Floral biology of plum *(Review article)*

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1. Phenology of blooming

The main efforts of studying the phenology especially of the blooming process are aimed to find suitable polliniser varieties for the self-incompatible or weakly (partially) self-fertile plum varieties in commercial plantations. The time of blooming process is a relatively short period determined genetically. As differences in blooming time between varieties are considerable, coincidence of blooming within a population of inter-breeding species becomes decisive from the point of view of yield. Varieties of the diploid species as *Prunus cerasifera* Ehrh. and *Prunus salicina* Lindl. start blooming earlier than those of *Prunus domestica* L. (*Schaer*, 1952).

Szabó (1989) and *Szalay & Szabó* (1999) stated that Japanese plums (*P. salicina* group) started blooming earlier by one week than the European plums (*P. domestica*) as a mean of many years and all growing sites observed in Hungary. Observations of other authors present similar differences between the two groups although the intervals are narrower, 5 (*Efimov*, 1959), or wider, 20 (*Bellini* et al. 1982).

Expression of inherited traits is subject to several environmental effects of ecological, physiological, morphological as well as technological nature. *Tóth* (1957) stated that variation of the start of blooming due to weather conditions is much higher than inherent differences between the varieties.

Tóth (1957) compared his own data with those of other authors' referring to the same varieties. Blooming started by 23–36 days earlier in California (*Philp & Vansell*, 1944), 21–26 days later in Sweden (*Johansson*, 1956) than in Hungary.

Keöpeczy Nagy (1943) estimated April 19 as the mean beginning in plum blooming for the Budapest area, whereas *Tóth* (1957) put it to April 18 for the experimental orchard Kamraerdő at close vicinity to Budapest.

For European plums, *Szabó* (1989) observed an average interval of 8 days as the difference between the earliest and latest blooming varieties. It changes to 9 days by Iliev (1985/a), 10 days by *Faccioli & Marangoni*, (1978) and 11 days By *Tóth* (1957). Much larger differences are reported by *Nicotra* et al. (1983): in Rome the variety *Valor* started blooming 22 days earlier than *Jefferson*, whereas at Cesena, *Utility* by 13 days earlier than *Richard Early Italian*.

Japanese plums, on the other hand, started blooming within an interval of 5 days as a mean according to *Szabó* (1989), whereas 7 (*Iliev*, 1985) and 8 days (*Bellini*, 1975) are observed elsewhere. However, *Nicotra* et al. (1983) stated a substantially larger interval in Rome, i.e. 19 days.

Variants of the same variety may differ considerably in blooming time. According to *Tóth* (1967/a), the variety *Agen 1* started blooming at mid time, whereas *Ageni 2* on the late end of the blooming period within the assortment.

The genetic basis of blooming date is complex. One component is the rest period which has to be eliminated by chilling, i.e. low temperature, subsequently, on the contrary, the raising temperature expressed by the heat sum, characteristic for the particular variety ought to be accumulated as a condition of bud break and blooming. According to *Vitanov* (1963), a heat sum of 399 °C should be accumulated from February 1 until blooming of plums in general. *Timon* (1970) calculated 425 °C for the variety *Besztercei* starting the accumulation with January 1.

Phases of the blooming process are not defined unambiguously in the literature *(Table 1)*. The blooming period is the interval between the start and the end of blooming. In addition, distinctions are proposed between the main blooming when about 50% of flowers are open, and the day of main blooming when most flowers are open at once (*Nyéki* et al., 1985).

The length of the blooming period is equally inherited and largely modified by environment, i.e. weather, as well.

Table 1 Definition of phases of blooming in plums

Start of bloom	Main blooming	End of blooming	Reference
Ratio of open flowers		Ratio of faded flowers	
Less than 10%	70%	70%	Tóth (1967)
Less than 10%	90%	90%	Timon (1970)
Less than 25%	80% and start of petal fall	80% of petals fell	Bellini & Bini (1978)
Less than 5%	Blooming reached the maximum	More than 90% Faded	Nyéki et al. (1985)

Tóth (1957) stated that in seasons of earlier spring with slow and gradual warming up, the period of blooming is longer than in seasons of steep gradients. Consequently, blooming period of earlier blooming varieties usually lasts longer, whereas varieties of late start finish blooming sooner. The 10-year mean of blooming period was 8.8 days long. There is rough agreement with *Johansson's* (1956) report of 9.6 days. On the contrary, 12.2 days are calculated in California (*Philp & Vansell*, 1944). The extreme, shortest and longest, blooming periods were 4 and 15 days as indicated by *Petre & Pislaru* (1981). *Levickaja & Kotoman* (1980) mentioned 3 and 12 days, *Iliev* (1985/a) 9 and 16 days.

Taking individual varieties, the average length of blooming periods were between 6.4 to 6.6 as the shortest and 11.0 to 11.2 days as the longest blooming varieties in Hungary (*Tóth*, 1957). More to the south, in Italy, *Bellini & Bini* (1978) distinguished three groups of the varieties with short (7–10 days), intermediate (10–15 days) and long (15–20 days) blooming periods.

Szabó (1989) attempted the grouping of varieties according to the length of **blooming periods** in Hungary:

	Short	Intermediate	Long
European plums	Less than 8 days	Between 8 and 11 d	More than 11 days
Oriental plums	Less than 9 days	Between 9 and 12 d	More than 12 days

According to blooming data, the daily mean temperatures before and during the blooming period are considered to be low if less than 10 °C, intermediate between 10 and 13 °C, and high if more than 13 °C for both, European and Japanese plums.

Szalay & Szabó (1999) stated that during three subsequent seasons, the blooming period of all European and Japanese type plums lasted more than 10 days but the Japanese plums bloomed even 2–3 days longer than the European plums.

In seasons of *late-blooming* (when the start of bloom is later than April 24 according to *Szabó* 1989) the blooming period is short, in *intermediate seasons* (when the start of blooming is between April and 20 and 24) the blooming lasts long. Whereas *early blooming* seasons (when the start was earlier than April 20) produce the most variable lengths of blooming periods.

Temperatures before the blooming period is less effective than those after the start of blooming which is decisive to the speed of flower opening process.

The data of daily mean temperatures, however, have to be supplemented by the variation of temperature due to sunny hours, cold spells and precipitation.

The statement that the earlier the longer the blooming period of *Tóth* (1957) refers to seasons of gradual warming up.

Szabó (1989) evaluated the relation between the length of blooming period and meteorological data at several sites and years in the *Stanley* variety. There was tight negative correlation between the mean temperature and the blooming period ($r = -0.570$; $n = 16$), similarly, with the sunny hours ($r = -0.583$; $n = 12$). Rainy days, on the contrary, did not influence the length of the blooming period. *Figure 1* presents proofs of that claim.

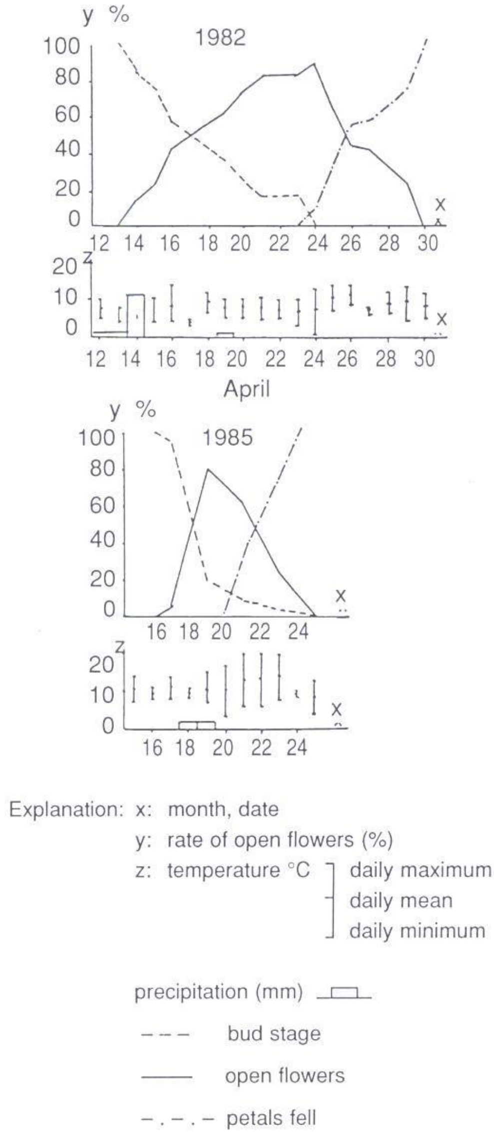

Figure 1.

In 1983, the Japanese plum variety, *Methley*, started blooming slowly and its blooming period was prolonged. The temperature was, meanwhile, constantly below 10 °C. On the contrary, in 1985, mean temperatures kept mainly above 10 °C, thus the graphics of blooming was steep in both, rising and drooping phases.

Blooming dynamics of the plum is characterised with the following statements:

In early blooming varieties (which start blooming at lower temperatures):

- the start of blooming of varieties is more variable, the differences are more pronounced,
- blooming period is prolonged,

- blooming rhythm is lagging,
- end of blooming is sluggish.

In late blooming varieties (and in warm springs):

- differences in the start of blooming between varieties are reduced,
- blooming period is short,
- blooming intensity is high,
- end of blooming is abrupt.

When the weather before blooming is cool and rainy, differences in the start of blooming become more pronounced, whereas heat and sunshine during the first part of the blooming period caused quick start and abrupt end of the blooming process in spite of the subsequent cool weather.

The sequence of blooming

Tóth (1957) compared his own data with those available in the literature and concluded that the sequence in blooming time of the plum varieties is stable over years as well as over growing sites. However, present authors experienced contradictory results in the start of blooming and in the time of main blooming as the relative sequence of varieties was variable. Taking the variety *Stanley* as a reference, the relative blooming data of plum varieties are presented in *Table 2*. The sequence of varieties proved to be rather variable depending on growing sites. Deviations of 6 or more days were noted in the relative start of blooming at about the half of the varieties. Records of relevant authors referring to the start of blooming exhibited variable sequences. According to *Nicotra* et al. (1983) in Rome, the varieties *Ontario, Zöld ringló (Green Reine Claude), Czar (Tsar), Opal, Ruth Gerstetter* and *Bluefre* start blooming later than *Stanley*, whereas at Cesena and according to *Szabó* (1989) they start blooming earlier than *Stanley*.

Szabó (1989) summarised data on the relative sequence of blooming dates over several years and growing sites in *Table 3*. Ecological conditions, age and understock of the trees, training and cultivation practices of the plantations are all to be taken into account let alone the different seasons and growing sites, in the evaluation of data. The mean date of the start of blooming has been registered. Largely, the varieties belonging to groups of early and of late start of blooming were well defined over years, but their relative sequence within the group was variable in both, start of blooming and main blooming time. Nevertheless, it is taken as a fact that blooming dates of plum varieties are genetically determined but subject to environmental effects as the relative sequence (within the early or late blooming groups) may change yearly.

For the self-incompatible plum varieties adequate polliniser varieties ought to be chosen which are sufficiently coincident in blooming time. For that reason relevant varieties are assigned to blooming time groups. As most convenient seems to be a system of three groups (*Hedrick*, 1911; *Tóth*, 1957; *Faccioli & Marangoni*, 1978), whereas four groups are proposed by *Bellini & Bini* (1978) and *Belmans* (1986). *Moreover*, *Kellerhals* (1986/b), *Szabó* (1989), *Szabó & Nyéki* (1995) established five blooming time groups.

