Floral biology and fertility in peaches *(Review article)*

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Introduction

Peach is one of the esteemed temperate fruits, and certainly, the most important stone fruit, as its relative popularity increased significantly due to the new varieties which extended its season of consumption by early ripening varieties following immediately to the cherry season. In the world trade peach production is more than 10 million tons.

The species (*Prunus persica* L.) has a particularly extended geographic distribution. Its gene pool represented in the diversity of varieties comprises also rather high resistance to winter frosts and variable chilling requirement owing partially to its continental origin, but on the other hand, varieties adapted to mild winter temperatures have much less chilling requirement and consequently, are prone to suffer from late frost spells in the north. The chilling requirement proper to northern adaptation may prohibit peach production in areas of mild winter because of the insufficient break of bud dormancy. Special breeding programs are designed to conquer southern areas, even subtropical climates with low chilling type varieties.

The most concentrated growing areas are between the 35 and 40 northern latitude, whereas on the northern border (between the 45 and 49 degree of latitude, i.e. in the Carpathian basin) of economically feasible peach production, there is still an important production where the assortment of the most up to date peach and nectarine varieties bred in the north-eastern United States are more or less well adapted. Thus experiences accumulated in that area may deserve attention as being relevant to most of the marginal peach growing areas.

The phenology of blooming
The time of blooming

Temperate fruit species are assigned to three groups according to their time of blooming, early, intermediate and late, in a rough approach based on data of Hungarian observations (*Brózik* 1975) where peaches are representants of the intermediate group. Later, *Soltész* (1997) attempted a system of six groups (very early, early, medium early, medium late, late, very late) where peaches are put into the medium early category. Within the genus Prunus the sequence in the beginning of blooming is the following: almonds, apricots, sweet cherries, peaches, European plums, sour cherries. This order in blooming of species is rather stable. There is, however, considerable seasonal variation at the same growing site with occasional overlaps. Thus spontaneous hybrids are frequently found between almonds and peaches assigned to different blooming time groups too.

Brózik (1975) recorded in Hungary the beginning of peach blooming in some seasons as early as April 3 or 6, and on the contrary, April 30 or May 5, as extremes. More recent papers (*Nyéki & Brózik*, 1980 and *Szabó* et al. 1998) report on cases of blooming as early as in the last week of March too.

The relative order of varieties as for the beginning of blooming within the species, however, depends on the site. The further in the north peach is grown the narrower the spread of blooming dates as well as the length of the blooming period (*Ryabov*, 1975). In Central Italy (around Rome, 42° latitude) the earliest varieties started blooming earlier than February 25, whereas the late ones even after March 18. Further north in the Po valley (45° latitude) those dates correspond to March 26 and April 4 (*Della Strada* et al., 1984). *Bellini & Scaramuzzi* (1976) noted a delay of 21 days in Toscana (43–44° latitude). In Geogia State (USA, 31–35°) 16 days are observed between the extremes of varieties (*Savage & Price*, 1972). For Hungary, the corresponding mean interval lasts 4 to 7 days, only (*Nyéki & Szabó*, 1996 and *Szabó* et al., 1998)

The seasonal variation of the same varieties is also considerable, e.g. in the nectarine variety *Springcrest* 15 days (*Pitacco* et al., 1992). Being grown in southern Italy, the possibility cannot be excluded that insufficient chilling might have delayed blooming in some seasons.

The time of blooming depends on several circumstances, mainly on meteorological moments, first of all temperature. The effect of temperature, however, is ambiguous. First the varietal (i.e. genetically determined) chilling requirement of the tree must be satisfied, then the warming up of the spring is decisive.

