Selected *Pyrus* Genotypes as Pollinizers for *Pyrus communis* Cultivars

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Abstract

Probably the most important factors affecting the financial outcome of commercial fruit growing is the success of pollination and fertilization, which in turn are dependent on weather conditions, activity of pollinators and compatibility and flowering overlap of the pollinizers. Before introducing pollinizer accessions, it is obviously important to know the compatibility and flowering characteristics of the genotypes as well as tree characteristics like vigour, tree habit and pest and disease susceptibility. In order to find out these attributes, 25 accessions belonging to eight *Pyrus* species have been evaluated. Further, eight promising genotypes were tested in more detail for pollen production and germination, pollen compatibility with *Pyrus communis* cultivar 'Conference' and flowering phenology. As a result, four recommendable ornamental *Pyrus* accessions, both early and late flowering were found. To ensure maximal overlap of the flowering period of the main cultivar every year, a mix of 2 or 3 different pollinizers will be advised for commercial orchards.

INTRODUCTION

The majority of the commercially grown Common Pear (*Pyrus communis*) cultivars is predominantly self-sterile (Wertheim and Schmidt, 2005). Therefore, planting more than one cultivar in an orchard is needed. A planting scheme which includes two or more commercial cultivars implies certain difficulties. Using an ornamental pollinizer instead of a fruiting pollinizer pear cultivar offers many benefits. Orchard design and management becomes easier, as the grower can plant a single cultivar block. The cultural practises, as pest and disease control and pruning, are simplified. There is also no risk of mixing fruits at harvest, as the ornamental *Pyrus* species have very small and easily distinguishable fruits. If well treated, ornamental pollinizers flower abundantly annually and produce large amounts of good pollen.

In Belgium and the Netherlands, pear growing is increasingly focused on just one cultivar, 'Conference'. Although this cultivar has a certain level of parthenocarpic fruit set and fruit set after self pollination (Chiusoli, 1966), cross pollination is favoured. Cross pollination ensures seed set, which improves fruit set and the development of the preferred (belly) shape of 'Conference' pears. Without or with only a small number of seeds, fruits frequently develop into more or less sausage shaped pears, which causes decrease of the fruit diameter and the market value of the fruits.

When choosing ornamental species as a pollinizer, there are many aspects that should be taken into account (Wertheim and Schmidt, 2005). Obviously, it is important that the ornamental species are capable of inducing fruit set in the commercial cultivar(s). Moreover, the flowering characteristics should match those of the commercial cultivar in terms of flowering time, flower morphology and the abundance of flowering. The ornamental species should flower every year, preferably also on one-year-old wood, produce pollen of sufficient quantity and quality and have fruits that are clearly different from the fruits of the commercial cultivar. Finally, the disease and pest resistance of the pollinizers should be similar to or even better as those of the commercial cultivar, in order not to complicate plant protection procedures.

Not only the choice of the appropriate pollinizer genotype(s) is important, it is also worthwhile to consider the spatial arrangement of the pollinizer trees. A good

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(ornamental) pollinizer has a compact growth habit, which enables planting in high density plantations (≥2500 trees/ha). The majority of *Pyrus* genotypes has strong tree vigour. Even on quince (*Cydonia oblonga*) rootstocks, several accessions of different species have to be classified as very vigorous compared to Common Pear cultivars like 'Conference' and 'Doyenné du Comice'.

For a long time, it has been recommended to plant pollinizer trees within every row, as it has been presumed that bees are flying more often along the rows than between them (Barden and Neilsen, 2003; Wertheim and Schmidt, 2005). However, the results of a trial carried out by Kron et al. (2001), suggest that bees may fly just as effectively between the rows as along the rows. Nevertheless, the maximum distance between compatible cultivars should not exceed 25–30 metres as the effectiveness of a pollinizer drops sharply as the distance increases. According to Wertheim (1991) and Chiusoli (1966), the most effective range for a pollinizer tree is within a 5 to 10 metre radius.

