

Tom Chamberlin (now with Ito Packing) worked for H. P. Metzler's operation and selected plums from large lots of open-pollinated seedlings of standard cultivars. He named 'Anna Sun' (1986), 'Ebony Sun' (1986), 'Howard Sun' (1987), 'Midnite Sun' (1987), 'Scarlet Sun' (1988), and 'October Sun' (1992).

SOUTHERN NORTH AMERICA. Objectives in the southeastern United States (Georgia, Alabama, Texas, Florida) include those of California plus additional disease resistance. Fruit firmness is somewhat less important because many local markets are available. Resistance is required to three primary diseases: bacterial leaf spot, fruit spot and twig canker caused by *Xanthomonas campestris* pv *pruni* (Smith) Dye; bacterial canker caused by *Pseudomonas syringae* pv *syringae* van Hall; and plum leaf scald caused by *Xylella fastidiosa* Wells. The first two diseases are problems in many other countries that are trying to grow Japanese plums, such as Australia, New Zealand, Italy, and South Africa (Topp et al., 1989). Leaf scald is also a serious problem in Argentina and Brazil. In general, later bloom is more desirable but regions such as Florida (Topp and Sherman, 1990) and parts of Texas, Australia, and Brazil require even lower chilling requirements than those common in Japanese plums. 'Frontier' is the only California plum grown to any extent commercially in the southern United States. 'Fortune' is also surprisingly productive and moderately healthy in Georgia, in contrast to the short-lived 'Blackamber'. 'Angeleno' survives fairly well although the fruit rarely hangs on the tree long enough to ripen properly.

Victor Prince began testing plums in 1958 at Fort Valley, Ga., and started making crosses in 1964 after the USDA facility moved to Byron. Much of the early seed for evaluating came from John Weinberger in Fresno, Calif. Unfortunately the large attractive California plums would not survive in the humid climate of Georgia. This California plum germplasm was crossed with southern varieties such as 'Morris', 'Methley', 'Bruce' and the native *P. angustifolia* (Fig. 5). Jim Thompson continued the plum breeding from 1972–86, followed by W.R. Okie. Since 1964, >40,000 plum seedlings have been grown resulting in 'Robusto' (1980) and 'Segundo' (1984), early plums sold green; 'Explorer' (1980), a firm but unproductive black plum; 'Byrongold' (1985), a yellow plum with vigorous tree; 'Rubysweet' (1989), a high-quality blood-fleshed plum; and 'Black Ruby' (1994), a firm dark-skinned plum. Current goals are to combine good quality, large, firm fruit with consistent production on a healthy long-lived tree. About 4000 seedlings per year are grown, with most prescreened for vigor in the greenhouse. Most of the advanced selections are highly resistant to *Xanthomonas* and *Pseudomonas* but only tolerant of leaf scald, which can ultimately kill them. Late blooming is needed to ensure a crop every year. Only a few selections have most of these desirable characteristics, and for some seasons good selections do not exist. Much of this adapted plum germplasm is also being used for rootstock development (for both peaches and plums) by T.G. Beckman.

A second long-term breeding program has been conducted at Auburn University in Alabama (Fig. 5), where Joe Norton began in 1955. Releases are 'Crimson' (1973), 'Purple'

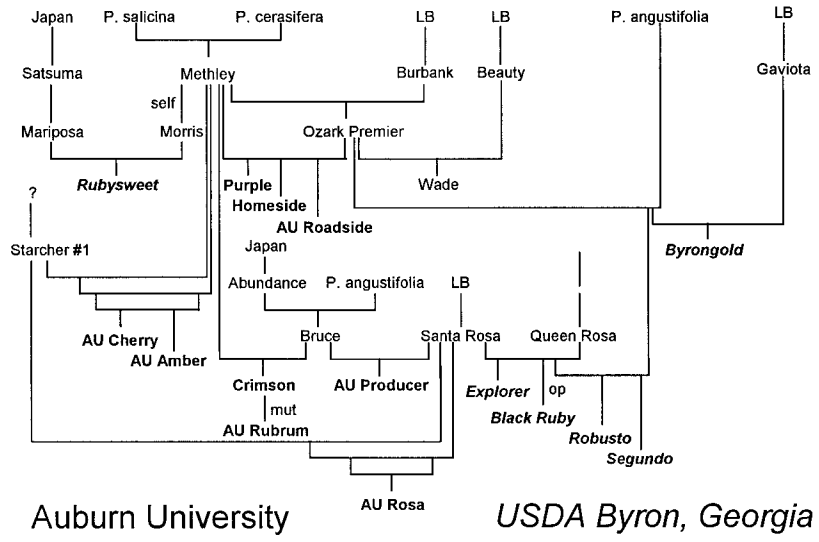

Fig. 5. Genetic relationships of important Japanese plum cultivars developed in the southern United States. Auburn University cultivars in bold; USDA–Byron cultivars in bold-italic. LB indicates complex hybrid produced by Luther Burbank.