Similarly, changes in the varietal sequence of blooming time may have resulted from combinations of bud dormancy

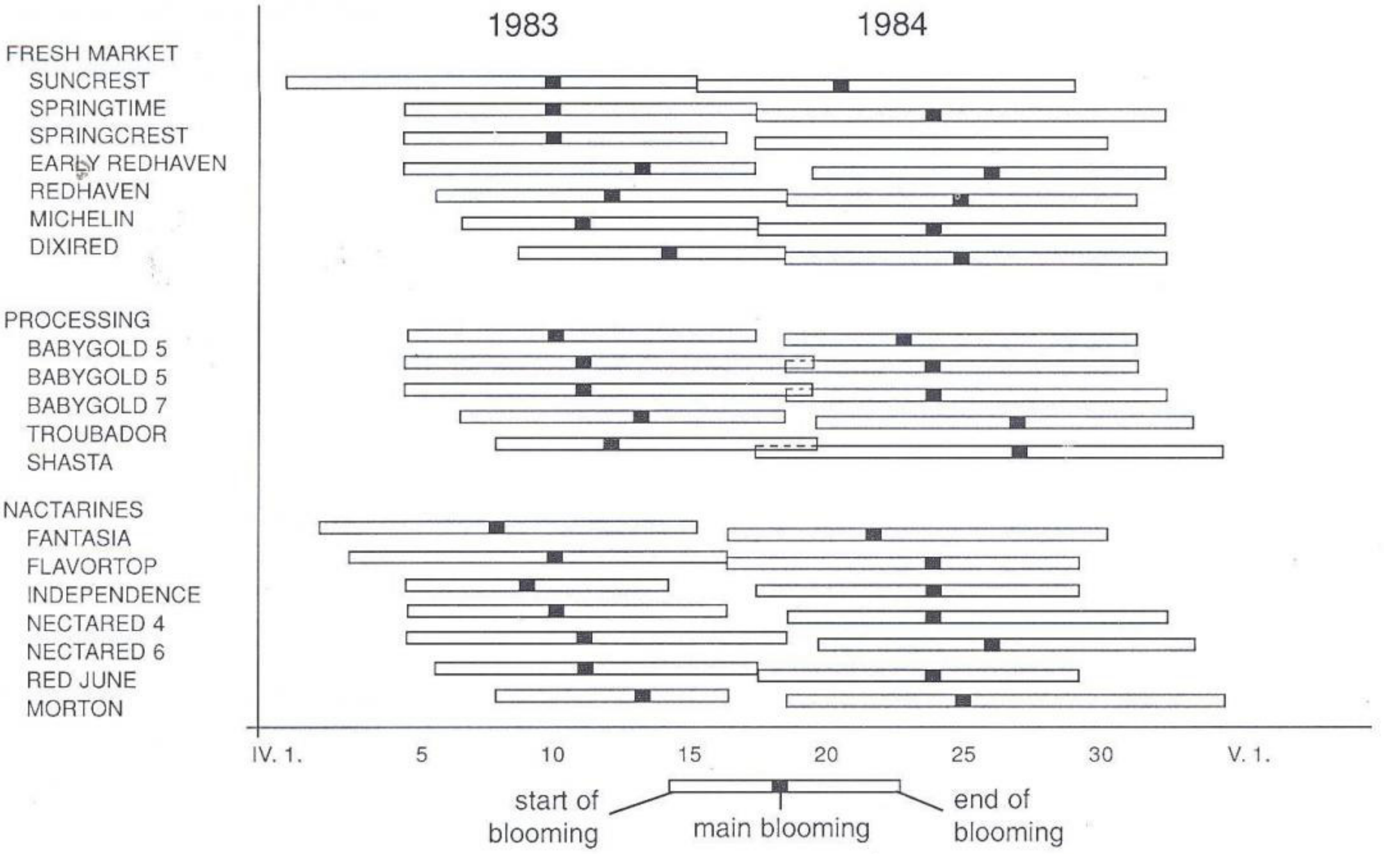

Figure 1 Blooming time of peaches in two seasons with different spring temperatures (Siófok)

and different speed of warming up of spring weather. Where the latter moment prevails and chilling requirement has been satisfied, the order remains stable. Thus, *Weinberger* (1944) advocated its stability of the sequence while *Nyéki & Szabó* (1996) allowed some limited variation but the relation of the earliest and latest varieties was stable. Figure 1 shows blooming dates of an assortment of 19 varieties in two extremely different years, one early and another late warming season. *Reighard* (1998) proposed a technique of intergrafting with a variety of high chilling requirement (and infected by an unknown viroid) in order to delay blooming time by up to 13 days.