According to Nyéki and Soltész (1984), various forms of *Pyrus pyraster* (which is considered a form of *Pyrus communis*) have been evaluated in terms of fruit setting capability, flowering time, pollen germination, growth habit and disease and pest resistance. Although the fruit set capability of the ornamental *Pyrus* forms varied between 2.6 and 37.8%, it was evident that the forms capable of setting commercially acceptable fruit yield on European pear were also able to set a sufficient number of seeds. In addition to the mentioned *Pyrus* species, *P. balansae*, *P. longipes* and *P. canescens* have been proven to give a good fruit set on 'Doyénne du Comice' (Parry, 1980). Parry (1976) also screened *P. amygdaliformis*, *P. nivalis* (snow pear) and *P. salicifolia*. Furthermore, the pollen germination percentage of the ornamental *Pyrus pyraster* forms ranged between 30 and 82% as compared to 51 and 48% achieved with 'Conference' and 'Doyénne du Comice', respectively (Kemp, 1990). Kurennoi (1985) investigated *Pyrus salicifolia, P. betulaefolia* and *P. syriaca*. Ketchie et al. (1996), found that *P. calleryana*, *P. ussuriensis* and *P. pyrifolia* cv. Nijisseiki were able to set an adequate percentage of fruit in European pear cv. Anjou. Recently, Le Lezec et al. (2005) have introduced a selection (P337-41) from *Pyrus betulaefolia* with abundant, regular and lasting flowering and a pollen germination of around 50%, as a pollinizer for B.C. Williams, 'Conference' and 'Doyenné du Comice'.

According to Wertheim and Schmidt (2005), bees tend to make a distinction between flowers of different colour, thus visiting cultivars of similar flower morphology. In a trial where honey bee behaviour was examined on ornamental *Malus* pollinizers and commercial apple cultivars, it was observed that bees incline to show high fidelity to red, rose or pink colour. Thus, if the ornamental pollinizer has darker coloured flowers than the commercial cultivar, pollination is likely to be poor. Recent investigations suggest that bees use not only colour but also flower morphology (for instance length of the stamen) as a criterion to visit certain flowers that they recognize as good pollen sources. On this relevant topic additional investigations are needed. According to Mayer et al. (1989) and Wertheim and Schmidt (2005), there are year-to-year fluctuations in the flowering dates of different cultivars. Therefore, it is recommended to plant at least one or two early flowering ornamental pollinizers and another one or two to cover the end of the flowering period of the main cultivar(s) every year. These year-to-year fluctuations are an effect of pre-bloom temperature regimes in combination with climatic condition of the previous season and possibly also related with bud dormancy (Wertheim and Schmidt, 2005).

Both pollen germination and the rate of pollen tube growth are highly dependent on the prevailing temperature and there are genotype-dependent differences between cultivars and species at divergent temperatures (Petropoulou and Alston, 1998; Vasilakakis and Porlingis, 1985). Furthermore, the optimal temperature for pollen germination is somewhat lower than that of pollen tube growth, as observed by Hedhly et al. (2004) and Vasilakakis and Porlingis (1985). Differences between cultivars are evident especially at low (4–10°C) temperatures. According to Rohitha and Klinac (1994), the optimum temperature for pollen germination of Japanese pear (*P. serotina* var. *culta*) cultivars can vary from 12 to 21°C.

In 1997, a selection and testing program was initiated, because ornamental *Pyrus* pollinizers with proven suitability were scarce. The aim of the experiments was to find suitable ornamental *Pyrus* accessions in terms of fruit set capability, pollen germination and flowering characteristics and acceptable tree characteristics, to be used as pollinizers for Common Pear cultivars, especially cv. Conference.