The changing sequence of blooming time necessitates data of several (at least 3) years as well as growing sites to establish the blooming time groups valid for a defined region.

The coincidence of blooming time

As indicated, the proper association of plum varieties in order to secure a safe cross pollination for the varieties either

Table 2 The relative sequence of European plum varieties according to start of blooming

Variety	Relative start of bloom compared with the variety *Stanley* (days)						Difference (days) in the start of blooming between sites
	References						
	Szabó (1989)	Faccioli & Marangoni (1978)	Sansavini et al. (1981)	Nicotra et al. (1983)		Iliev (1985/a)	
				Roma	Cesena		
Utility	–5.0			–6	–4		2
Ontario	–3.7		–4	2	–4		6
President	–3.1	–3	–4	–5	–1		4
Zöld ringló	–3.0	0	–2	2		–1	5
Early Laxton	–3.0	–6	–2	–1	–3		5
Debreceni muskotály	–2.8					2	5
Czar	–2.5	–2	–2	4			6.5
Althann ringló	–2.3	–4			–1		3
Ersinger frühzwetsche	–2.3	–2	–2				0
Opal	–2.3		–2	7	–1	–1	8
Ruth Gerstätter	–1.7	–2	–3	4	–3		7
Italian blue	–1.3		–3			5	6
Bluefre	–0.9	0	0	6	–2	1	8
Richards Early Italian	–0.4	1	2	11	8		11***
California Blue	–0.3		1		0		1
Stanley	Apr 21	Apr. 5	Apr. 5	March 28	Apr.1.	Apr.8	
Tuleu Timpuriu	0.0			10		3	10
Tuleu gras	0.7	1	4	7	3		7
Besztercei szilva	1.5	2	5		4	5	3

Table 3 Flowering and fertility groups of plum varieties (Szabó et al., 1999)

Varieties according to their blooming	Blooming-time group	Fertility relations	Fruit set in open pollination
Utility	Early	self-sterile	medium
Bourdett Angelina	Early	completely self-sterile	high
Silvia	Early	completely self-sterile	high
Ontario	Early	highly self-fertile	very high
Reine-Claude de Bavay	Early	partially self-fertile	medium
Volosko	Early	completely self-sterile	medium
Zimmer Frühzwetsche	Early	self-sterile	high
President	Early	completely self-sterile	high
Growers Late Victoria	Early	partially self-fertile	high
Early Laxton	Early	self-sterile	medium
Debreceni muskotály	Early	self-sterile	high
Czar	Early	partially self-fertile	medium
Bartschis Frühzwetsche	Early	completely self-sterile	high
Althan ringló	Early	completely self-sterile	medium
Ersinger Frühzwetsche	Early	self-fertile	high
Opal	Early	not studied	not studied
Sentyabrskaya	Early	male sterile	medium
Cambridge Gage	Early	self-sterile	high
Cacanska lepotica	Early	partially self-fertile	medium
Cacanska najbolja	Early	completely self-sterile	medium
Victoria	Early	self-fertile	very high
Ruth Gerstätter	Early	not studied	low
Krikon	Early	self-fertile	high
Cacanska rodna	Early	highly self-fertile	very high
Cacanski II/II/80/59	Early	completely self-sterile	not studied
Centenar	Medium	male sterile	not studied
Röhr Pflaume	Medium	self-fertile	very high
Italian Plum	Medium	self-fertile	high
Valor	Medium	completely self-sterile	high
Pescarus	Medium	male sterile	low
Gras ameliorat	Medium	not studies	high
Bluefre	Medium	partially self-fertile	medium
Szopernyica	Medium	self-fertile	high
Early Italian	Medium	self-fertile	high
Alvena	Medium	not studied	not studied
Kisinevskaya rannaya	Medium	self-sterile	low
Richards Early Italian	medium late	self-fertile	high
Schwabs Frühzwetsche	medium late	self-fertile	high
Tuleu dulce	medium late	completely self-sterile	high
Fellenberg T. 24	medium late	self-fertile	high
Laxton blau	medium late	completely self-sterile	high
California blue	medium late	partially self-fertile	low
Chrudiemer	medium late	partially self-fertile	high
Albatros	medium late	male sterile	high
Stanley	medium late	partially self-fertile	high
Ageni	medium late	partially self-fertile	high
Frühe Fellenberger	medium late	not studied	not studied
Tuleu Timpuriu	medium late	male sterile	low
Besztercei Bt. 2	Late	highly self-fertile	high
Korai Besztercei	Late	self-fertile	high
Besztercei Bt. 1	Late	partially self-fertile	high
Tuleu gras	Late	male sterile	high
Asatan	Late	self-sterile	medium
Besztercei Nn. 122	Late	highly self-fertile	very high
Pozegaca	Late	highly self-fertile	high
Pacific	Late	completely self-sterile	high
Besztercei Bb 416	Late	partially self-fertile	high
Myrabelle de Nancy	Late	highly self-fertile	very high
Hauszwetsche Rudin	Late	self-fertile	high
Hauszwetsche Grider	Late	partially self-fertile	high
Vinatte Romanesti	Late	not studied	not studied
Hauszwetsche T.F.	Late	partially self-fertile	high
Besztercei szilva	Late	not studied	not studied

self-incompatible or of low female fertility claims more or less coincidence of blooming. Coincidence in blooming means a quantitative measure of efficiency in pollination. *Szabó* (1989) worked out the patterns of blooming times and coincidences of the most important European plum varieties based on data of 5 years as shown in *Table 4*. The self-incompatible and partially self-fertile varieties need cross-compatible pollinisers chosen from the respective blooming time group. Combinations of varieties checked at least during two seasons are analysed and recommended regarding to the ratio of overlap in their blooming times. As a rule, a 70% overlap in blooming time between the varieties (i.e. the variety to be pollinated and the respective polliniser variety or varieties) is considered to be sufficient (*Soltész*, 1980).

There are varieties of moderately early start and a prolonged blooming period, e.g. ***Čačanska najbolja.*** It will be pollinated almost by all of the cultivated varieties, and inversely, the blooming of almost all varieties needing cross pollination are overlapped by the blooming period of ***Čačanska najbolja*** at a rate of 70 to 100%. At the same time, some varieties are difficult to supply with adequate polliniser because of its utmost early blooming time, as ***Utility,*** or its late blooming, as the male sterile ***Tuleu gras.*** The latter variety is especially difficult to catch its blooming time being highly variable, yearly. Some varieties as ***Čačanska rodna, Debreceni muskotály, President*** and ***Silvia*** being utterly variable in blooming time, their mutual combination is not recommended. In the case of complications of that type, the association of more than one

Table 4 Coincidence of blooming in European plum varieties in %. (Szabó, 1989, Kecskemét 1985–1989)

♂ / ♀	Besztercei Bb. 416	Bluefre	Cacanska lepotica	Cacanska rodna	Stanley	Althann ringló	Cacanska najbolja	Debreceni muskotály	President	Silvia	Utility
Althan ringló	36–67	50–78	88–100	83–100	50–75	–	89–100	78–100	89–100	50–100	67–88
Cacanska najbolja	40–75	60–89	70–100	75–100	62–90	75–89	–	67–90	50–88	67–90	56–80
Centenar	71–75	62–100	88–100	75–86	62–86	75–100	100	71–88	86–88	71–75	57–62
Debreceni muskotály	33–71	36–62	78–100	86–100	50–67	86–89	75–100	–	69–100	86–100	71–89
Pescarus	43–78	62–100	88–100	67–100	62–89	75–100	89–100	56–100	67–100	56–100	44–86
President	38–62	50–100	75–100	62–100	50–75	75v100	57–100	88–100	–	88–100	75–88
Silva	30–57	50–75	70–89	43–60	43–60	56–80	67–90	86–90	88–100	–	86–90
Tuleu gras	71–86	58–100	50–71	58–100	58–100	42–74	50–86	25–71	33–71	25–71	11–57
Utility	18–43	28–50	54–88	57–88	28–45	64–75	62–72	71–88	64–88	82–100	–
Bluefre	67–100	–	56–89	67–88	70–100	56–87	67–100	56–80	56–80	56–60	40–44
Cacanska lepotica	43–71	50–80	–	80–100	64–90	82–100	71–100	73–100	60–100	73–100	64–86
Stanley	67–86	71–100	67–100	71–80	–	57–86	78–100	57–71	50–71	57–67	43–57

polliniser, i.e. one starting about 2 days earlier, the other synchronously or 2 days later than the variety to be pollinated, seems to be a sound solution. The moment when the flowers open is considered optimal for pollination from the point of view of receptivity of stigmata, and it means that during the whole blooming period pollen must be available. The early blooming variety, ***Utility*** which has a blooming period of medium length cannot be supplied but with a few early blooming varieties, similarly, ***Besztercei Bb. 416*** starting late with a short blooming period is satisfied by late blooming pollinisers, only.

Varieties belonging to the same blooming time group are coincident sufficiently, i.e. by 75–100% with each other, whereas varieties belonging to neighbouring blooming time groups overlap each other's at a rate of 70% at the best.

Not only the overlap of blooming periods is important, however, the coincidence of the main blooming time (when about the 50% of flowers opened) offers the best opportunity of successful pollination.

Szabó (1989) indicated in *Table 5* the main blooming time of Japanese plums as a supplement of the dates of blooming periods. Varieties of intermediate blooming dates (*Santa Rosa, Burbank, Shiro*) coincide well also in main blooming time. A safe pollination requires the coincidence of main blooming times by a rate of more than 50%. From that point of view, *Methley* cannot be supplied safely by any known variety. The cincidence of blooming times in Japanese plums used to be much more variable than in European plums. Blooming phenograms of varieties visualise those relations well. In *Figure 2* it is evident that blooming period of ***Ruth Gerstätter*** is overlapped entirely by that of the earlier blooming ***President*** and the later blooming ***Besztercei Bt. 2.***

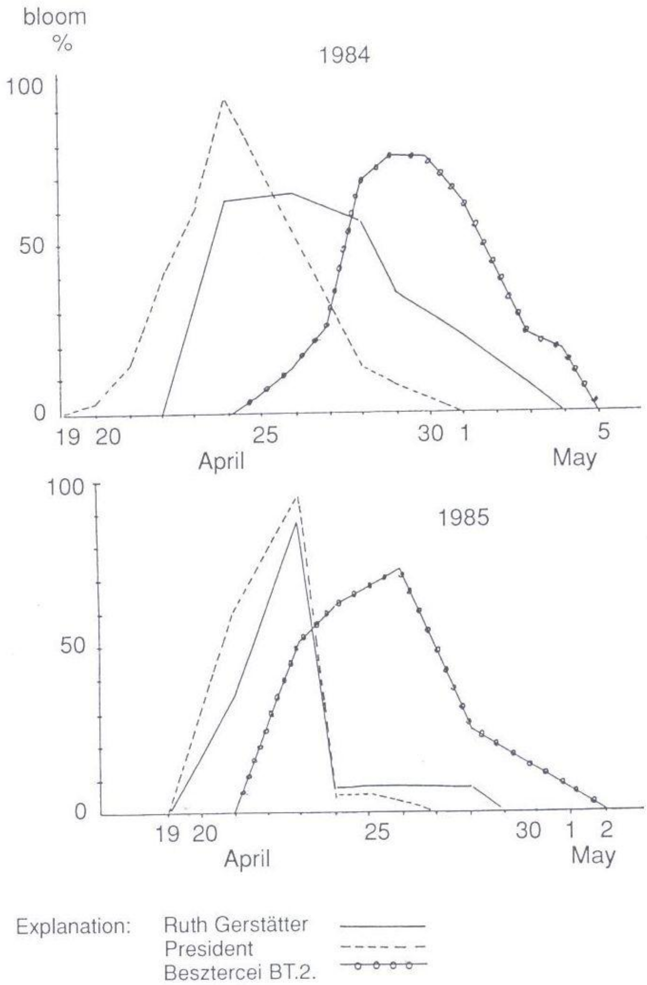

Figure 2 Effective pollination of Ruth Gerstätter by two pollinizers blooming at different periods (*Nyéki* 1989)

2. Fertility relations

2.1. Self-incompatibility and self-fertility

Self-fertility of plum varieties is genetically determined (*Tóth*, 1957). The extent of self-fertilisation is, however, highly subject to different external and internal conditions.