(1973), 'Homeside' (1975), 'AU-Producer' (1977), 'AU-Roadside' (1984), 'AU-Cherry' (1989), 'AU-Amber' (1989), 'AU-Rosa' (1989) and 'AU-Rubrum' (1989). While most have improved disease resistance, only 'AU-Rubrum' has size and firmness adequate for commercial shipping. Breeding has been discontinued with the recent retirement of Norton.

Limited breeding was done at several other locations in the eastern U.S. (Fig. 1). In the 1940s the Missouri State Fruit Experiment Station released 'Bonnie', 'Brilliant', 'Marvel', 'Ox-Heart', 'Ozark Premier', 'Redbud', and 'Twilight'. 'Ozark Premier' has been widely grown in the southeastern United States for its large fruit size but tree health of it and its first-generation offspring (Fig. 5) is marginal. 'Wade' was released in 1974 by Clemson University in South Carolina and also has been grown in the southeastern United States. Both these programs are now closed. 'Morris' (Fig. 5), another popular southern plum, was also released in 1974 from Texas A&M University. Plum breeding there has been renewed by David Byrne who has been intercrossing USDA–Byron plums with others to develop cultivars with a slightly lower chilling requirement. Byrne has been a leader in the use of isozymes and genetic markers to distinguish cultivars, verify parentages, and determine the relationships between plum species.

Wayne Sherman at the University of Florida has been developing low-chill plums for several decades, intercrossing USDA–Byron selections, low-chill imports from Taiwan (such as 'Hungyou Li'), and local selections including *P. angustifolia*. Two old, discarded selections have been propagated by local nurseries under the names 'Gulf Gold' and 'Gulf Ruby' (Sherman and Lyrene, 1985). The newest Florida selections have much better fruit size and quality than locally grown plums, but susceptibility to plum leaf scald remains a concern (Sherman et al, 1992; Topp and Sherman, 1990). With the release of 'Gulfbeauty' and 'Gulfblaze' in 1997, the work is being phased out.

A modest plum breeding program at Chapingo, Mexico, was initiated in the early 1980s by Jorge Rodriguez-A. The major goal is development of large, firm-fleshed cultivars adapted to subtropical climates. Two low-chill cultivars were released in 1994, 'Cirena 1' and 'Corazon Rojo', both developed from Florida selections.

NORTHERN NORTH AMERICA. None of the public breeding programs developing cold-hardy plum hybrids are still active (Fig. 1). Many cultivars were released before 1950, especially from South Dakota and Minnesota Agriculture Experiment Stations, using the most cold-hardy plum species: *P. nigra* Ait., *P. besseyi* Bailey, and *P. salicina* (from Manchuria) (Kadir and Proebsting, 1994). 'Sapa' (=*P. besseyi* x 'Sultan') and its many hybrid offspring, although poor in quality, are widely adapted. These hybrids are often called "cherry plums", the same term used for *P. cerasifera*, and are now used more for rootstock development than for fruit production. The University of Minnesota breeding program, long inactive, recently released an old selection as 'Alderman'.

Plum crosses were made at Iowa Agricultural Experiment Station but the only hybrid released was 'Lantz' in 1958. New York and Ontario, Canada, have also had Japanese plum breeding as a minor adjunct to the European plum breeding. 'Vanier', was released by Ontario in 1984. Neither program has continued Japanese plum breeding. The most important northern cultivar has been 'Early Golden', a chance seedling found in Ontario >50 years ago but still widely grown. Other programs developing cold-hardy stone fruit were the Horticultural Experiment Station, Brooks, Alberta; Dominion Experiment Station, Morden, Manitoba; USDA Northern Great Plains Field Station, Mandan, N.D.; and the University of Saskatchewan, Saskatoon, Saskatchewan (Okie and Weinberger, 1996). Modest efforts to improve northern plums have been continued by private individuals and Brian Smith at the University of Wisconsin at River Falls.

SOUTH AMERICA. Brazil has five Japanese plum breeding programs in traditional plum-producing areas, with chill requirements ranging from 200 to 500 h. An older program at the Instituto Agronomico de Campinas under Fernando Campo-Dall'Orto and Mario Ojima develops red-fleshed plums adapted to the warm areas around Sao Paulo (≈200 h of chilling). The primary disease problem is leaf rust. Low-chilling Japanese plums have been released: 'Carmesim' (1973), 'Rosa Paulista' (1978), 'Grancuore' (1978), 'Gema-de-ouro' (1979), 'Golden Talisma' (1979), 'Rosa Mineira' (1983), 'Januaria' (1985), 'Kelsey-31' (1987) and 'Centenaria' (1989). Most of these are seedlings of 'Kelsey Paulista', which was a local selection of 'Kelsey' (Ojima et al., 1992).