MATERIALS AND METHODS

In Randwijk (52° North latitude), since 1999, 25 accessions belonging to nine *Pyrus* species have been evaluated. Species involved were: *P. communis, P.* (*communis*) *caucasica* or *pyraster, P. canescens, P. amygdaliformis, P. regelii, P. nivalis, P. salicifolia, P. betulaefolia, P. calleryana* and *P. pyrifolia.* The pollinizer accessions as well as 'Conference' were relatively densely planted and all on Quince MC rootstock (with an interstem of *Pyrus communis*). Planting distances in single rows were around 3.50 x 1.50 m and all trees were grown with fertigation. The soil is river clay with a top layer (0–30 cm) of 12 and 30% lutum, an organic matter content between 2 and 4% and a calciumcarbonate percentage of 0.3 and 1.4%. Locally, sand can be found in the subsoil (between 60 and 120 cm depth). The precipitation per year is 600–1,000 mm (avg. 800 mm) and the average temperature 9.8°C. For spring frost protection, overhead sprinklers are used. Cultural practises were carried out according to good agricultural practises, but with the exception of a reduced fungicide application scheme in order to observe fungal disease susceptibility.

Tree characteristics, phenological stages and flowering abundancy have been observed during at least 5 years. In 2005, 8 promising ornamental accessions and Gieser Wildeman were studied more in detail regarding flower colour and size, pollen production and germination. In 2005 and 2006, test crosses have been performed in order to assess the fruit set ability of the pollinizers with Conference. Common Pear cv. Gieser Wildeman, known as a good pollinizer (Kemp and Wertheim, 1999), was used as control. The maternal Conference trees were planted in 1999.

Tree Characteristics

Tree habit and vigour have been observed. Susceptibility to important Common Pear diseases as *Venturia pirina, Stemphylium vesicarium, Pseudomonas syringae* and *Alternaria alternata* were recorded under natural infection conditions.

Pollen Germination

In 2005, germination tests were carried out in vitro. Two sets of pear pollen germination tests were carried out. The first set was made on pollen acquired from forced twigs. The second set was made with pollen acquired from fresh flowers from the field. The germination medium consisted of demineralised water and 10% sucrose solution, plus 15 ppm boron, supplied as boric acid. A drop of germination solution was placed on an objective slide and a little pollen was mixed in the solution. The slide was placed in a Petri dish that contained a small amount of water to prevent the drop from drying out. Pollen was germinated in a climate chamber in dark at a constant temperature of 12°C and in the lab room under natural light conditions (but no direct sunlight) at a room temperature of 20.5°C, in order to see the effect of temperature on the pollen germination. One treatment in dark at 20.5°C was carried out in order to determine the effect of light on the pollen germination rate. The progress of germination was checked under a microscope with enlargement of 100 after 24 hours of germination. For that point of time, the pollen germination percentage was counted for 100 pollen grains per replicate. There were three replicates per treatment. Pollen was considered germinated when the pollen tube was longer than the pollen diameter. The results of the pollen germination tests were analysed with Genstat 8.0, IRREML-procedure.

Crossings

In 2005 and 2006, crossings (hand pollinations) were carried out according to the method described by Wertheim (1996). One crossing consisted of 100 flowers, distributed over 5 replicates with each 20 flowers on 10 clusters. Flowers were pollinated in balloon stage and not emasculated. The stigmas were covered with vaseline after pollination. Weather conditions on the day of crossing and during the following five days were recorded. Incidentally two extra replicates were made to be able to take the effect of poor weather conditions into account. Fruit set results were counted partly before and after June drop and in all cases at harvest. The fruit set percentage was expressed as: number of fruits at harvest/number of pollinated flowers x 100%. Standards for evaluating fruit set were (Wertheim, 1996): 0–4% = poor, 5–9% =moderate, 10–24% =good and >25% =very good. At harvest, numbers of good and flat seeds per fruit were recorded. The results were analysed with Genstat 8.0, ANOVA.

Flowering Phenology, Abundancy, Pollen Production, Flower Colour and Size

From 2002–2007, the phenological stages of flower development were recorded from 1st open flower till the end of flowering and from 2005–2007, stages were recorded from the B- or C-stage onwards, all according to the scale of Fleckinger (1955). The dates of five flowering stages were recorded: first open flower, 20% open flowers, 80% open flowers, 80% and 100% worn flowers. Flowering intensity and frost damage (only 2005) were recorded at the stage of full bloom. For flowering intensity a scale from 1 to 9 was used: 1 = (almost) no flowers and 9 = abundant flowering. For spring frost damage, the scale ran likewise from 1 to 9, where 1 = (almost) no damage and 9 = all flowers completely frozen. In 2005, the size and colour of the flowers and the amount of pollen per flower were determined at full bloom stage.