The pollen grown in the same flower has the most chances of arriving to the stigma. In self-fertile varieties that means also fruit set with high probability (*Keulemans*, 1991).

Asian plum species (*Prunus salicina* Lindl., *Prunus simonii* Carr.) and the American species (*Prunus americana*

Table 5 Coincidence of blooming in Japanese plum varieties in %. (Szabó, 1989, Siófok 1982–1985)

♀ \ ♂	Methley	Santa Rosa	Burbank	Shiro	Elephant Heart	Duarte
Methley	53–88	53–88	58–88	58–83	53–75	50–63
		0–100	0–63	14–100	0–50	0–88
Santa Rosa	71–100		86–100	83–100	83–100	71–100
	0–83		60–100	67–80	60–100	0–100
Burbank		69–92		75–92	85–100	77–92
	0–63	75–100		50–100	80–100	20–100
Shiro	50–100	71–100	79–100		86–100	71–100
	25–100	50-100	50–100		50–100	0–50
Elephant Heart	36–91	50–100	73–100	55–100		91–100
	0–50	33–75	44–88	33–50		63–100
Duarte	30–92	47–92	70–92	50–100	92–100	
	0–17	0–75	17–67	0–50	83–100	

Remark: first row: mutual coincidence during the blooming period
second row: mutual coincidence of the main blooming of the respective varieties

Marsh., *Prunus angustifolia* Marsh., *Prunus hortulana* Bailey, *Prunus nigra* Alt.), being of diploid chromosome constitution, as well as their inter-specific cross combinations are all essentially self-incompatible. Self-fertility was found to be an exceptional phenomenon among them (*Waugh*, 1897; *Alderman & Angelo*, 1933).

The cherry plum (*Prunus cerasifera* Ehrh.) also a diploid, cannot be considered as entirely self-incompatible, but the fruit set after forced self pollination in any variety does not exceed the rate of 4.9% (*Shoferistov*, 1986).

Plum production is based, world-wide, on the hexaploid (*Prunus domestica* L.) European plum varieties, mainly. Fertility relations of those varieties are variable between self-fertility, partial self-fertility and self-incompatibility which is attributed to interaction of several incompatibility alleles in each of the six-fold constitution of chromosomes (*Levickaja & Kotoman*, 1980).

Tóth (1969) stated that isolated flowers of self-fertile plum varieties set more fruits by 45.2% after artificial self-pollination than without it. According to him, isolation (bagging) of the flowers, alone, does not reveal the potential self-fertility of the respective variety.

For checking that claim *Szabó* (1989) explored the fruit set of 5 self-incompatible and 5 self-fertile plum varieties after having isolated (i.e. autogamy in the narrow sense) and alternatively, isolated plus pollinated with the pollen of the same variety (i.e. geitonogamy) *(Table 6)*. There was, as a matter of fact, some (very low) fruit set in isolated flowers of self-incompatible varieties too (*Debreceni muskotály* and *President*), however, artificial pollination (geitonogamy) nearly doubled the rate of fruit set in self-fertile varieites .

The ability of self pollination (fruit set by autogamy) depends also on structural (spatial) relations of the flower parts according to *Surányi* (1970). He claimed (*Surányi*, 1985) that in stone fruit species the quotient of the length of pistil and the number of functional anthers within the flower is causally related with self-fertility. He also referred to the relative number of anthers, and especially, the diameter of the stigma, or in other words, the trend of epistyly and of polycarpy.

The ability of self fertilisation may differ according to the group of varieties. *Tóth* (1980) stated that self-fertilisation in the variants of the variety *Besztercei* changed between 2.6% and 57.1%. *Szabó* (1989) reported 2.0% and 37.4% values. Similarly, *Ageni 1* set fruit at a rate of 37.2%, whereas *Ageni 2* at 7.% by their own pollen (*Tóth*, 1980).

Self-fertile plum varieties proved to be superior to self-incompatible ones due to several advantages. *Tóth* (1969) proved that differences in the genuine ability of setting fruit are in favour of self-fertile varieties. That means also differences in the case of free pollination which is convincing as entirely self-fertile varieties set most (24.4%) in average, whereas all other types as weakly self-fertile, practically self-incompatible and entirely self-incompatible ones produced maximal fruit set in decreasing order (15.3, 15.2 and 9.8%, respectively). The same tendency has been expressed by *Gavrilina* (1986), *Szabó* (1989) and *Nyéki & Szabó* (1995).

Table 6 Comparison of fruit set (%) in self pollinated flowers, efficiency as pollinisers and in free pollinated flowers (Szabó 1989, Kecskemét 1988–1989)

Group of varieties Variety	Fruit set (%) Mean of two years		
	Self-fertility as polliniser	Cross fertility	Open pollination
Self-incompatible varieties			
Althann ringló	0	0	21.4
Cacanska najbolja	0	0	17.6
Debreceni muskotály	0.3	1.5	30.1
Pacific	0	0	34.1
President	1	0.4	36.5
Mean of self-incompatible varieties	0.6	0.4	27.8
Self-fertile varieties			
Besztercei Bb. 416	10.3	25.7	34.6
Bluefre	9.8	8.3	30.1
Cacanska lepotica	12.0	15.9	41.2
Cacanska rodna	33.5	58.3	67.6
Stanley	7.4	16.4	37.1
Mean of self-fertile varieties	14.6	24.9	42.1

The minimal rate of fruit set necessary for safe yields in plums is estimated in the literature differently. In Italy, more than 5 % is considered as sufficient (*Bellini &Bini*, 1978; *Faccioli & Marangoni*, 1978; *Bellini*, 1980). The variety is regarded to be self-incompatible if it set fruit less than 1 %, whereas partially self-fertile with records between 1 and 5%.

Rudloff & Schanderl (1950) and *Tóth* (1967/b and 1969) draw the limit at 10%, moreover, *Levickaja & Kotoman* (1980) at 15%.

The number of groups representing varieties of different degrees of self-fertility varied between 2 (*Backhouse*, 1911; *Kostina*, 1927) and 7 (*Paunovic*, 1971). Most frequently a system of 3 groups (self-incompatible, partially self-fertile and self-fertile) is used (*Rawes*, 1921; Crane, 1925; *Rudloff & Schanderl*, 1937; *Tóth*, 1966 and 1967/b, *Szabó & Nyéki* (1989). Finally, four groups have been suggested by *Tóth* (1969) *(Table 3)*

More than 29.5% of the varieties set fruit on more than 10% of the flowers. In the production, however, self-fertile varieties are much more represented than that.

The majority of Japanese plums is self-incompatible which mans that an association of polliniser varieties is necessary (*Sansavini* et al., 1981). Low levels of self-fertility has been registered, however, in some varieties (*Methley, Santa Rosa*). *Palara* et al. (1990) observed some self fertilisation in all varieties but at very low levels (below 2%). *Gautier* (1977) considered the variety *Santa Rosa* as

Szabó (1989) established 5 fertility groups for the 56 European plum varieties, studied.

Group	Fruit set (%)	Distribution of varieties (%)
Entirely self-incompatible	0	28.6
Self-incompatible	0.1–1.0	14.3
Partially self-fertile	1.1–10.0	25.0
Self-fertile	10.1–20.0	21.4
Highly self-fertile	more than 20.0	10.7

Table 7 The fertilisation (%) of *Stanley* flowers depending on the kind of pollination (*Szabó* 1989, Kecskemét, 1987–1989)

Kind of pollination	1987		1988		1989		Mean of years	
	Number of flowers	Fruit set (%)	Number of flowers	Fruit set (%)	Number of flowers	Fruit set (%)	Number of flowers	Furiut set (%)
Self pollination	309	6.4	383	9.8	340	5.1	1032	7.1
Self-fertility	231	18.1	588	20.1	236	12.7	1055	17.0
Pollination of emasculated flowers								
With the own pollen	300	0	200	20	209	2.3	709	7.4
With pollen of Cacanska rodna	213	20.2	206	26.0	192	4.5	611	16.9
Free pollination of Flowers left open	1350	42.7	1029	26.5	1216	47.8	3595	40.6

self-fertile, whereas *Bellini* & *Bini* (1978), *Costa* & *Grandi* (1982), *Szabó* (1989) as partially self-fertile, *Albertini* (1978) and *Cobianchi* et al. (1978) as self-incompatible. Higher rates of self-fertilisation (16%) has found in the variety *Premier*, only (*Bellini*, 1975; *Cobianchi* et al., 1978).

2.2. Fruit set and parthenocarpy

The plum fruit cannot be set and grown without regular fertilisation. Parthenocarpy has never been observed (*Constantinescu*, 1939; *Tóth*, 1975), neither induced artificially by treatment with Gibberelline (*Crane* et al. (1960).

2.3. Free pollination

Stigmata of freely blooming plum flowers are supplied with pollen from different sources by visiting insects, mainly bees (and air wafts). As the probability of getting pollen of other trees is high, fruits set usually at higher rates than in isolated flowers. Self-fertile flowers, however, set more safely because, especially under unfavourable weather conditions for insect activity, pollen of its own has more chances to reach the stigma. (*Tóth*, 1969).

The genuine fertility of any plum variety is expressed by the fruit set of free blooming flowers (*Tóth*, 1980). There is a large scale of variation in the fertility of varieties under free pollination conditions. As extreme values 1.9% (*Kék datolya*) and 58.1% (*Penyigei szilva*) are presented by *Tóth* (1969). Other authors report values as 9.9% (*Bluefre*) and 33.4% (*Imperial*) in an assortment of 14 varieties (*Iliev* 1985/b), whereas 6.7% and 61.2% by *Chiriae* et al.(1981).

Criteria of abundant yield in stone fruits are estimated by *Stösser* (1980) as 15–20% fruit set, for plums only around 20% (*Marshall*, 1919; *Paunovic*, 1971; *Iliev*, 1985/b). Lower values of fruit set may be sufficient for varieties with high flower density and large fruits. The variety *Zimmers Frühzwetsche* produced a heavy yield at low rates of fruit set (7–13%) as shown by *Lee* & *Bünemann* (1981). *Szabó* (1989) found significant negative correlation between flower density and the rate of fruit.

Results of *Tóth* (1969) proved also that, similarly to the quantitative expression of self-fertility, differences exist also in the tendency of fertility under conditions of free pollination. Some groups of varieties (*Ageni*, and *Besztercei szilva*) are inclined to be fertile at different rates not only in isolation but under free pollination. According to *Harsányi* (1975), the variability of fertility in the group of *Besztercei szilva* is the consequence of its generative propagation. *Tóth* et al. (1988) observed more than 12-fold differences in fruit set under free pollination and 10-fold differences in fertility within the group of *Besztercei szilva*.

Szabó (1989) assigned 58 European plum varieties according to their fruit set in freely blooming flowers to four groups.