Roberto Hauagge at the Instituto Agronomico de Parana in Curitiba, Parana, Brazil has a large (30,000 seedlings) but young program to combine resistance to leaf scald and bacterial spot with moderate chill (200 to 500 h). Byron germplasm tested there shows good disease resistance but is not low-chill enough for reliable cropping.

In Santa Caterina, breeder Emilio Dela Bruna with EPAGRI (Empresa De Pesquisa

Agropecuaria E Extensao Rural) in Urussanga, Brazil has produced 20,000 seedlings from crosses of local plums such as 'Amarelinha' with imports like 'Kelsey' and 'Methley'. The chilling requirement here is only 250 h, less than that needed at a similar but smaller program run by Jean-Pierre Ducroquet in Videira (Ducroquet, 1994). Both need high levels of disease resistance to bacterial spot and leaf scald.

At EMBRAPA/CPACT (Empresa Brasileira de Pesquisa Agropecuáária / Centro de Pesquisa Agropecuáária de Clima Temperado) in Pelotas, Rio Grande do Sul, Brazil, Bonifacio Nakasu and Maria Raseira have a small program to develop 300 h plums with resistance to bacterial spot and leaf scald (Nakasu et al., 1981). Releases include 'Pluma 7' (='The First' x 'Santa Rosa') and 'Pluma 2' ('Satsuma' open-pollinated).

OTHER SOUTHERN HEMISPHERE. In South Africa plum breeding is done by Chris Smith and Michael Oosthuizen at the Infruitec Centre for Fruit Technology. Their program has released a series of plums to satisfy their shipping industry. The goal is development of large-fruited plums with resistance to bacterial spot and bacterial canker, and the ability to store without internal breakdown. Storage ability of four weeks is crucial to exporting the fruit by ship. Plums also need a moderate chilling requirement to enhance crop set in lower chilling areas of South Africa. Releases are 'Songold' (1972), 'Harry Pickstone' (1973), 'Reubennel' (1978), 'Redgold' (1979), 'Laetitia' (1985), 'Celebration' (1989), 'Sapphire' (1992) and 'Souvenir' (1993). Pending releases are in Table 2. 'Celebration' is their first black-skinned cultivar. These cultivars represent a slightly different gene pool for breeders because of the use of local cultivars 'Methley' and 'Golden King' as parents (Fig. 6). Several of these plums are being used as parents in Brazil and elsewhere.

Plum breeding in Australia, under the direction of Bruce Topp at the Granite Belt Horticultural Research Station in Queensland, was begun in 1967. 'Queensland Bellerosa' ('Burbank' x 'Santa Rosa') and 'Queensland Earlisweet' ('Early Jewel' x 'Early Gem') were named in 1988. The latter plum is descended from local cultivars with at least partly *P. cerasifera* parentage. Impending releases are listed in Table 2. Their goals are large sized, early ripening, high quality fruit suitable for export to Asia, combined with resistance to bacterial spot and blemishes due to summer rainfall (Topp and Russell, 1989). Most of the latest research on bacterial spot resistance in plum has been done by Topp. An intense prescreening is done in the greenhouse to eliminate the most spot susceptible

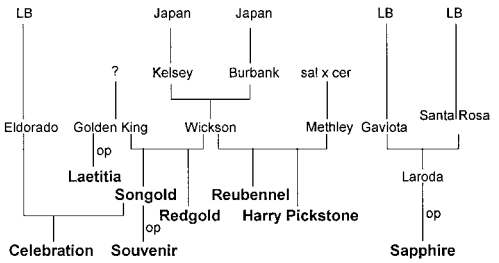

Fig. 6. Genetic relationships of important Japanese plum cultivars developed in South Africa (in bold). LB indicates complex hybrid produced by Luther Burbank. Golden King may have come from Australia.

seedlings before they are planted to the field (Russell et al., 1992; Topp et al., 1993). This is a large program, with over 30,000 seedlings now in the field.

In New Zealand, Mike Malone of HortResearch has begun a small plum and plumcot breeding program to develop disease-resistant cultivars suited for local use and export. Existing seedlings are open-pollinated populations from 'Flavorella' and other plumcots, as well as from local plum selections.