RESULTS AND DISCUSSION

Tree Characteristics

Pyrus amygdaliformis, *Pyrus (communis) caucasica*, and *Pyrus salicifolia* Pendula were discarded because of strong vigour and (too) poor flowering (not precocious or irregular).

Also P337-41 and P9939 (*Pyrus nivalis*) proved to be (very) vigorous. Most of the *Pyrus calleryana* accessions also were too vigorous and not so compact, excepted *Pyrus calleryana* Chanticleer. *P. call.* Chanticleer (P9935) was also vigorous, but with a compact canopy and generally rich flowering. *Pyrus calleryana* Redspire (P0232) and *Pyrus regelii* proved to be(very) susceptible to die back of flower buds, probably due to *Alternaria alternata* and *Pseudomonas syringae*. In 2005, P0232 also showed relatively much damage after mild spring frosts. Excepted P0232, the promising accessions (Table 1), sofar, proved to be healthy regarding *Venturia pirina, Stemphylium vesicarium, Pseudomonas syringae* and *Alternaria alternata* compared with *Pyrus communis* ’Conference’.

Pollen Germination

Pollen germination rates were high (Table 1) and the pollen tubes were well-formed except for the cultivar ‘Conference’, which had approximately 30% of distorted pollen tubes at both temperatures. Generally, the first set (pollen from forced twigs) gave lower germination percentages than the second set. The germination percentages in Table 1 are the averages of the both sets (Gieser Wildeman only the 2nd set because the 1st set pollen was aged). Pollen germination in light and in dark at 20.5ºC were similar and no significant differences between pollen germination in light and in dark were found (data not shown). The ornamental pollinizers germinated well, also at 12^{o}C.

Comparing the germination percentages of the ornamental accessions to that of the control cultivar ‘Gieser Wildeman’, only two accessions showed significantly lower pollen germination percentage at 12ºC. At 20.5ºC all the accessions had similar or better pollen germination percentages than the control. The results gained during this trial for 'Conference' are in accordance with pollen germination percentages reported by Deckers and Porreye (1984).

Crossings

The fruit set and seed set percentages induced by the ornamental accessions are presented in Table 1. All ornamental accessions were able to induce fruit set on Conference. In 2005, no significant differences were found between the accessions nor between the accessions and Gieser Wildeman (control). The fruit set percentage induced by the control is in compliance with previous results (Kemp, 1996). The results obtained are well in accordance with the results of Parry (1980) and Ketchie et al. (1996). However, it could not be excluded that a part of the fruits obtained in 2005, was a result of self-pollination. Therefore, in 2006, a selfing was included in the experiment. Table 1 shows a clear effect of selfing in 2006, probably due to the very favourable weather conditions during pollination and the week after (averaged 24-hours-temperatures of 12–18°C), that are known to be positive for self-fertilization. As the flowers were not emasculated and (as an exception) in 2006 many anthers were already dehished in balloon stage, a substantial proportion of the fruits from the crosses are probably resulting from self-pollination. According to Visser and Marcucci (1984), fruits that are induced by self-pollination often contain less seeds than fruits resulting from pollination with compatible pollen. Moreover, according to Nyéki et al. (1993), fruits containing a small number of seeds (i.e., less than 3) have an inclination for dropping during the June drop. Thus, the fruits that remained at the tree after the June drop probably contain a relatively high number of seeds and therefore result from cross-pollination. However, in 2006 at harvest, a part of the fruits from the crosses had low numbers of good seeds, although the average numbers of good seeds per fruit were high compared with the good seeds numbers from selfing. So, counting with the effect of selfing, the net effect of the cross pollinations in 2006 was probably around 20%, that means, somewhat higher than in 2005. In 2005, temperatures were obviously lower than in 2006. In 2005, the average 24-hours-temperatures during pollination and the week after ranged from 8 to 12°C. These temperatures are known not to be optimum for good pollen germination and pollen tube growth (Wertheim and Schmidt, 2005). According the standards (Wertheim, 1996), fruit set percentages above 10% are good and above 25% very good. Fruit set as a result of cross pollination needs to meet these standards, especially with relatively low flowering temperatures, because of the small role of selfing then. The tested pollinizers proved this ability.