Groups	Fruit set (%) (%)	Distribution of varieties
Low	Less than 10 %	10.3
Intermediate	10.1–20 %	22.4
High	20.1–40 %	54.0
Very high	more than 40 %	10.3

10.3%-of varieties set fruit on more than 40% of flowers. Safe yields require more than 20% fruit set.

The majority of Japanese plums produce much higher flower densities and larger fruits than European plums which means that a lower rate of fruits set (5–10 %) may satisfy the requirement of high yields. *Szabó* (1989) estmated the fertility relations of oriental plums as follows:

Group	Fruit set (%)
Low	below 5
Intermediate	5.1–10.0
High	above10

2.4. Cross fertilisation

As the majority of plum varieties is self-incompatible or partially self-fertile, the availability of pollen sources for cross-pollination remains critical from the point of view of reliable yield.

For Japanese plums, the cherry plum proved to be a good polliniser. European plums and Japanese plums, however, fertilise each other, mutually but scarcely (*Einset*, 1939).

Ogasanovic (1985) considered those which fertilise varieties of the *Cacak* group at a higher rate than 2–5% as adequate pollinisers. For European plums, a polliniser variety securing a rate of at least 10% fruit set seems to be sufficient (*Roman & Radulescu*, 1986). *Tóth & Erdős* (1985) and *Szabó* (1989) presented experimental proofs that for *President* pollinisers producing more than 10% fruit set are safely recommended (e.g. *Debreceni muskotály, Bluefre*).

Relevant literature (*Faccioli & Marangoni*, 1978; *Roman*, 1981; *Stösser*, 1984; *Roman & Radulescu*, 1986) deals with *Stanley* as an excellent polliniser variety. However, *Misic* et al. (1988) proved that the pollen of *Stanley* lost viability much easier than that of *Besztercei szilva*, therefore, experimental evidences emphasise its superiority.

Crosses performed with Japanese plums suggested as good pollinisers all varieties which produced above 4% (*Tehrani*, 1972 and *Cobianchi* et al., 1978) or 5% (*Costa & Grandi*, 1982; *Szabó*, 1989) fruit sets.

Yearly changes in the ability of fertilisation of plum varieties reported *Stösser* (1984). However, the potential female fertility of varieties is even more variable than the fertilising ability of their pollen (Ro, 1929). The pollination with a mixture of different pollens produces synergistic effects according to *Arora & Ranvir Stingh* (1987).

Flowers blooming freely plus a pollination with alien varieties produced greatly enhanced fruit set in relation to being self pollinated (*Cociu*, 1961; *Kellerhals*, 1986/a). Cross pollination caused even higher rates of fruit set than free pollination alone (*Keulemens*, 1991 and 1994).

The rate of elongation was slower in self pollinated than in cross-pollinated styles as stated by *Levickaja & Kotoman* (1980). Tubes of the own pollen reached the ovule in 3–5 days, whereas alien pollen tubes needed 2–3 days, only.

For experimental cross pollination, as a rule, flowers are emasculated. The self pollinated flowers, if emasculated, set less fruits than the intact ones. Alien pollen gave better sets in *Čačanska rodna* over three years. In 1987 and 1988, emasculation has been performed by excising stamina and corolla together, whereas in 1989 also the upper part of the calyx has been eliminated in one move with the stamina and corolla. That way, the emasculation gained in efficiency (5 fold), though the scare caused some reduction in the rate of fruit. Highest fruit set was experienced in flowers left freely. Obviously, the pollen reaching those stigmata came from different sources, from the same flower by gravitation, wind wafts, as well as other pollen carried by several bee visits. In some cases, the rate of fruit set was higher on emasculated flowers than on intact ones (*Kellerhals & Rusterholz*, 1984).

The effect of pollination depends also on the phenological as well as physiological status of the plant. Stigmata are already receptive 1–2 days before the bud opening (*Randhava & Nair*, 1960; *Knuth* cit. *McGregor*, 1976). Practically, pollination has no chance before the opening of flower (except when opened by force), because anthers used not burst in closed flower buds.

Szabó (1989) pollinated the flowers of *Cacanska najbolja* at different stages of its development. At the start of opening (first day), the rate of fruit set was high (25.3%), in full opening (on the third day), 4.5%, whereas before petal fall (on the 5th day of blooming), 5.1 %, by using the pollen of *Stanley*. Flowers pollinated at every three time set fruit as much as those pollinated the first time, once (26.5%). Stigmata are most receptive in buds before opening which suggests that the provision of pollen is most important just after opening involving the earliest phase of blooming.

Stösser (1985) made an experiment of the above type using the *Lützelsachser* variety, and stated the gradual decline in the rate of fruit set after the fifth day of blooming (*Figure 3*).

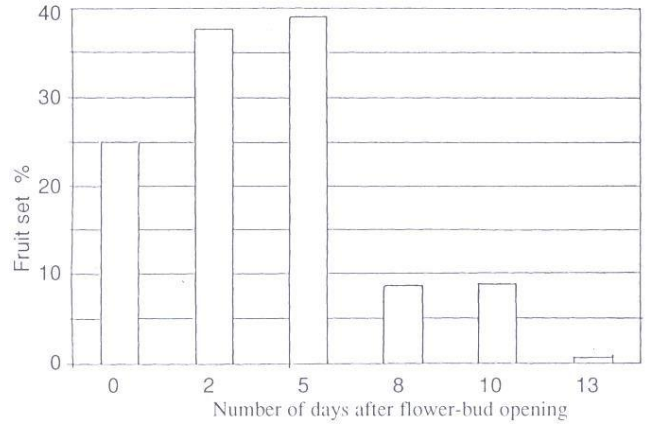

Figure 3 Fruit set of the flowers pollinated on different days after bud opening in the variety Lützelsachsen

Data of *Szabó & Nyéki* (1989) prove that the rate of cross fertility highly varied according to growing site and season (*Table 8*).

It is generally true that the fertilising ability of some varieties used to be in every year and at each growing site, stable, either poor (*Ruth Gerstetter, Stanley*) or good (*Čačanska rodna*). For *Čačanska najbolja* adequate pollinisers causing about 20% fruit set, are the varieties *Bluefre, Čačanska lepotica, Čačanska rodna* and *President*. At the same time, *Ruth Gerstätter* and *Stanley* were less efficient pollinisers with rates of set below 10%, although that would be even higher than the set on free blooming flowers f the respective varieties.

As a conclusion, it is largely true that in the assortment of European plums where inter-incompatibility is a rare phenomenon, the rate of fruit et is dependent, first of all, on the female fertility of the respective variety rather than on the quality of the polliniser.

For the purpose of efficient polliniser, varieties of abundant pollen production are to be chosen, however, experimental proofs of good fertilising ability (with about 30% fruit set) over several years are also necessary. As excellent polliniser, partially self-fertile varieties are *Bluefre, Stanley*, moreover, *Čačanska najbolja, Čačanska rodna* and *President* which are compatible with most of the important varieties as far as their blooming is coincident.

Varieties with low fertility even in free pollination (*Duarte, Elephant Heart, Late Santa Rosa, Santa Rosa*)

Table 8 Cross fertility of the self-incompatible plum variety, *Čačanska najbolja*, at different sites and years (Szabó & Nyéki, 1989)

Polliniser variety	Siófok		Csány				Kecskemét		Mean
	1985		1985		1986		1986		fruit
	Number of flowers	Ripe fruits%	Number of flowers	Ripe fruits%	Number of flowers	Ripe fruits%	Number of flowers	Ripe fruits%	set %
Besztercei szilva	44	2.3	385	31.4	513	8.6	114	7.0	12.3
Bluefre	140	47.1	308	24.7	1239	11.2	131	6.9	22.5
Cacanska lepotica	83	45.8	88	20.4	818	6.0	145	2.1	18.6
Cacanska rodna	79	49.4	290	24.1	644	12.0	172	8.7	23.6
President	197	34.5	445	33.0	97.4	3.4	118	2.5	18.4
Ruth Gerstätter	95	7.4	140	7.8	–	–	–	–	7.6
Stanley	206	3.9	319	9.1	1059	8.7	89	0	5.4
Cacanska najbolja free pollinated	6043	5.0	16654	1.1	12197	1.4	1416	4.9	3.1

produced few sets in most cross combinations, on the contrary, the most fertile *Methley* set fruit abundantly by most varieties as pollinisers.

2.5. Unilateral and reciprocal incompatibility

Cross-incompatibility may prevent fertilisation in combinations which are but few among plum varieties. *Crane* (1925) established 4 inter-incompatibility groups, where within-group combinations are mutually incompatible but between groups the combinations are fertile. In Hungary *Zöld ringló (Green Reine Claude)* and *Italian blue* are inter-incompatible (*Vahl*, 1961), whereas that, between *President* and *Italian blue*, has been reported by *Bellini* & *Bini* (1978).

Crane & *Lawrence* (1929) explained the low frequency of inter-incompatibility among European plums with the hexaploidy of the species.

Inter-incompatibility cannot be found between self-fertile varieties as stated by *Crane* & *Brown* (1939).

Tehrani (1991) screened as many as 91 combinations of European plum varieties, and found 20 cases, on the other hand, out of 35 combinations between Japanese plums, 17 proved to be inter-incompatible..

Szabó (1989) explored 51 combinations from the point of view of fruit set *(Table 9)*. The majority of varieties fertilised well each other (i.e. caused more than 10% fruit set). Out of 51 combinations 14 were excellent, 24 good, and only 15 were poor in fertility. Low fertility has been experienced with *Tuleu timpuriu* as poor fertiliser (being highly male sterile), *Čačanska lepotica* and *Čačanska rodna* were less fertile. *Stanley* and *Čačanska najbolja* fertilised each other poorly.

As indicated, free pollination and cross pollination are tightly related. In the assortment of 12 plum varieties *Tuleu timpuriu* (31.1% and 3.7%) produced the lowest, *Čačanska rodna* (66.0 and 47.9%) the highest fertility (fruit set) values.

Bellini (1975) inter-crossed *Burmosa* and other 26 Japanese and further 2 cherry plum varieties, and concluded that no one mutually fertilising combination could find. For *Burmosa* 5 varieties were good pollinisers whereas *Burmosa* was good for other two varieties. *Palara* et al. (1990) achieved fairly good (more than 5%) fruit set by artificial cross pollination in Japanese plums of low fertility at free pollination.

The 48 cross combinations of Japanese plums in the experiment of *Szabó* (1989) were classified as follows: about half of them, 25 set poorly, 9 well, whereas 14 set excellently *(Table 10)*. *Duarte*, *Methley* and *Shiro* fertilised the majority poorly (with less than 5% sets), there were, however, few combinations with satisfactory results (e.g. *Friar x Methley* = 23.4%). Self- and inter-incompatibility is much more frequently met in Japanese plums as in European plums. Low fruit set in the combinations of *Methley* and *Shiro* suggests inter-inompatibility (*Methley x Shiro* = 1.5%, *Shiro x Methley* = 0.6%).

Some varieties proved to be "universal" pollinisers, as *Elephant Heart*, *Friar*, *Laroda*, *Late Santa Rosa* and *Santa Rosa*" as most of the varieties set fruit at higher rates than 5% or more.

The statement claimed in relation of European plums that the result of cross pollination depends mainly on the fruit setting ability of the female parent, makes sense also for Japanese plums.