EASTERN EUROPE AND ASIA. In Japan, most new cultivars have come from private sources. Most prominent is the program of Mr. Ohishi, who has released 'Ohishi-Nakate' and 'Ohishiwase' among others. Yukio Kanno recently released 'White Queen', 'Beniryouzen', and 'Ryozenwase'. Other new cultivars are 'Shichiro' and 'Pararu'. Much of the 9900 acres (4000 ha) of commercial production is from U.S. cultivars such as 'Santa Rosa', 'Sordum' ('Sultan'), and 'Beauty'. 'Methley' is also popular. Masami Yamaguchi at the Fruit Tree Research Institute in Tsukuba has a small plum breeding program, with two releases, 'Tsukuba No. 4' and 'Tsukuba No. 5' (both= 'Sordum' x 'Nishida').

Breeding in China is apparently limited to the colder regions. A large germplasm collection has been made for plums under Zhang Jia-Yan at Liaoning. In Changchun, Jilin, Li Feng has developed several selections, including Changli #15, Changli #84 and Changli #109 (Table 2) (Li, 1993). A second program in Heilongjiang Province has released a new cold-hardy plum 'Sui Li 3' (Wu, 1993). Breeding to improve *P. humilis* Bge. for size and quality is being done by Du Junjie at Taigu, Shanxi (Du et al., 1993).

In Korea, the National Horticultural Research Institute in Suweon began a small program in the late 1980s, but no new cultivars have been released. The principal objective in the plum breeding program is the development of new early-ripening cultivars that have high sugar content and large fruit.

Primary parents are also the most popular cultivars: 'Oishi-wase', 'Formosa', 'Santa Rosa', and 'Soldam'.

Plum breeding began just 5 years ago in Thailand with goals to develop 100 to 400 chill hour cultivars with good size, flavor and firmness and long shelf life. Parents include 'Gulf Ruby', Australian selections, and Taiwanese selections. The work is cooperative between the Royal Project Foundation and Kasetsart University, under the direction of Unaroj Boonprakob. A program with similar objectives was also started at the Taiwan Agricultural Research Institute in Wu-Feng by Wen Jen-Chie, but currently managed by Shyi-Kuan Ou.

In Siberia and Krasnodar Territory of the USSR, cold hardiness is the primary goal (Burmistrov, 1992). Despite the relatively lower chilling requirements of many Japanese plums, midwinter tree and bud hardiness is quite high, often higher than for peaches (Quamme et al., 1982). New cultivars include 'Altaiskaya Yubileinaya', 'Katunskaya', 'Kulundinskaya', 'Amurskaya Rannaya', 'Rassvet Rannii', 'Tikhookeanskaya', 'Urozhainaya Dalnevostochnaya', and 'Khabarovskaya Rannaya'. These types are extremely cold hardy. In Krymsk, Eremin has had a large program using interspecifics to develop cold-hardy plums. Winter-hardy, disease-resistant diploid releases include 'Kubanskaya Kometa' ('Kuban Comet'), 'Puteshestvennisa' ('Traveler') and 'Neberjaiskaya Early'. Several of these diploid cultivars have recently been imported into the U.S. for testing. A new program in Latvia has named three hybrids of *P. ussuriensis* Kov. & Kost. x *cerasifera* (Table 2) (Ikase, 1992).

WESTERN EUROPE. Japanese plum breeding in Europe is relatively new but will be important as demand continues to increase for the large-fruited Japanese plums. Antonino Nicotra at Istituto Sperimentale Frutticoltura in Rome, Italy has selected a compact-sized tree with good fruit using X-ray treated pollen. Smaller trees are desirable to reduce production costs. A small program at Forli, Italy, under Alessandro Liverani has also selected some dwarf types. He has crossed California plums with local types. Goals are large size, a range of skin and flesh colors, bacterial spot resistance, and good eating quality. Silverio Sansavini and Salvatori Martelli aim to develop plums for the area around Bologna, Italy where spring weather makes pollination difficult and productivity low. Initial crosses were between local myrobalan cultivars (for reliable cropping) and Japanese plums. Backcrosses to the Japanese side are needed to improve fruit quality and size, and extend the season. The program of Elvio Bellini and V. Nincetti at Florence, Italy, is larger in size. The goals are to develop self-fertile, late-blooming plums with high quality, particularly yellow-skinned types. Self-fertility would improve productivity and facilitate genetic analyses. Their most valuable cross has been Black Gold x Burmosa, and several thousand seedlings of this combination have been produced. To overcome problems with seed germination, all the seeds are embryo-cultured.

H. Duval at Institut National de la Recherche Agronomique in Avignon has begun plum breeding for southern France, where the plum production area is now ≈6200 acres (2500 ha) (Duval et al., 1994). Poor weather during pollination is a major problem, so improved productivity is a primary goal. Resistance to plum pox (sharka) virus and European stone fruit yellows (ESFY, formerly called chlorotic leaf roll) phytoplasma is also important. Japanese plums such as 'Red Beaut' seem less susceptible to plum pox, although they can serve as sources of inoculum. However, California plums are very susceptible to ESFY. *Prunus cerasifera* seems to be resistant to ESFY, but first generation selections of Afaska (=*P. cerasifera*) x Harry Pickstone have been too small in the first generation. The project is still evaluating advanced selections and introduced varieties, but no new hybrids are being made.