The length of the blooming period is equally subject to seasonal variation by the same temperature effect as the beginning of blooming. In seasons of early blooming the rate of warming up is usually slow, subsequently, the blooming period is much longer than in seasons of a "late spring" with steep rates of warming. *Nyéki & Szabó* (1996) claimed that the blooming period of individual trees lasts 14 to 21 days at most, but 5 to 9 days only, if temperature was relatively high. *Tamássy* et al. (1978) stated essentially similar figures (i.e. 10 to 15 and 3 to 6 days). Both papers prove that the weather may reflect Atlantic, continental or also Mediterranean climatic influence, alternatively, typical for the Carpathian basin.

Blooming time groups

According to the beginning of blooming, peach varietes are assigned to three groups by *Bellini & Scaramuzzi* (1976) supposedly applied to conditions of Toscana as well as *Nyéki & Szabó* (1996) for Hungary. The groups are determined according to the time of main blooming (when the most flowers opened) by *Tamássy* et al. (1978), whereas *Mohácsi* et al. (1967) observed the maturity of sexual organs.

However, for the Po river valley, *Della Strada* et al. (1984) established 5 blooming time groups of peach varieties (early, medium early, intermediate, medium late and late). For Rome, more in the south, that scheme with an extremely early blooming group must be supplemented.

Bellini et al. (1984) classified peach varieties according to the beginning of blooming and characterised each group by a standard variety: very early *(Sunred)*, early *(Springtime)*, intermediate *(Redhaven)*, late *(Philp)*, very late *(Summerqueen)*. Considering varieties of low chilling requirement as well as mild climates (Mediterranean and subtropics), the blooming period is much more extended. *Bellini* et al. (1984) used a scale of 9 to characterise varieties. Blooming time groups and standard varieties are associated to those numbers *(Table 1)*.

Table 1 Blooming time groups of peach varieties (Bellini et al., 1984)

Key of groups	Blooming time groups	Varieties	
		Peaches	Nectarines
1	Extremely early	MARAVILHA	SUNRED
2	Very early	TEJON	SUNLIGHT
3	Early	SPRINGTIME	ARMKING
4	Medium early	FLAVORCREST	MARIA LAURA
5	Intermediate	REDHAVEN	MARIA AURELIA
6	Medium late	CRESTHAVEN	NECTARED 4
7	Late	FILLETTE	NECTARED 6
8	Very late	SUMMER QUEEN	GOLDEN STATE
9	Extremely late	BUTTERCUP	

Tamássy et al. (1978) and *Nyéki & Szabó* (1986) stated that the blooming time of varieties belonging to different blooming time groups overlapped each other sufficiently. Under mild climatic conditions that overlap is adequate within the groups or, accidentally, between the neighbouring groups.

Blooming time groups do not coincide with the type of peach varieties. All groups, early and late blooming ones, are represented in each type, i.e. freestones, clingstones and nectarines. Earlier and recent observations indicate (*Nyéki & Szabó*, 1996) a loose tendency of earlier blooming to be associated with nectarines rather than clingston peaches for processing which are later in blooming *(Table 2)*.

Fertility relations
Self-sterility and self-fertility

The self-fertilisation of peaches has been studied by several students (*Branscheidt* 1933, *Detjen*, 1945, *Maliga* 1961, *Ryabov & Kancerova* 1970, *Fogle* 1977, *Tudor* 1981 and *Perfileva*, 1982) and stated that the vast majority of the varieties is self-fertile and some of them is male sterile. *Ryabov & Kancerova* (1970) classified peach varieties according to the measure of their self-fertility into four categories: (1) self-sterile varieties, e.g. Laureat, Uspeh (0% fruit set), (2) male steriles, (3) partially self-fertiles (fruit set up to 10%), (4) self-fertiles (more than 10% fruit set). There was no correlation between fertility and flower type (showy and nor showy flowers). *Quarta* et al. (1992) dealing with dwarf-type peaches distinguished two different types of self-sterility.