As incompatibility in Japanese plums is more frequent, their fertilising ability is more variable, the extreme mean values of several growing sites and seasons were 0.9% (*Shiro*) and 14.2% (*Elephant Heart*). The ability of setting fruit (female fertility) varied between 0.9% (*Elephant Heart*) and 17.8% (*Friar*).

2.6. Sterility

The frequent cause of low rate in fruit set is of morphological nature (short style, small stigma, underdeveloped ovary). Those phenomena are more frequent in Japanese plums than in the Europeans (*Bellini* et al., 1996; *Palara*, 1996).

Irregular and necrotic pistils are often found is plum flowers. According to Waugh (1897) anomalies in flowers of the variety *Burbank* are variable depending also on the geographic location of growing sites. At some locations, sterile pistils are found at rates of 21–36%, whereas at others they did not exceed even 9%.

Young plum trees produce more sterile pistils than later. *Waugh* (1897) considered the frequency of sterile pistils as an indication of sanitary conditions of the tree in the *Burbank* variety. On healthy trees, the anomalies were about 2% whereas on ill trees up to 58%. *Goff* (1901) claimed that nutritional-physiological moments are decisive. On poor

Table 9 Cross-fertility of European plum varieties (Szabó, 1989, Siófok 1982–1985, Kecskemét 1985–1989, Csány 1985–1986)

♂ / ♀	Besztercei	Bluefre	Cacanska najbolja	Cacanska rodna	Cacanska lepotica	President	Ruth Gerstätter	Silvia	Stanley	Female fertility	Fruit set by free pollination %
Althann ringló	No of fl.	303(1)		460	564	752		242(1)	710	3031	1341
	Fr. set %	15.5		15.7	12.6	5.9		7.4	24.0	13.9	18.4
Besztercei Bt.2.[x]		74				69			90	233	468
	40.3				47.6			38.0	42.0	7.6	
Bluefre[x]	113					148			175	436	2183
	11.3					29.8			17.4	19.5	17.7
Cacanska najbolja	1056	1818	1134		1716	2304	325		2329	10592	37973
	12.3	22.5	18.6		2.3	16.9	7.6		4.2	14.9	8.2
Cacanska rodna[x]				214(1)		445			441	100	1241
			47.2		47.6			49.0	47.9	66.0	
Centenar		241(1)	85(1)						180(1)	506	1188
	10.8	22.4						17.2	16.8	7.8	
Pescarus[xx]			172(1)						145(1)	317	535
		9.6						11.0	9.3	5.8	
President	703	1035	41(1)	1044	849			241(1)	1524	5437	6123
	16.7	25.6	14.6	19.0	32.0			7.0	18.4	19.0	26.6
Silvia			96(1)			246			145(1)	487	956
		11.5			12.7			16.6	13.6	32.2	
Stanley[x]	85	93		400	611	524		225(1)		1938	4098
	10.2	15.4		4.2	16.3	21.5		11.6		13.2	31.6
Tuleu gras[xx]			198(1)						201(1)	399	562
		13.6						0.5	7.0	48.6	
Tuleu timpuriu		441(1)	592(1)	493(1)	287(1)	418(1)			332(1)	2567	718
	0	13.5	0.2	8.7	0			0	3.7	3.1	
Ability of	1957	4009	2318	2611	4027	4906	235	708	6272		
fertilisation	12.6	18.9	14.5	17.3	18.4	22.8	7.6	8.7	17.8		

Legends: x = flowers of self-fertile varieties have been emasculated before pollination
xx = male sterile varieties
(1) = the combination has been checked once, only

Table 10 Cross-fertility of Japanese plum varieties (Szabó, 1989, Siófok 1984–1985, Kecskemét 1985, Helvécia 1985–1986)

♂ / ♀	Burbank	Duarte	Elephant Heart	Friar	Laroda	Late Santa Rosa	Methley	Santa	Shiro	Female fertility	Fruit set by free pollination %
Burbank	No of fl.	322	245(1)	80(1)	97(1)	214	229	233	189	1609	2595
	Fr. set %	2.8	20.0	21.3	18.6	21.0	4.7	12.5	0.5	12.7	12.4
Duarte	206(1)		126(1)				71(1)	232(1)	489(1)	1118	1895
	5.3		1.43				0	7.3	0	5.4	1.0
Elephant Heart	215	148				85(1)	175	173	163	959	1984
	0	0.6				0	3.7	1.2	0	0.9	0.8
Friar	249(1)				94(1)	190(1)	137(1)			670	787
	8.8				19.1	20.0	7.623.4			17.8	9.3
Laroda	83(1)					118(1)	115(1)			316	212
	3.6					4.2	0			2.6	8.5
Late Santa Rosa	151(1)			252(1)	116(1)		87(1)			606	1587
	1.3			4.0	4.3		2.4			3.0	1.3
Methley	384	235	131	218	251	186		105	142	1652	3580
	16.4	7.2	26.3	5.2	13.2	18.5		14.7	1.5	12.9	16.1
Santa Rosat	203	186	123(1)				246		76(1)	834	1025
	3.0	3.0	1.6				0		2.6	2.0	2.9
Shiro	386	419	306				416	491		2018	2584
	5.1	7.6	8.7				0.6	8.7		6.1	4.1
Ability of											
fertilisation	1877	1310	931	550	558	793	1476	1234	1053		
	5.5	4.2	14.2	10.2	13.8	12.7	4.4	8.9	0.9		

Legend: (1)= the combination has been checked once, only

soil, the plum trees produced many sterile pistils after a season of heavy yield.

Tóth (1980) met such trees in variety collections with high flower densities yet rather unfruitful from year to year. The cause of sterility is not the lack or scarcity of pollen but the defective pistil. That was described in the variety *Alutscha 1/15*. At closer study of that variety, variation in the length of pistils was stated. The underdeveloped pistils did not set fruit. Their mean frequency over three years was 32%.

Surányi (1994) explored over more than 20 years the flower anomalies of plums. He proved that occurrence of characters related to sterility (lack of pistil, defective anthers, poor growth of pollen tubes) are inherent properties though subject to seasonal effects as well as to virus infection.

Palara (1996) reported the same in Japanese plums where defective flowers are found in more than 50% of cases but the influence of the season is also important. Observations of *Szabó* (1997) on *Ozark Premier* and *Del Rey Sun* varieties.

The anthers and the male gametes may also display symptoms of degeneration. Male sterility is also a cause of reduced fruit set. It is known in plums since Crane (1925) at the variety *Golden Esperen*. Then *Johansson* (1956) referred to it in the common yellow plum. The variety *Tuleu gras* transmitted the male sterility to the F_1 generation. Anatomical studies prove that the defective anthers of the male sterile flowers developed normally until cell division finished. The tapetum layer of the pollen sack, however, preserves its integrity much longer time than normal, and does not allow the development of microspores and mature pollen cells after the tetrads were dissolved. (*Cociu* & *Bumbac*, 1968).

In *Table 11*, published information is summarised referring to male sterile plums.

Table 11 The male sterile plum varieties

Albatros	Dobrudja No. 205	Yalomita	Pusevka
Alutcha yellow	Earning delicious	Kabul greengage	Rouge hatif
Besztercei szilva sterile types	Early Red	Kishinyevska rannaya	Sentyabrskaya
Blue Date	Emurti Red	Common Yellow plum	Stafner Zwetschge
Common Yellow	Golden of Esperen	Large Red	Superb
Chabot	Excelsior	Minerva	Tuleu gras
Centenar	Great Yellow	Omurtaga Red	Tuleu timpuriu
Dubbéle Boerewitte	Howe	Pescarus	Vengerka Jubilejnaja

2.7. *Apomixis*

Aldreman & *Weir* (1951) concluded on the base of their experiments with plums that in variety hybrids the apomictic phenomena are frequent.

2.8. *Metaxenia*

Metaxenia (which means the appearance of properties of the polliniser on the fruit) was observed in plums too. The effect is expressed in the size of fruit and time of ripening (*Crane* & *Brown*, 1942). Fruits of *Tuleu gras* grew larger if *Althann ringló (Reine Claude)* was the polliniser (*Constantinescu*, 1939).

On the contrary, *Kostina* (1927) obtained fruits by self pollination and free pollination and was not able to distinguish them. Also *Tóth* (1975) did not find difference between fruits derived from selfing and from free pollination, i.e. measurements did not prove changes in size in favour of the latter.

3. Association of varieties in plantations for the planning of commercial orchards

The experimental pollinations are aimed to find the most advantageous associations of varieties for the plantations. For the planning one has to make use of all information concerning blooming phenology, fertility relations, the minimal number (or ratio), distance and placement of polliniser trees.

Varieties either self-incompatible or of genuinely low fertility deserve special attention as being aware of the chance of unfavourable weather conditions. First of all, conditions of an optimal pollination must be secured. Then, requirements in cultivation, training, pruning, vigour, etc. will determine the planting density, plant protection measures, conditions of time (coincidence) and techniques of (mechanical) harvest, etc. In up to date plantations, the varieties associated should represent nearly similar commercial values (*Soltész*, 1980).

3.1. *The choice of pollinisers*

In Table 12 there is a survey of European plum varieties mainly grown in Hungary (and in Europe) together with their recommended pollinisers compiled by *Szabó* (1989). An adequate (at least 70%) coincidence of blooming and (at least 10%) fertilising ability were the decisive criteria in the selection of the pollinisers.

Experimental cross-pollinations prove that most European plum varieties are inter-fertile with each other. It is highly probable that varieties belonging to the same blooming time group are also god pollinisers for each other as far as they produce pollen, abundantly. Before introducing a variety to the list, cross-pollination tests are required.

Although the offered list of *Table 12* contains popular varieties and commercially promising ones as main varieties as well as pollinisers, but it does not mean that there were no more good pollinisers in the respective blooming time groups. The multiple requirements, however, are not easy to satisfy, consequently, some but small weakness prevents the success of nearly excellent varieties in commercial production.

The "Cacak" plum varieties (*Čačanska lepotica*, *Čačanska najbolja*, *Čačanska rodna*) are medium early blooming, *Bluefre* is intermediate whereas *Stanley* medium late, together would cope by their fertilising ability with most plum varieties. For early blooming varieties *President*, For late blooming ones *Besztercei szilva* and *Stanley* is advisable pollinisers.

The overlap in blooming of the early *President*, intermediate *Bluefre*, medium early *Čačanska najbolja*, moreover, medium late *Stanley* varieties rarely reaches the critical level of 70%, all the same, furnishing pollen abundantly and the high level of fertility of *President* deserves to consider those varieties associated as an excellent ensemble.

The fertility of *Ruth Gerstätter* being low (less than 10%) in spite of abundant pollen supply, several pollinisers would do better than one single.

Among varieties to be pollinated there are also partially self-fertile ones as *Čačanska lepotica, Bluefre* and *Stanley*, the fruit set of which could be enhanced in some years by means of moving bee hives either to promote self pollination or to improve efficiency of poor pollen producers.

In seasons of adverse weather during the blooming period, cross pollination improved substantially fruit set of *Felenberg (Italian blue)*, a self-fertile variety (*Kellerhals*, 1986/b.).

Tóth (1980) claims that fruit set is enhanced in self-fertile varieties too in mixed plantings of 2 or 3 varieties.

Also *Szabó* & *Nyéki* (1989) observed in some years relatively poor fruit set on self-fertile varieties which may be improved in mixed plantings.

Low levels of self-fertilisation are observed at some growing sites in Japanese plums. The extent of that type of self-fertility is, however, unstable and by all means less than required. The varieties had better to be considered as self-incompatible ones. Japanese plum varieties being widely grown in Italy are also recommended to be associated according to recommendations in *Table 13*.