European plums

European plums (*P. domestica*) are generally adapted to cooler regions, and may be eaten fresh or processed in a variety of ways. U.S. production is mainly in California, but small amounts are also grown in Idaho, Washington, Oregon, Michigan, and New York for both fresh and canned use. European plums with a high enough sugar content so that they can be dried unpitted are called prunes. In some countries the term prune refers to the dried product; elsewhere the term refers to the fresh fruit as well. Most prune production in California and elsewhere is of 'French Prune', also called 'Prune D'Agen', 'Petite Prune' or 'Prune D'Ente'. In contrast to Japanese plum production in the United States, the California prune industry continues to expand.

Historical background

Prunus domestica has been the most important plum species historically. Crane and Lawrence (1956) thought it originated in Asia Minor as a triploid hybrid between *P. cerasifera* and the tetraploid *P. spinosa* L., which then doubled to produce a fertile hexaploid. More recently, Eremin (1991) proposed *P. spinosa* resulted from *P. cerasifera* x *P. microcarpa* C.A. Mey. while *P. domestica* is

P. spinosa x *P. cerasifera macrocarpa*. Newer cytological work (Reynders-Aloisi and Grellet, 1994) suggested *P. spinosa* itself carries the genome from *P. cerasifera* plus a second one from an unknown ancestor that was not *P. microcarpa*. Thus *P. domestica* may be descended from polyploid forms of *P. cerasifera*, which has a long history of local use and selection across the continent, and occurs in a range of fruit color and palatability. Although sometimes used for drying and processing, most wild *P. spinosa* fruit are bitter. It ranges from Scandinavia across Europe to Asia Minor.

Plums have been a commonly grown garden tree in Europe since the first century A.D. Several cultivars known in 1597 are still grown, such as 'Reine Claude'. One of the earliest plum breeders was Thomas Andrew Knight in England, whose work encouraged nurseryman Thomas Rivers who released 'Early Rivers' in 1834, followed by 'Early Transparent Gage', 'Czar', 'Monarch' and 'President'. By the early 1900s, plum breeding was being carried out at research stations at Long Ashton (later East Malling) and John Innes (Roach, 1985). In other European countries local selections of the older cultivars were made and became established, but little formal breeding was done until later.

Modern breeding objectives and programs

Whereas most Japanese plums are shipped for fresh, dessert use, European Plums may be eaten fresh, canned, dried, processed for cooking use or distilled into brandy (Ramming and Cociu, 1990). Each use requires different selection criteria in the breeding program. Current programs seem to favor dessert use, with only a few for dried fruit (Table 3).

NORTH AMERICA. One of the oldest European plum breeding programs is that of the Horticultural Research Institute of Ontario in Vineland, Ontario, Canada, which was under the supervision of G. Tehrani until his recent death. Objectives are to develop high-quality dessert plums ripening in late August to complete a sequence of plums ripening from July to October. Selection criteria are cold hardiness, productivity, and blue color (Tehrani, 1990). They released six fresh market cultivars: 'Valor' (1967), 'Verity' (1967), 'Vision' (1967), 'Veeblue' (1984), 'Voyageur' (1987) and 'Victory' (1992), all of which are commercially planted in Ontario. 'Voyageur' provides a self-fertile, early-ripening plum extending the season before 'Stanley'.

The New York Agricultural Experiment Station at Geneva has also been an important source of plum cultivars. Releases include 'Hall' (1923), 'American Mirabelle' (1925), 'Stanley' (1926), 'Albion' (1929), 'Iroquois' (1966), 'Mohawk' (1966), 'Oneida' (1966) and 'Seneca' (1972). 'Stanley', the most successful, is grown around the world, and is the basis of the current New York industry. New releases are 'Castleton', 'Longjohn' and 'Polly', all dessert plums (Table 3). A few other selections from Geneva are still under test by Bob Andersen and may be released, but no breeding is expected in the future. These selections include a 'Mirabelle'-type for processing (NY858), a 'Damson'-type for jam (NY58.911.1), two fresh market plums (NY1456, an improved 'Yellow Egg'-type and NY77.610.1), two selections for infant food puree and canned or frozen uses (NY6 and NY9) and two supersweet prune plums for fresh eating (NY71.385.1 and NY71.387.1).

UCD has renewed plum breeding under the direction of Ted DeJong to develop prunes ripening before and after 'Improved French Prune'. New cultivars must resemble and perform like 'Improved French' in order to fit standard production practices for dried fruit. Self-pollinated seedlings of 'French Prune' display uniformly poor fruit quality, thus it is being crossed with other parents. 'Emperor' was recently released for dessert use, but no new prunes are near release.