Bellini & Scaramuzzi (1976) rated varieties as scarcely self-fertile, as fruit set below 20%, intermediate between 20 and 50% fruit set, and highly self fertile, above 50% fruit set. Our own system of rating (*Nyéki*, 1990) was similar, as partially self-fertile peach cultivars set fruit up to 10%, self-fertile ones yielded 10 to 20% fruit set, and highly self-fertile varieties more than 20% under conditions of self pollination.

Experimental results prove, indeed, that the majority of peach varieties is self-fertile, though the rate of fruit set varied substantially year to year. (*Nyéki* et al., 1980; *Nyéki*, 1990; *Nyéki & Szabó*, 1996). Seasonal variation of fruit set in five peach varieties after self- and free pollination is

Table 2 Comparison of the mean blooming dates in different types of peach varieties (Szalymaz)

Group of cultivars	Number 1995	Cultivars 1997	Studied 1998	Average start 1995	Of blooming 1997
Fresh market type	26	30	28	April 2.5	April 13.5
– white flesh	8	9	9	April 2.7	April 14.1
– yellow flesh	18	21	19	April 2.5	April 13.3
Processing clingstones	4	4	4	April 2.5	April 15.0
Nectarines	21	26	26	April 2.5	April 11.9

presented in *Table 3.* In most cases, the rate of fruit set was lower after self-pollination than after open pollination but the seasonal variation was much higher. Some varieties yielded 0% fruit set in selfed flowers. The mean self fertility of about 120 varieties during 13 different seasons varied between 1.5 and 54.4% with an individual maximum of 89.9%.

Detjen (1945) followed up the self fertility of 37 peach cultivars for 4 years. He stated that self pollination, performed by hand, produced higher rates of fruit set than natural self pollination of isolated flowers, nevertheless, the fruit set was satisfactory as well.

Figure 2 shows the fruit set obtained by different types of pollination conditions. In most cases, the rate of fruits set on open pollinated flowers was higher than on isolated flowers (autogamy), however, isolated flowers hand pollinated with the pollen of the same variety (geitonogamy) produced, possibly, even more fruits than open pollinated ones.

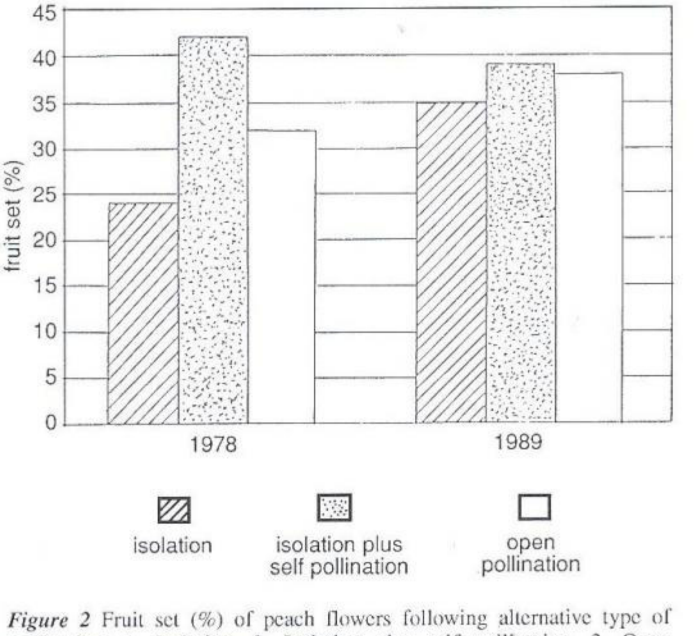

Figure 2 Fruit set (%) of peach flowers following alternative type of pollination: 1. Isolation, 2. Isolation plus self pollination, 3. Open pollination

Experiments performed in Hungary did not prove the existence of self-sterile varieties (*Nyéki*, 1980; *Nyéki & Szabó*, 1986; *Nyéki* et al., 1998). According to their fruit set, two partially self-fertile varieties were found (J. H. Hale, otherwise rated as male sterile, and Fuzador). As for their average