3.2. The volume and ratio of pollinisers

Cociu (1961), *Kellerhals* (1986/a) and *Szabó* (1989) proved, convincingly, the superior fruit set caused by cross-fertilisation even in self-fertile pulm varieties. Safe yields of univarietal plantations are expected with highly self-fertile varieties (*Besztercei Bt. 2, Čačanska rodna*), only.

Self-incompatible varieties should be associated to two different polliniser varieties, at least, as suggested by *Tóth* (1967/b), *Chiriae* et al. (1981), *Bellini* et al. (1982) and *Roman* & *Radulescu* (1986).

Sufficiently safe fertilisation is conditioned by a continuous supply of pollen from the start during all the time

Table 12 Polliniser varieties recommended for European plums (Szabó, 1989)

Varieties to be pollinated	Pollinisers renown as of good fertilising ability	Varieties of coincident blooming period	Additional polliniser varieties recommended by the literature
Self-incompatible and male sterile varieties			
Althann ringló	Cacanska najbolja, Cacanska rodna,	Cacanska lepotica Dereceni muskotály	Ageni (1, 10, 13), Besztercei szilva (1), Silvia (13), Stanley (8, 11, 13)
Cacanska najbolja	Bluefre, Cacanska lepotica, Cacanska rodna	Althann ringló, Debreceni muskotály, Silvia	Ruth Gerstätter (9), Stanley (9)
Centenar	Bluefre, Cacanska lepotica, Stanley	Althann ringló, Besztercei szilva, Cacanska najbolja, Cacanska rodna, Dereceni muskotály, President, Silvia	Ageni (13), Althann ringló (12), Bluefre (13), Silvia (7, 12, 13), Stanley (7, 12, 13)
Debreceni muskotály		Ageni, Althann ringló, Cacanska lepotica, Cacanska najbolja, Cacanska rodna, President, Silvia	Ageni (1), President (10)
Pescarus		Althann ringló, Cacanska najbolja, Cacanska rodna, President	Ageni (13), President (7, 13)
President	Bluefre, Cacanska lepotica, Cacanska najbolja, Cacanska rodna	Althann ringló, Debreceni muskotály	Althann ringló (3, 11), Bluefre (3, 4, 11), Debreceni muskotály (10), Ruth Gerstätter (2, 3, 8, 11), Stanley (2, 3, 4, 8)
Ruth Gerstätter		Ageni, Bluefre, Cacanska najbolja, Debreceni muskotály, President,	Ageni (27), Althann ringló (11), President (2, 3, 11, 12), Silvia (7), Stanley (2, 3, 7, 11)
Silvia	Cacanska lepotica, President	Cacanska najbolja, Cacanska rodna, Debreceni muskotály	Althann ringló (13), Bluefre (7, 12, 13), Stanley (7, 12, 13)
Tuleu gras		Besztercei szilva	Ageni (3, 13), Althann ringló (3, 13), Bluefre (3), President (3, 12), Ruth Gerstätter (3), Silvia (13), Stanley (3, 7, 13)
Partially self-fertile varieties			
Bluefre	Besztercei szilva, President, Stanley	Ageni, Cacanska najbolja, Cacanska rodna	Preident (3, 4, 6), Ruth Gerstätter (3, 4, 6), Stanley (3, 6)
Cacanska lepotica		Althann ringló, Cacanska najbolja, Cacanska rodna, Debreceni muskotály, President, Silvia	Cacanska najbolja (9), Cacanska rodna (9)
Stanley	Besztercei szilva, Bluefre	Ageni	Ageni (13), Bluefre (3, 6), President (4, 6), Ruth Gerstätter (3, 7), Silvia (13)

References:
1. Tóth (1967/b)
2. Paunovic (1971)
3. Bellini & Bini (1978)
4. Faccioli & Marangoni (1978)
5. Keulemans (1980)
6. Nicotra (1980)
7. Roman (1981)
8. Stösser (1984)
9. Ogasanovic (1985)
10. Tóth & Erdős (1985)
11. Kellerhals (1986/b)
12. Roman & Radulescu (1986)
13. Cociu (1996)

Table 13 Polliniser varieties recommended for the most known Japanese plum varieties (Bellini et al., 1986)

Variety	Polliniser variety
Early Golden	Morettini 355, Ozark Premier
Morettini 355	Shiro, Sorriso di Primavera, Sangue di Drago, Santa Rosa, Obilnaya
Black Beauty	Santa Rosa, Ambra*, July Santa Rosa
Burmosa	Laroda, Morettini 355, Ozark Premier, Sorriso di Primavera, Santa Rosa
Sorriso di Primavera	Shiro, Morettini 355, Santa Rosa
Obilnaya	Morettini 355, Sorriso di Primavera, Shiro
Shiro	Morettini 355, Sorriso di Primavera, Early Golden, Angeleno, Santa Rosa
Frontier	Friar, Laroda, Morettini355, Sorriso di Primavera, Santa Rosa
Black Star	Black Diamond Sorisso di Primavera, Frontier, Angeleno, Simka, Laroda, Black Gold
Calita	Friar, Laroda, Morettini 355, Santa Rosa, Sorriso di Primavera
Black Amber	Friar, Santa Rosa, Laroda, Black Star
Black Gold	Black Amber, Angeleno, Laroda, Black Diamond, Ozark Premier, Black Star, Calita, Simka
Ozark Premier	Santa Rosa, Friar, Sorriso di Primavera, Morettini 355, Laroda, Sangue di Drago, Early Golden
Golden Plum	Midnight Sun, Del Rey Sun, July Sun, Yellow Sun, Green Sun
Black Diamond	Calita, Sorriso di Primavera, Ozark Premier, Angeleno, Black Star, Laroda, Friar, Obilnaya, Simka
Green Sun	Midnight Sun, Friar, Obilnaya, July Sun, Yellow Sun
Laroda	Ozark Premier, Calita, Friar, Santa Rosa, Burmosa, Black Gold, Sorriso di Primavera
TC Sun	Howard Sun, Globe Sun, Zanzi Sun, Tracy Sun
Fortune	Friar, Santa Rosa, Laroda
Friar	Black Amber, Satsuma, Laroda, Calita, Morettini 355, Laroda, Santa Rosa, Ozark Premier, Queen Rosa
Bella di Barbiano	Friar, Ozark Premier
Angeleno	Black Amber Gold, Black Star, Black Diamond, Friar, Santa Rosa, Sorriso di Primavera, Ozark Premier, Simka Obilnaya

of blooming. For that purpose, two polliniser varieties are needed, at least. Regarding the 2 to 4-day yearly variation of blooming time we have to cope with the fact that cool weather may delay the burst of anthers to the second day of blooming. One of the polliniser varieties should precede (by 2 days) the main variety, the other should lag (by 2 days) after in order to overlap the whole blooming time of it.

For self-incompatible varieties, the association of at least 2 pollinisers is recommended which should be planted alternatively in every 2nd or 3rd row (*Tóth*, 1967/b).

For safe fertilisation a mixture of planting inter-compatible varieties are recommended by *Bellini* et al. (1982) 2 to 3, by *Chiriac* et al. (1981) 3 to 4, at least. The majority of Romanian plum varieties, being self-incompatible or male sterile, need the combination of 2, 3 or more varieties (*Roman* & *Radulescu*, 1986).

Male sterile varieties (e.g. *Centenar, Tuleu gras*) require further two pollinisers to provide mutually sufficient pollen for them. Inherently poor yielding varieties (e.g. *California Blue, Ruth Gerstätter*) are to be associated with more pollinisers, preferably.

As for ratio of the variety to be pollinated and two pollinisers, *Tóth* (1980) attempted the following suggestions:

Fertile varieties	4 : 1 : 1
Intermeadately fertile varieties	2 : 1 : 1
For varieties yielding poorly	1 : 1 : 1

3.3. The spatial placement of varieties

Large blocs planted to single varieties facilitate cultivation, however, conditions of pollination may deserve priority. For self-incompatible and partially self-fertile varieties the planting schemes of *Figure 4* are recommended. According to our observations, the yield of the inner rows within the 4-row blocks of self-incompatible varieties may decline. It is preferable to reduce the width of blocks assigned to a self-incompatible variety to two rows, and to use 2 or more polliniser varieties. The planting of single rows of the main variety is not recommended by reasons of organisational inconveniences.

Blocks larger than two rows planted to self-incompatible varieties are denounced by *Tóth* (1980). In the third row away from the polliniser the decline of yields was stated (*Tóth*, 1967/b) which is equivalent with a distance of 15 m (*Keulemans*, 1980). The maximum distance admitted from he pollen source is set about 16 m (*Soltész*, 1979). In *Figure 5*, the yield of the variety *Debreceni muskotály* is shown as a function of distance to the polliniser according to the means of three years.

On the variety *Wydale* 7% fruit set was registered in the neighbouring 1st row to the polliniser but less than 1%, only, in the 4th row as reported by *Free* (1962). The yield of *Debreceni muskotály* declined, significantly, away from the polliniser variety *Besztercei szilva* in the 2nd row, moreover, scarcely reached 40%, only, in the 6th row (*Tóth*, 1967/b). *Belmans* & *Keulemans* (1985) suggested to plant a polliniser tree as each 5th within the row.

In Japanese plums, pollinisers yielding relatively poor quality of fruit (e.g. *Sorriso di Primavera*), are combined at a rate of 10% within the rows.

Griggs & *Hesse* (1963) suggest for Japanese plums that each 4th tree in every 4th row should be a polliniser coincident in blooming with the main variety. *Bellini* et al. (1982) recommend cherry plums for that purposes, as *Brandt* et al. (1978) assign *Myrabolan B* as polliniser to be combined into blocks of one or two varieties of Japanese plum.

European plums known to be self-fertile (e.g. *Bluefre, Cacanska lepotica, Stanley*) used to bear low flower densities following adversities caused by frost damage or as a consequence of heavy yield. The hope of an almost normal yield, however, still could be maintained by a higher rate of fruit set due to cross-pollination. As a matter of fact, fruit set has improved substantially by allogamy. Thus, in order to exploit that relation, *Szabó* et al. (1989) suggest blocks to be planted to single varieties of that type about 20 x 40 m as optimal.

It is reasonable to stick to the principle that planting of larger univarietal blocks should be avoided, except of highly self-fertile varieties as *Besztercei Bt. 2* and *Cacanska rodna*.