At Prosser, Wash., USDA and later Washington State University conducted limited breeding from 1949–75. Harold Fogle and later Tom Toyama made crosses to replace 'Early Italian' with higher fruit quality and a range of ripening times. Primary parents were 'Italian', 'Parson', 'Stanley', and V33016 (='Imperial Epineuse' x 'Italian'). Currently Greg Lang is conducting final testing on the remaining few selections, with PP6975-2 and PP7524-7 slated for release (Table 3). Fogle continued this work when he transferred to Beltsville, Md., in 1963. Recently one of Fogle's selections was named 'Bluebyrd' by Ralph Scorza at USDA–Kearneysville, W.Va. (Table 3), where a limited program of plum development continues. Scorza and colleagues have also genetically engineered plums highly resistant to plum pox virus (Ravelonandro et al., 1997).

The Missouri State Fruit Experiment Station released three European plums in 1947: 'Bluebell', 'Bluefre', and 'Radiance'. 'Bluefre' has become an important plum in Ontario, Canada. No other American programs have developed European plums except for 'Gardner' (1923) from the Oregon Agricultural Experiment Station in 1923 and 'Hildreth' (1982) from USDA in Cheyenne, Wyo.

WESTERN EUROPE. Breeding efforts in Europe have increased in recent years. At INRA in Bordeaux, France, the goals of R. Renaud are to develop a series of drying prunes and

dessert plums that are adapted to French conditions. Cross-fertile prunes are needed that produce fruit with similar traits to improve cross-pollination and maximize fruit set. Fresh plums are needed that ripen before and after 'Reine Claude', with equal or better flavor and firmness, and high productivity (Renaud and Roy, 1990). Initial results of the breeding were three new prune cultivars—'Primacotes', 'Lorida', and 'Tardicotes'. Selections of 'French Prune' have also been made available—Prune d'Ente GF626, GF642, GF707, GF303, and 'Spurdente', the last of which, obtained through irradiation, ripens earlier, is more precocious, and needs less pruning. 'Fermareine' is the first of a series of dessert plums that will be released (Hilaire and Renaud, 1985; Renaud, 1994). The success in irradiation has led to a similar program to irradiate 'Reine Claude' to obtain a selection with low vigor and precocious bearing. A new program seeks to develop selections similar to 'Mirabelle de Nancy' that will spread the ripening season and have larger fruit size.

At Horticultural Research International

Table 3. European plum and *prune* cultivars and selections since 1990. Ripening shown by date and relative to 'Stanley'.

Cultivar	Origin	Ripe date	±Stanley (d)	Skin and flesh color[z]	Parentage
			1995 or later		
Bluebyrd	USDA–WV	1 Sept.	–10	p/y	NY H4 op[y]
V66071	Ontario	17 Aug.	–32	p/y	Early Rivers x Stanley
V70031	Ontario	14 Aug.	–35	bl/y	Valor x California Blue
V72511	Ontario	10 Sept.	–8	p/gy	Verity x Bluebell
V72521	Ontario	15 Sept.	–3	p/y	Verity x Blufre
DOFI-70S.507	Firenze	15 July	–30	p/y	Ruth Gerstetter x President
DOFI-70S.68	Firenze	20 July	–24	p/y	Ruth Gerstetter x Jori's Plum
Geisenheimer Spatzwetche Top	Geisenheim	15 Sept.		bl/y	Auerbacher x Stanley
Tipala	Hohenheim	5 Aug.	–40	y/y	Tiroler Zuckerzwetsche x Opal
Tegera	Hohenheim	25 July	–50	bl/y	Ortenauer x Gerstetter
NY6	NYAES–Cornell	1 Sept.	–14	bl/y	Stanley x Standard
NY9	NYAES–Cornell	7 Sept.	–8	bl/y	Valor x Iroquois
NY858	NYAES–Cornell	10 Sept.	–5	pink/y	unknown
NY1456	NYAES–Cornell	15 Sept.	0	y/y	Agen x Grand Duke
NY58.911.1	NYAES–Cornell	15 Sept.	0	p/yg	Late Muscatel op
NY77.610.1	NYAES–Cornell	28 Aug.	–18	r/y	Imperial Epineuse op
NY71.385.1	NYAES–Cornell	25 Aug.	–21	p/y	Peche x Early Rivers
NY71.387.1	NYAES–Cornell	25 Aug.	–21	p/y	Tuleu Gras x Stanley
			1994		
Felsina	Hohenheim	15 Aug.	–30	p/y?	Italian Prune x Ersinger
			1993		
Elena	Hohenheim	25 Sept.	10	p/y	Italian Prune x Stanley
Castleton	New York	28 Aug.	–18	p/y	Valor x Iroquois
Longjohn	New York	6 Sept.	–9	bl/y	Iroquois x Cal.4A33L
Polly	New York	6 Sept.	–9	p/y	Oneida op
Emperor (PPat#8188)	UCD	5 Aug.	10	bl/y	UC11-15,27 x Imp. French Prune?
Punian (PP#7168)	G. Punian–Cal.	7 July	–21	bl/y	French Prune mutation
			1992		
Fermareine Bellina	INRA Bordeaux	25 Aug.	–1	yg/y	Green Gage x Reine Claude de Bavay
Katinka	Hohenheim	Jul 20	–50	p/y	Ortenauer x Ruth Gerstetter
			1991		
Victory	Ontario	Sep 22	4	p/gy	Vision x Valor
Hanita	Hohenheim	25 Aug.	–20	p/y	President x Auerbacher
Vilcean	Romania				H.8/12 x H.5/23
Baragan 17	Romania				Tuleu Gras x Rivers Timpuriu
Renclod de stepa	Romania				Wilhelmina Spathe x Renclod Althan
Tita	Romania				Tuleu Gras irradiated
Alina	Romania				Tuleu Gras irradiated
			1990		
Firenze 90	Firenze	7 Aug.	–15	p/y	Ruth Gerstetter x President