Table 3 Fruit set of some peach varieties following autogamy and free pollination (source: *Nyéki* et al., 1998)

Variety	Pollination Type	Fruit set 1978	Fruit set% 1981	Fruit set% 1982	Fruit set% 1983	Fruit set% 1984	Mean % Over years
Dixired	Autogamy	30.4	19.8	29.9	36.0	0	22.1
	Free-pollination	41.7	36.2	45.5	58.6	25.5	41.5
Springtime	Autogamy	16.9	8.3	40.4	34.0	2.4	18.2
	Free-pollination	45.9	29.0	64.0	59.4	17.0	43.8
Babygold 5	Autogamy	13.8	0	24.2	31.2	0.5	13.9
	Free-pollination	23.1	7.7	33.8	54.0	13.7	26.5
Babygold 7	Autogamy	40.3	8.9	19.0	62.4	0	26.1
	Free-pollination	57.4	18.0	43.9	63.8	13.7	39.4
Nectared 6	Autogamy	11.8	19.0	21.7	26.2	1.8	16.1
	Free-pollination	17.9	10.3	25.0	27.7	10.1	18.4

Table 4 Fruit set% of peach variety groups following autogamy and free pollination (source: *Nyéki* et al., 1998)

Group of cultivars	Type of Pollination	No of cultivars	1978	1981	1982	1983	1984	Mean over years
Freshmarket	Autogamy	29	32.5	20.1	27.6	32.2	2.0	22.9
Types	Free-pollination	24	42.0	17.9	46.8	47.0	15.0	34.2
Processing	Autogamy	11	26.0	4.1	27.6	44.3	0.6	20.6
Clingstones	Free-pollination	11	37.5	13.0	41.8	53.8	15.4	34.0
Nectarinres	Autogamy	14	19.5	13.0	18.3	28.6	1.4	16.2
	Free-pollination	14	23.3	11.3	41.1	38.4	10.3	26.5

Table 5 Distribution of peach varieties according to their fruit set following free pollination.

Group of fertility	Fruit set (%)	Distribution of varieties within the type of utilisation (%)		
		Fresh market	Clingstone	Nectarine
Low	below 10%	–	–	–
Intermediate	between 10 and 20%	–	–	36
High	between 20 and 30%	37	33	36
Very high	between 30 and 40%	42	67	21
Excellent	above 40%	21	–	7

rate of fruit set by autogamy, nectarines displayed the lowest values in relation to other peach varieties. The autofertility of fresh market peach varieties and processing clingstones was rather similar. In some seasons and varieties the rate of autogamous fruit sets was below 10%, but generally, the majority of nectarines could be rated as self fertile, whereas fresh market and clingstone peach varieties as highly self fertile.

Bellini & Scaramuzzi (1976) compaired some 200 peach varieties after self- and free pollination. As many as 11 cultivars (5.5%) did not set fruit because of being male sterile. Fruit set of most (92%) varieties after self-pollination attained or superated the 10%-level, whereas 72.5% produced more than 20%. The distribution of varieties according to their autogamous tendencies was presented in *Figure 3.*

Fruit set by free pollination

Open flowers without isolation used to set fruit freely but, obviously, the highest probability to reach the stigma is contributed to the pollen of the same flower. The chance of allogamy is estimated to be 5–33% only, according to *Scorza & Sherman* (1996).

The rate of fruit set by free pollination is also highly variable seasonally as well as varietally (*Nyéki* et al., 1980; *Nyéki & Szabó*, 1996; *Nyéki* et al., 1998; *Szabó* et al., 1998). It was observed that the highest rate of fruit set is expected at sunny, mild and dry weather prevailing during the blooming time. Proofs are presented that among stone fruits, peaches attained the highest rates of fruit set following free pollination, reaching some 70–90% in a plantation of a variety-collection.

The fruit set of varieties, mean over growing sites varies according to seasons between 13.5% and 83.2%. The maximum fruit set was registered in 1973 at Érd in the variety *Halehaven* (*Nyéki* et al., 1998). *Bellini & Scaramuzzi* (1976) mentioned rates of 100% too.