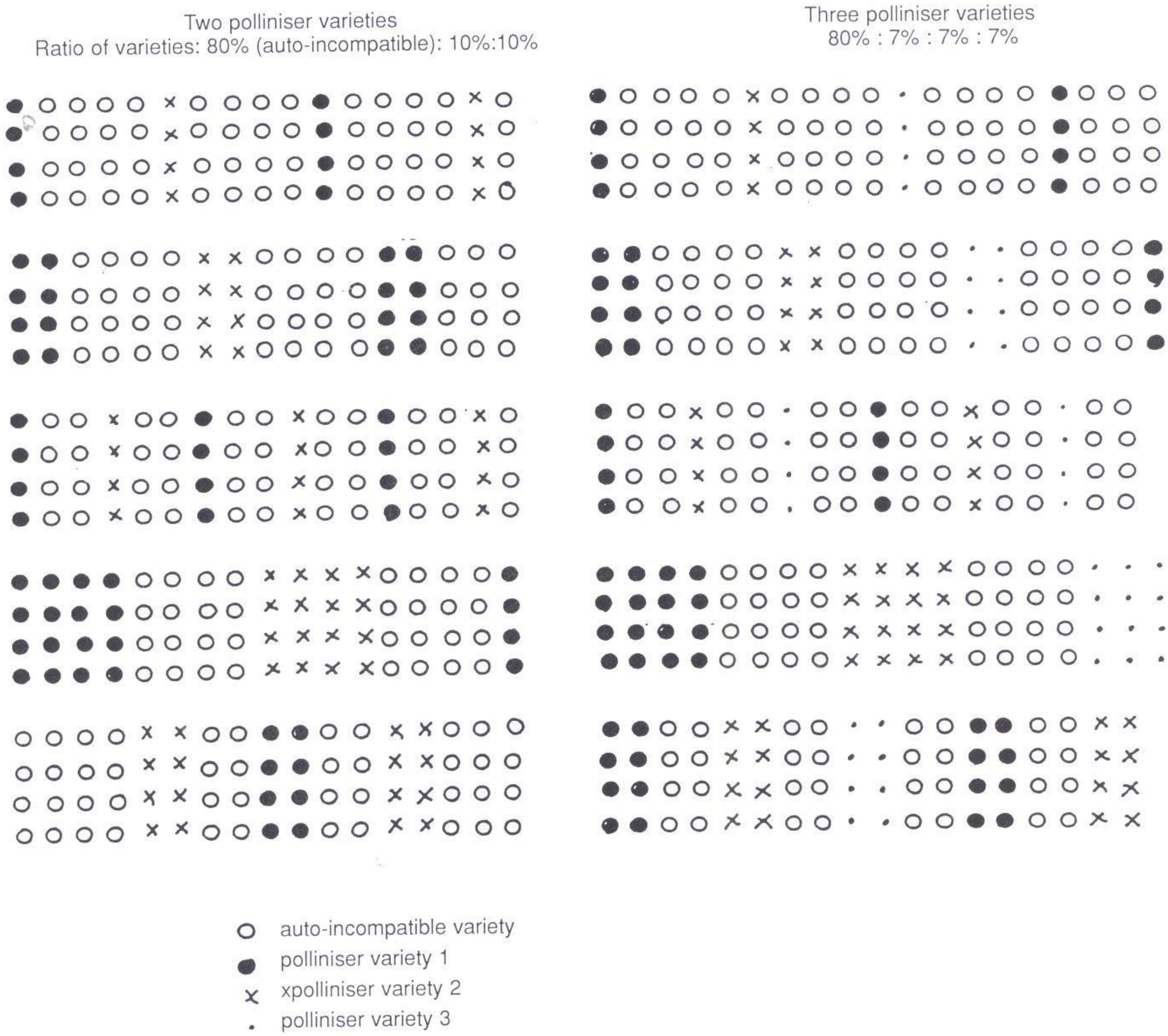

Figure 4 – Sketch of the planting of varieties

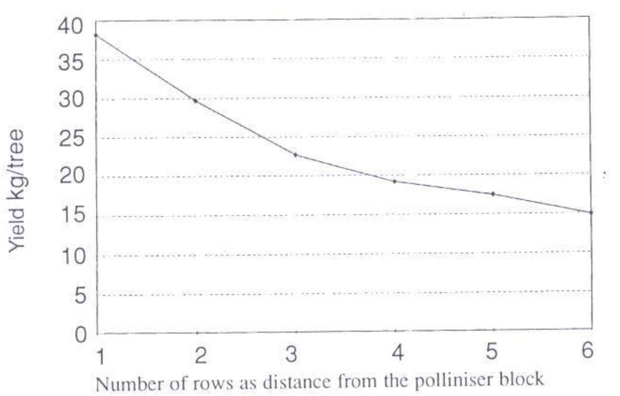

Figure 5 Yield per tree of the self-incompatible variety, *Debreceni muskotály*, depending on the distance (number of rows) from the block of polliniser *Besztercei szilva* variety. (Tóth, 1967)

References

Albertini, A. (1978): Valutazione agronomica e pomologica di alcune cultivar di susino allevate nel Trentino. Frutticoltura, 40. (7–8): 9–16.

Alderman, W. H. & Angelo, E. (1993): Self-and cross – sterility in plum hybrids. Proc. Am. Soc. Hort. Sci. 29: 118–121. Ref:

Knight, R. L. (1969): Abstract Bibliography of Fruit Breeding and Genetics to 1965. Prunus. Comm. Agr. Bur. East Malling. 4.

Alderman, W. H. & Weir, I. S. (1951): Pollination studies with stone fruits. Minnesota Agric. Exp. Sto. Tech. bull. 198...

Arora, R. L. & Ranvir Singh (1987): Investigations on effect of mixed pollination on fruit set in subtropical plum (Prunus salicina Lindl.). Incompatibility Newsletter No 19: 4–9.

Backhouse, W. O. (1911): Self-sterility in plums. Gdnrs'Chron. 3 rd. Ser. 50: 299.

Bellini, E. (1973): Prugne e susine: "vecchie" e "nouve" cultivar a confronto. L'Inf. Ag. 29 (14): 12077–12111.

Bellini, E. (1975): Indagini sulla biologia fiorale della „Burmosa" e di alcune sue cultivar impollinatrici. Riv. Ortoflorofrutti. Ital. 59. (3): 210–221.

Bellini, E. (1980): Cultivar. (in Baldini, E.–Scaramuzzi ed.: Il susino. Manuale Reda.) 9–73.

Bellini, E., Liverania, A. & Sansavini, S. (1982): Osservazioni su cultivar di recente introduzione e revisione delle liste varietali del susino. Cent. Oper. Ortofrutticolo, Ferrara. 39–55.

Bellini, E., Nencetti, V. & Nin, S. (1986): La scelta degli impollinatori. Terra e Vita 37 (26): 26–28.

Belmans, K. & Keulemans, J. (1985): Die Pflaumenkultur und Pflaumenforschung in Belgien. Erwerbsobstbau. 27 (9): 213–216.

Belmans, K. (1986): Les Verietes de prunes. Fruit. Belge. 54 (413): 53–76.

Bradt, O. A., Hutchinson, A., Leuty, S. J. & Ricketson, C. L. (1978): Fruit varieties – A guide for commercial growers. Ministry of Agriculture and Food, Ontario, Publication 430 (1): 112.

Chiriase, St., Roman, R. & Rudi, E. (1981): Cercetari privind sortimentul de prun pentru industrializare. Lucrarile Stiintifice ale Inst. Cers. Pomicult. Pitesti Bucuresti. 9: 155–164.

Cobianchi, D., Faedi, W., Rivalta, L. & Battelli, T. (1978): Ricerche sulla fertilita delle cultivar di susino cino-giapponose. Riv. Ortoflorofrutti. Ital. 62. (5): 552–562.

Cociu, V. (1961): Unele aspecte ale biologiei infloritului si fructificarii la prun si visin (Manuscript).

Cociu, V. & Bumbac (1968): Cercetari privind microsporogenesa si biologia infloritului la hibrizzi de prun. Annal. Inst. Cers. Pomicult. Pitesti. 1: 25–42.

Cociu, V. (1996): Prcticularitátile biologice ale cresterii si rodisii prunului comun (Prunus domestica L.). In. Cociu, V. ed.: Prunul. editura Conphys.

Constantinescu, N. (1939): (Contributions to the study of self-and inter-fertility in differnet plum varieties) Horticultura rom. 17. (9–10): 2–4. p. Ref: Knight, R. L. (1969): Abstract Bibliography of Fruit Breeding and Genetics to 1965. Prunus. Comm. Agr. Bur. East Malling. 130.

Costa, G. & Grandi, M. (1982): Contributo alla conoscenza delle esigenze di impollinazione di nouve cultivar di susino. Rivista di Frutticoltura e di Ortofloricoltura 44 (12): 74–76.

Crane, J. C., Primer, P. E. & Campbell, R. C. (1960): Gibberellin induced parthenocarpy in Prunus. Proc. Am. Soc. hort. Sci. 75: 129–137. Ref. Knight, R, L. (1969): Abstract Bibliography of Fruit Breeding and Genetics to 1965. Prunus. Comm. Agr. bur. East Malling. 132.

Crane, M. B. (1925): Self-and cross – incompatibility in plums and cherries. J. Genet. 15: 301–322. p. Ref: Knight, R. L. (1969): Abstract Bibliography of Fruit Breeding and Genetics to 1965. Prunus. Comm. Agr. Bur. East Malling. 134.

Crane, M. B. & Lawrence, W. J. C. (1929): Genetical and cytological aspects of incompatibility and sterility in cultivated fruits. J. Pomol. 7: 276–301. Ref: Knight, R. L. (1969): Abstract Bibliography of Fruit Breeding and Genetics to 1965. Prunus. Comm. Agr. Bur. East Malling 134.

Crane, M. B. & Brown, A. G. (1939): Incompatibility and sterlity in the gage and dessert plums. J. Pomol. 17: 51–66. p. Ref: Knight, R. L. (1969): Abstract. Bibliography of Fruit Breeding and Genetics to 1965. Prunus. Comm. Agr. Bur. East Malling. 137.

Crane, M. B. & Brown, A. G. (1942): The causal sequence of fruit development. J. Genet. 44: 160–168. p. Ref: Knight, R. L. (1969): Abstracts Bibliography of Fruit Breednig and Genetics to 1965. Prunus Comm. Agr. Bur. East Malling 138.

Efimov, V. A. (1959): Posledovatelnosty zacvetaniya raznith vido i sortov vishni i szlivy. Izvestyiya. TSZHA. 1: 165–174.

Einset, O. (1939): Experiments in plum pollination. Gartenbauwiss. 13: 318–326.

Faccioli, F. & Marangoni, B. (1978): Ricerche sulla fertilita delle cultivar di susino europeo (Prunus domestica L.) Riv. Ortoflorofrutti Ital. 62 (6): 584–596.

Free, J. B. (1962): The effect of distance from pollinizer varieties on the fruit trees in plum and apple orchards. J. Hort. Sci. 37: 262–271.

Gautier (1977): La prunier et sa culture. L'arboriculture Fruitiere 24 (285): 31–73.

Gavrilina, Z. V. (1986): (Self-fertility in promising plum varieties in Leningrad provinde) Sbornik Nauchnykh Trudov po Prikladnoi Botanike, Genetike i Selektsii 99: 54–57. (In Russian)

Goff, E. S. (1901): A study of certain conditions affecting the setting of fruits. Rep. Wis. agric. Exp. Stn, 289–303. Ref.: Knight, F. L. (1969): Abstract Bibliography of Fruit Breeding and Genetics to 1965. Prunus. Comm. Agr. Bur. East Malling 210.

Griggs, W. H. & Hesse, C. O. (1963): Pollination requirements of Japanese plums. Calif. Agr. Exp. Stat. Ext. Serv. Leaflet 163.

Harsányi J. (1975): Besztercei szilva klónok összehasonlító vizsgálata. Fajta kísérletezés – Fajtaminősítés. 1974. 25: 415–437.

Hedrick, V. P. (1911): The plum of New York. Dept. Agr. Annual Report Albany 616. p.

Illiev, P. (1985/a): Srok i sila na coftezs pri introducirani slivovi sortove. Rastenevödni Nauki 22 (1) 85–92.

Johansson, E. (1956): Undersökningar av befruktningsfőrhallanden hos fruktsorter vid Alnarp 1945–1955. Medd. Tradgardsförs. Malmo, 101.

Kellerhals, M. (1986): Die Befruchtungsverhältnisse der Obstsorten (1. Teil). Schweiz. Zeitschrift für Obst-und Weinbau. 122. (12): 319–327.