[z]Colors (skin/flesh): bl = blue, g = green, p = purple, r = red, y = yellow.
[y]Open-pollinated = op.

in East Malling, Kent, U.K., goals included late bloom to improve productivity, large fruit size [>1.6 inches (40 mm)]) and dessert quality. With consumers now less interested in processed plums, there is increasing demand for red, purple, and blue freestone fresh-market plums. Resistance to pests and disease will become more important as usage of pesticides is restricted. Primary disease problems are bacterial canker [*Pseudomonas syringae* pv *morsprunorum* (Wormw) Young, Dye and Wilkie], silver leaf [*Chondrostereum purpureum* (Pers.:Fr.) Pouzer] and fruit rot (*Monilinia frutigena* Honey). A long juvenility period (4 to 6 years) slows the progress toward these goals by increasing generation time (Jones and Wilson, 1987). 'Avalon' and 'Excalibur', released in 1988, are vigorous plums with large, high quality fruit suitable for the dessert market, but self-incompatibility and poor weather at bloom limit their productivity. This breeding program is suspended for the moment as R. P. Jones has retired, but selection testing is continuing.

In Italy, E. Bellini at Florence began breeding in 1970 to develop early-ripening dessert plums with large, high quality fruit and vigorous productive trees (Bellini et al., 1990). Resistance to biotic and abiotic stresses is also important. 'Ruth Gerstetter' has been the most important parent. The first release of the breeding program was 'Firenze 90', a very productive, firm, high-quality plum for fresh market. Other advanced selections spread the season, and are highly productive on very healthy trees. Other smaller programs at Rome, Bologna, and Forli are aimed at developing very early-ripening plums, particularly with semicompact tree size. Bologna also has a small program for development of drying plums.

Germany revived plum breeding in 1980 at the University of Hohenheim. Goals of W. Hartmann are to extend the season, improve quantity and quality, and have resistance to plum pox (Hartmann, 1994). 'Stanley' has been a good parent to transmit tolerance to plum pox. Hartmann (1991) has made clonal selections of the tolerant 'Buhler Fruhzwetsche' with a range of ripening dates to develop a series of plums that can be grown in sharka-infested areas. Six hybrid cultivars have also been released for fresh fruit or processing (Table 3), most of which are self-fertile. 'Tegera' is relatively resistant to brown rot for an early plum. The breeding program at Geisenheim recently released a damson type plum (Table 3).

In 1984 a new breeding program began in Switzerland under M. Kellerhals at the Swiss Federal Research Station in Wadenswil. Their goals include development of early and late ripening plums for fresh use, particularly with high quality, long shelf life and *Monilinia laxa* ((Aderh. & Ruhl.) Honey) resistance (Kellerhals and Rusterholz, 1994).

In Sweden, more compact tree habit and high cold hardiness are sought by Viktor Trajkovski at Balsgård. Fruit goals include high sugar and Vitamin C and less need for thinning. Releases include 'Ive', 'Herman', 'Meritare', 'Jubileum' and 'Anita', and dwarf plums 'Violetta' and 'Madame'. The program has recently expanded to include diploid breeding.

Modern plum breeding in Norway began at the Agricultural University in Ås in 1979 and moved in 1990 to the Research Station at Njøs. Breeding has continued intermittently since 1934. Current goals are high quality, large attractive fruit with good shelf life, and high annual cropping. 'Edda' was released in 1983. The programs currently serves Denmark and Finland as well by producing seedlings for evaluation in their climates (Hjeltnes, 1994).