Fresh market and clingstone peaches used to be comparable whereas nectarines are somewhat lower regarding fruit set by open pollination *(Table 3 and 4).*

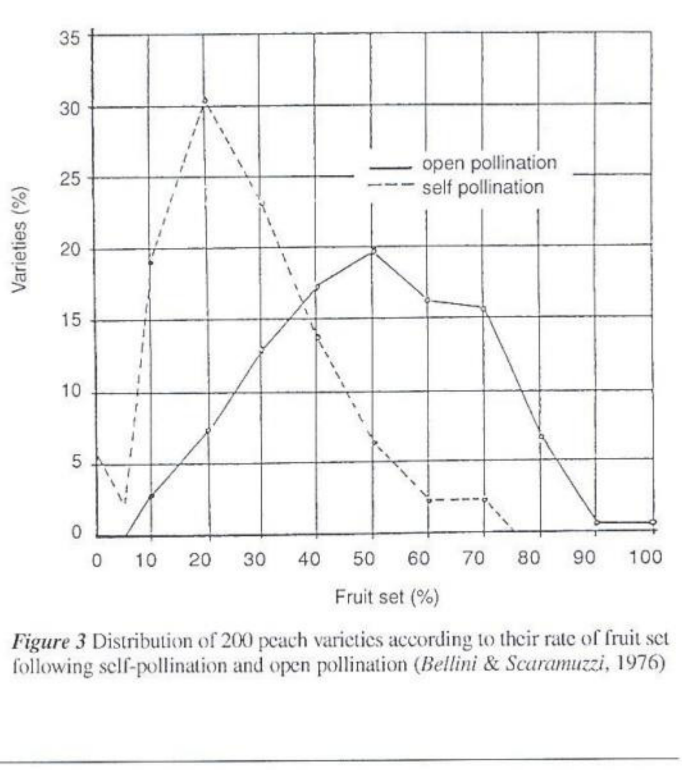

Figure 3 Distribution of 200 peach varieties according to their rate of fruit set following self-pollination and open pollination (*Bellini & Scaramuzzi*, 1976)

Varieties are grouped according to *Nyéki* (1990) according to their fruit set under free pollination conditions in *Table 5.*

According to *Bellini & Scaramuzzi* (1976), 89.5% of varieties passed the threshold of 20% flowers setting fruit, and 59% of varieties, 50% flowers setting fruit as shown in *Figure 3.*

Allogamy

Branscheidt (1933) stated large differences between the rate of fruit set in different female x polliniser combinations of varieties. Maliga (1961) claimed, generally, that allogamy produced higher rates of fruit set than self-pollination in peaches.

Similarly to apricots, the allogamy-relations of peaches are poorly represented in scientific literature. In most cases, only pollinisers are sought for male sterile peach varieties. One of those was *Atzukanova* (1974) dealt with the self-sterile and male sterile variety *J. H. Hale.* The results are shown in *Table 6,* as all of the 5 varieties were adequate for *J. H. Hale* as pollinisers.

Table 6 Effect of polliniser varieties on fruit set (%) in J. H. Hale male-sterile peach variety (after *Tsukanova*, 1974)

Polliniser variety	Fruit Set	
	1970	1971
J. H. Hale self pollinated	0	0
Open pollination	69.6	–
Sotshny	61.7	64.1
Moldavsky zholty	80.0	47.4
Golden Jubilee	68.0	47.5
Galbenika	76.0	32.9
Kishinyovsky ranny	61.6	52.2

J. H. Hale was also studied in cross combinations in 1978 at Érd (*Nyéki* et al., 1980). The polliniser varieties studied caused more than 10% fruit set. Best of them proved to be the varieties Sunbeam and Elberta (26.1% and 25.9%, respectively).

In the practice of breeders, fruit set between 10 and 40% is considered to be a successful pollination. Higher values are rarely experienced (*Scorza & Sherman*, 1986).