Kellerhals, M. (1986/b): Die befruchtungseerhältnisse der Obstrsorten. (Schuluss). Schweiz. Zeitschrift für Obst und Weinbau. 122. (13): 363–371.

Keöpeczy-Nagy Z. (1943): Gyümölcsfáink különböző fejlődési időpontjai. M. kir. Kert. és Szől. Főisk. Közl. 2.

Keulemans, J. (1980): Pollinisaiton et fecondation chez le prunier. Le Fruit Belge. Liege. 48 (390): 117–121.

Keulemans, J. (1991): Cropping behavior, flowerbud formation, pollination and fruit set of different plum cultivars in Belgium. Acta Horticulturae. 283. 117–129.

Keulemans, J. (1994): Pollination and fruit set in self incompatible plum cultivars. Acta Horticulturae 359. 260–268.

Surányi D. (1994): Ontogenetic characteristics in flowers of some plum cultivars. Acta Horticulturae. 359: 278–286.

Kellerhals, M. & Rusterholz, P. (1994): Plum breeding at Wädenswill. Acta Horticulturae 359. 82–86.

Kostina, K. F. (1927): (Experiments on self-pollination of fruit trees.) Zap. gos. nikit. bot. Sada, 9: 53–76. p. Ref: Knight, R. L. (1969): Abstract Bibliography of Fruit Breeding and Genetics to 1965. Prunus. Comm. Agr. Bur. East Malling. 284.

Lee, C. L. & Bünemann, G. (1981): Befruchtungsverhalten ausgewählter Pflaumensorten in Nord-Deutschland. Erwerbsobstbau, 23 (3): 52–55.

Levickaja, L. L. & Kotoman, E. M. (1980): Samoplodnosti nekotoryh sortov slivy. Sadov. Vinogr. Vin. Moldav. 7: 21–24. p.

Marshall, R. E. (1919): Report of three years' results in plum pollination in Oregon. Proc. Am. Soc. hort. Sci. 16: 42–49. p. Ref.:

Knight, R. L. (1969): Abstract Bibliography of Fruit Breeding and Genetics to 1965. Prunus Comm. Agr. Bur. East Malling. 330.

Mc.Gregor, S. E. (1976): Insect pollination of cultivated crop plants. Agriculture Handbook No. 496.

Misic, N., Kurtovic, M., Duric, G. & Cmezik, Z. (1998): Oblik i tranjanje klijavosti polena sljive Pozegace is Stenleja pri razlicitim uslovima cuvanja. Radovi Poljoprivednog Fakulteta Univerziteta u Sarajevu. 36. (40): 147–155. Ref: Pl. Breed. Abstr (1989) 59 (3): 249.

Nicotra, A. (1980): Le principale cultivar di susino. Frutticoltura 42 (1): 15–23. pl.

Nicotra, A., Moser, L., Cobianchi, D., Damiano, C. & Faedi, W. (1983): Monografia di cultuvar di susino. Roma.

Nyéki J., Szabó Z., Tóth F.-né & Pete A. (1985): Szilvafajták virágzása és termékenyülése. Kertgazdaság 27 (2): 35–63.

Nyéki J. (1989): Csonthéjas gyümölcsűek virágzása és termékenyülése. Doktori értekezés. MTA, Budapest.

Ogasanovic, D. (1985): Iznalazenja napjpogodnijih oprasicana za nove sorte sljiva. Jug. vocar 19. (71–72): 109–115.

Paunovic, S. A. (1971): Proucavanje i izbor najpogodnijik aprasivaca za vaznije sorte sljiva. Jug. Vocar. 17–18: 109–122.

Palara, U., Passerini, V. & Stocchetti, B. (1990): Biologia fiorale e caratterizzazione di alcune cultivar americane di susino ciano-giopponese della serie "Black". Frutticoltura 6: 39–43.

Palara, U. (1996): Situazione, sviluppi e particolaritá della cultura del susino da tavola in Francia. Frutticoltura 9: 45–48.

Petre, G. H. & Pislaru, C. (1981): Contributi la stabilirea sortimentului de prune pentru valea Licrarile Stiientifice Dimbovitei. Lucranile Stiinftifice de Inst. Cers. Pomicult. Pitesti. Bucuresti. 9: 135–144.

Philp, G. L. & Vansell, G. H. (1944): Pollination of deciduous fruits by bees Calif. Agr. Ext. Serv. Vir. 62.

Randhawa, G. S. & Nair, P. K. R. (1960): Studies on floral biology of plum grown under sub-tropical conditions. II. Anthesis, dehiscence, pollen studies. and receptivity of stigma. III. Pollination. Fruit set and fruit development. Indian J. Hort. , 17: 83–95. p., 96–101. p. Ref: Knight, R. L. (1969): Abstract Bibliography of FruitBreeding and Genetics to 1965. Prunus. Comm. Agr. Bur. East Malling. 398.

Rawes, A. N. (1921): Pollination in orchards. IV. Self-fertility and self-sterility in plums. J. R. Hort. Soc. 46: 353–356. p. Ref: Knight, R. L. (1969): Abstract Bibliography of Fruit Breeding and Genetics to 1965. Prunus. Comm. Agr. Bur. East Malling. 401.

Ro, L. M. (1929): Perekresztnoje opülenyije u razliesnük kplodovüh gyerevjev. Mlejer. 3–37.

Roman, R. (1981): Cercetari privons sortimentul de prun destinat Consumulut in stare proospata. Lucralile Stiintifice ale Inst. Cerc. pomicult. Pitesti-Bucuresti. 9: 145–153.

Roman, R. & Radulescu (1986): Pollenizatorii soiurilor noi de prun recent create in tara. (Sokszorosított anyag).

Rudloff, C. F. & Schanderl, H. (1937): (Studies in the biology of pollination in plums, myrobalans, and greengages. II.) Gartenbauwiss. 10: 669–687. p. Ref: Knight, R. L. (1969): Abstract Bibliography of Fruit Breeding and Genetics to 1965. Prunus. Comm. Agr. Bur. East Malling. 415.

Rudloff, C. F. & Schanderl, H. (1950): Die Befruchtungsbiologie der Obstgewaschse, 3. Aufl. Stuttgart.

Sansavini, S., Zambrini, M., Costa, G. & Cavicchi, C. (1981): Indagine su nuove e vecchie cultuvar di susino: poche le cultivar pienamente "affidabili" per la valle padana. Scelte varietali in frutticoltura, Ferrara, 95–102.

Shoferistov, E. P. (1986): Experiments on the seft pollination of mzrobalan plum) Byulleten' Gosudarstvennogo Nikitskogo Botanicheskogo Sada 61: 35–39. Ref: pl. Breed. Abst. 1989. 59 (1): 68.

Soltész M. (1979): Fajtatársítás a gyümölcsültetvényben in Gyuró F.–Vig P. szerk.: A gyümölcsök telepítéstervezésének irányelvei. Ma ujdonság, holnap gyakorlat. Mezőgazdasági Kiadó, Budapest. 52–55.

Soltész M. (1980): A gyümölcsültetvények faj- és fajtatársításának alapjai. in. Nyéki J. szerk.: Gyümölcsfajták virágzásbiológiája és termékenyülése. Mezőgazdasági Kiadó, Budapest. 83–110.

Stösszer, R. (1980): Zusammenhaenge zwischen Befruchtung und Ertrog im Obstbau. Obst. und Garten 99 (4): 185–1988.

Stösser, R. (1984): Untersuchungen über die Befruchtungs biologie und Pollenproduktion innerhalb der Gruppe Prunus domestica. Erwerbobstbau 26 (5): 110–115.

Surányi D. (1970): A csonthéjasok termékenyülési mutatója a virág-index. Bot. Közl. 57 (2): 135–138.

Surányi D. (1985): Gyűjteményes és termesztett szilvafajták virágszerkezete, alaktani bélyegek és az öntermékenyülés kapcsolata. Kandidátusi értekezés. MTA Budapest. (Kézirat)

Szabó Z. & Nyéki J. (1985): Floweing phenology of plum cultivars under Hungarian ecological conditions. Acta Horticulturae 423: 23–29.

Szabó Z. & Nyéki J. (1989): Selection of pollinating plum varieties and their placement in the orchard. Acta Agronomica Acad. Sci. Hung. 38. (3–4): 313–329.

Szabó Z. (1989): Európai és japán szilvafajták virágzása, termékenyülése, társítása. Kandidátusi értekezés. MTA, Budapest

Szabó Z. (1997): Szilva. In. G. Tóth M. szerk.: Gyümölcsészet. Primom, Nyíregyháza.

Szalay L. & Szabó Z. (1999): Szilvafajták virágzás idejének variabilitása. Kertgazdaság (in press).

Szabó Z., Nyéki J., Andrásfalvy A. & Soltész M. (1999): Association of European plum varieties in the orchards. Horticultural Science (in press).

Tehrani, G. (1972): Pollen compatibility studies with European and Japanese plums. Fruit Varieties and Horticultural Digest. 26 (3): 63–66.

Therani, G. (1991): Seventy-five years of plum breeding and pollen compatibility studies in Ontario. Acta Horticulturae, 283, 95–103.

Timon B. (1970): A fenológiai fázisok meghatározása, mint a technológia alapja a gyümölcstermesztésben. Egyetemi doktori értekezés. Kertészeti Egyetem, Budapest (Kézirat).

Tóth E. (1957): Élet- és alaktani összehasonlító vizsgálatok szilvajtákon. Kertészeti Kutató Intézet Évkönyve, 2: 11–129.

Tóth E. (1966): Öntermékenyülési és termékenységi vizsgálatok szilvafajtákon. FM és Kert és Szől. Tud. Tanácsadója 12–13.

Tóth E. (1967/a): Adatok a szilvafajták termesztési értékének megállapításához. Szőlő- és gyümölcstermesztés, 3:129–150.

Tóth E. (1967/b): Önmeddő szilvafajtáink legalkalmasabb megporzói. A mezőgazdasági kutatások 1966 évi főbb eredményei. 124–129.

Tóth E. (1969): Szilvafajták öntermékenyülésének vizsgálata. Egyetemi doktori értekezés. Kertészeti Egyetem. Budapest (Kézirat).

Tóth E. (1975): A szilva termékenyülési viszonyai. in. Brózik S.–Nyéki J.: Gyümölcstermő növények termékenyülése. Mező-gazdasági Kiadó, Budapest. 158–172.

Tóth E. (1980): A szilva (in Nyéki J. szerk.: Gyümölcsfajták virágzásbiológiája és termékenyülése. Mezőgazdasági Kiadó, Budapest) 234–247.

Tóth E. & Erdős Z. (1985): Honosított szilvafajta minősítése. Kertgazdaság. 17 (4): 33–37.

Tóth E., Surányi D. & Erdős Z. (1988): A Besztercei szilva változékonysága és klónszelekciója. Kertgazdaság. 20 (3): 24–36.

Von Vahl, E. (1961): (The fruiting behaviour of the most important pome and stone-fruit varieties.) Mitt. Obst Versuchsringes, Jork. 16: 112–121.

Vitanov, M. (1963): Vliyanie na temperatura varhu prodalzitelnostia na nyakoi fenolgichni fazi pri ovostnite rasztinija. Izv. Inst. Ovoscs. 4: 23–31.

Waugh, F. A. (1897): Problems in plum pollination. Rep. Vt. agric. Exp. Stn. 1886–1887, 87–98 és 124–133. p.