EASTERN EUROPE AND ASIA. Eastern Europe has a long history of plum breeding, with many cultivars released. Similar goals are important in Yugoslavia, Romania, Czechoslovakia, and Bulgaria. Since much of the plum production is dried or processed into brandy and other products, high soluble solids are essential.

In Yugoslavia, resistance to rust [*Transzschelia pruni-spinosae* (Pers.) Diet.] is also needed. Since the program began in 1947, Yugoslav breeders have released plums for fresh market use such as 'Cacak's Early', 'Cacak's Beauty', 'Cacak's Best', 'Cacak's Fruitful' and 'Cacak's Sugar'. These cultivars show good resistance to red leafblotch (*Polystigma rubrum* (Pers.) D.C.) and to rust. All but the last have the local cultivar 'Pozegaza' as a parent (Paunovic et al., 1975; Paunovic, 1988). Several clonal selections of 'Pozegaza' have also been disseminated. Their newest hybrid releases are prunes 'Valjevka' (1985) and 'Jelica' (1986), and 'Valerija' (1987) for dessert use (Ogasanovic et al., 1994). Recent breeding for sharka resistance has been most successful using as parents 'Large Sugar Prune' and 'Zh'lta Butilcovidna' (Rankovic et al., 1994).

Breeding in Romania began in 1950. Since then 20 cultivars have been named. They provide a succession of dessert plums from July through September. The best are 'Tuleu Timpuriu' (1967), 'Gras Ameliorat' (1970), 'Centenar' (1978), 'Silvia' (1978), 'Diana' (1981), 'Ialomita' (1981), 'Pitestean' (1981), 'Carpatin' (1981), 'Minerva' (1984) and 'Flora' (1989). Newest cultivars are 'Baragan 17', 'Renclod de stepa', 'Vilcean', 'Tita', and 'Alina' (Cociu, 1993).

Institutional plum breeding in Czecho-

slovakia traces back to the 1960s. Recently, several selections from the Institute for Fruit and Ornamental Plants at Bojnice have been tested. BO II / 65, a prune, ripens a week after 'Stanley'. Prunes BO III / 77 and BO IV / 39 ripen ≈3 to 3.5 weeks before 'Stanley'. Since 1988 breeding for plum pox resistance has been done at the Research and Breeding Institute of Pomology at Holovousy (Drobny, 1990).

There are at least 10 breeding programs in the former USSR (Burmistrov, 1992). They require cold hardiness, modest tree size, self-fertility, and productivity (8 to 10 years of harvest). In the more southern zones larger size [>1 oz (30g)], higher sugar content (>13%), purple fruit, and earliness are desired. In more northern zones these fruit quality parameters become less important as hardiness becomes the overriding consideration. Resistance to sharka, *Polystigma*, and *Monilinia* rot are also important. The breeding program at Krymsk has released 'Kubanskaya Legenda' ('Kuban Legend') and 'Kavasskay Vengerka' ('Caucasian Hungarian'), which are self-fertile, cold hardy, and suited for drying. 'Kurbansky Karlik' ('Kuban Dwarf') is a good-quality, self-fertile, dwarf tree [up to 10 ft (3 m)]. Other new cultivars grown in the southwestern region are 'Vengerka Krupnaya', 'Kubanskaya Rannaya', and 'Sochinskaya Yubleinaya'. In the west–central region of the U.S.S.R., newer cultivars are 'Bogatyrskaya', 'Evrazia 21', 'Volzhskaya Krasavitsa', 'Renklod Kuibyshevskyi', 'Renklod Kolkhoznyi', 'Pamyat Timiryazeva', 'Skorospelka', and 'Yaichnaya Sinaya'.

Conclusions

As better cultivars are becoming available, interest in plums is increasing, especially in light of the increased importance of local production. The wide range of fruit flavors and colors, ease of consumption, and apparent health benefits associated with consumption of highly colored fruits make plums a desirable product for local sales wherever they can be grown. Breeding programs having to select for local adaptation and disease resistance as well as fruit type, face a greater challenge. It will take time to develop a series of plums with high levels of size, firmness and quality that ripen over an extended season. However, there is an opportunity in these programs to use the diverse germplasm to develop plums with much more intense flavor than is commonly available. Fortunately the trend towards fewer plum breeding programs in the United States is offset by the increase in international programs. To maintain the progress made in plum improvement, efforts to collect and preserve germplasm are needed to help plum breeders increase their use of the wide, diverse array of *Prunus* that exists but is often not accessible. Such germplasm will allow the development of high-quality plums adapted to an even wider range of environments. Some of these complex hybrids will also provide a new generation of rootstocks for stone fruits.

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