Unilateral and mutual incompatibility

Mutual cross-incompatibility has not been observed in peaches (*Branscheidt,* 1933).

Sterility

The potential fertility of peach flowers is in most of the varieties between 75 and 100%. The pistils of those flowers is large, i.e. well developed (*Nyéki* et al., 1980). *Tamássy* et al (1978) stated that the rate of sterile flowers used to be low (3–10%). On the contrary, *Benedek* et al. (1991) revealed considerable variability of the peach flowers in depending on season and variety. The size of the pistil was classified into 5 categories: 1 – the pistil (or female organ) is entirely lacking, 2 – the pistil is very small (defective), 3 – the stigma is positioned underneath the level of anthers (the pistil is intermediately developed), 4 – the position of the stigma is on the level of anthers (the pistil is developed), 5 – the stigma emerges above the level of anthers (the pistil is developed). In the observed cases, flowers of category 1 occurred at a rate of 0–22%, those belonging to category 2 at a rate of 0–46%. Category 1 and 2 meant sterile (unfruitful) flowers.

Crossa-Raynaud et al. (1985) reported even higher rates of sterile flowers. Morphological (and pathological) defects of the pistil (nectrotic spots, extended necrosis, underdevelopment) and sterile (disfunction) of the ovules are distinguished. The sum of those makes up the total rate of sterile flowers. The rate of flower deformations varied between 1 and 49%, whereas defective ovules represented 18 to 74%, subsequently, the rate of sterile flowers was between 13 and 97%.

Quarta et al. (1992) observed a rate of sterile flowers in peaches between 0 and 21%.

The majority of peach varieties develops flowers with regularly developed stamina with anthers containing functional pollen. Male sterile flowers in peach varieties have been described first during the 1920-es (e.g. in *J. H. Hale, July Elberta, Candoka, Chinese Cling*) as lacking of normal pollen. Actually, male sterile varieties produce some normal pollen of low quantity, therefore their fruit set, in case of autogamy, is usually very low (*Connors*, 1927), but they set fruit freely following allogamous pollination (*Bargioni*, 1965; *Nyéki* et al., 1980). Male sterility is most frequently found among Chinese peach cultivars. (*Ryabov*, 1975). *Bellini & Scaramuzzi* (1976) listed 11 male sterile varieties out of a collection of about 200. *Quarta* et al. (1992) identified 2 as male sterile among the dwarf varieties. They are easily recognised by their white anthers containing scarcely any pollen.

Szabó et al. (1996) identified in variety collections 6 male sterile varieties. Out of twenty varieties of Chinese origin 4 proved to be male sterile. One of the total of six male sterile peach cultivars produced pollen but few pollen. The colour of the anthers was distinct, white, lemon or orange instead of the normal purple, whereas their size was definitely smaller.

Association of varieties

Peach cultivars commercially grown and registered in Hungary are highly productive and yield regularly in monovarietial blocks. It was claimed that mixed plantation of varieties may aggravate the grower's trouble caused by thinning of fruit set abundantly, otherwise the size of fruits would be diminished, drastically (*Maliga*, 1961).

Self-sterile and male-sterile peach varieties (e.g. *J. H. Hale*) are not kept any more on the list of recommended and commercially multiplied varieties in Hungary.

In plantations of self-sterile and male-sterile varieties, association of more, i.e. 2 or 3 normal, polliniser varieties are recommended to be placed in each 3^{rd} to 6^{th} row (*Ryabov & Kancerova* 1970).

Another form of association of varieties is, when self-sterile varieties are planted in two rows, only, and self-fertile ones, subsequently, in solid blocks as pollinisers.

Nyéki et al. (1998) forwarded the idea that on the northern border of peach cultivation, also the self-fertile varieties need to be cross pollinated by other varieties. After cool periods during winter and spring, moreover, low flower densities suggest that all possible means are to be applied to improve fruit set. In other words, blocks of self-fertile varieties should favour allogamy at a distance less than 40 metres between different varieties. For male-sterile varieties less than 15 to 20 metres from potential pollen producers *(Table 6)*.

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