Flowering Phenology, Abundancy, Pollen Production, Flower Colour and Size

Flowering overlap (Fig. 1) between 'Conference' and accessions *Pyrus canescens* Pollinya® 1, P0232, P9939, *Pyrus nivalis* Pollinya® 2, and *Pyrus nivalis* Pollinya® 4 was (very) good. P9935 flowered too early and *Pyrus communis* Pollinya® 3 early but still with sufficient overlap. P337-41 flowered (too) late. The overlap of Gieser Wildeman and 'Conference' is very good. The amount of flowering of all accessions was sufficient to (very) good. Pollinya® 3 showed a quite strong tendency to biennialism. On average, all 8 accessions had a flowering abundancy greater than that of 'Conference' and almost the same abundancy as Gieser Wildeman. However, Gieser Wildeman showed a stronger tendency to biennialism. Compared to 'Conference', P9939, Pollinya® 1 and Pollinya® 2 had the same size of flowers, whereas P0232, P9935 and P337-41 had smaller flowers and Pollinya® 3 and Pollinya® 4 were (very) large. At full bloom stage, petals of 'Conference' were white. The same was true for P337-41, Pollinya® 4 and Pollinya® 1. Gieser Wildeman, P9939 and Pollinya® 2 had somewhat greenish yellow-white petals and P9935, P0232 and Pollinya® 3 pinkish white. Pollinya® 1, 2, 3 and 4 were all slightly pinkish at (late) balloon stage, a bit more than 'Conference'. Pollen production of P337-41 and P0232 was sufficient to good and of the other 6 accessions abundant.

Averaged over 2002–2007, all accessions included in the trial except for P337-41 started flowering before (or almost at the same day as) ‘Conference’, thus covering the most important period of flowering of the commercial cultivar. In most of the years, accession P9935 started flowering some weeks before ‘Conference’, being too early for pollenizing the commercial cultivar. P0232 proved to be susceptible to die back of flower buds, probably due to Alternaria alternata and Pseudomonas syringae; it also showed relatively much spring frost damage. Accessions Pollinya® 1, Pollinya® 2, P9939, Pollinya® 3, and Pollinya® 4 covered the beginning of the flowering period of ‘Conference’ very well, but the flowering period of the accessions ended earlier than that of ‘Conference’. P337-41 started flowering late every year, mostly a few days after ‘Conference’. This accession had only a good overlap with the end of the flowering period. For the production of good fruit, pollination of the first (often strong) flowers, mainly located on the spurs on the older branches, is important (Wertheim and Schmidt, 2005). To avoid overset and overload, in general, pollination of the late flowers isn’t desirable, excepted in the case of (frost) damage of the first flowers. To increase the reliability of the flowering overlap determination, observations should be carried during 10 years, preferably comprising extremely early and late years as well (Wertheim, 1996).

CONCLUSIONS

Compared to the reference cultivar Gieser Wildeman, the ornamental accessions Pollinya® 3, Pollinya® 4, Pollinya® 1 and Pollinya® 2 seem to be equally good or even better in terms of pollen production and germination, fruit set ability, flowering precocity and time and flower morphology. Moreover, Gieser Wildeman is prone to biennial flowering and, therefore, it is advantageous to find more reliable pollinizers. P0232 proved to be unreliable due to its susceptible flowers. P337-41, P 9935 and P 9939 proved to be too vigorous. In France, P337-41 is recommended as pollinizer for Conference (Le Lezec et al., 2005), however, in The Netherlands, it flowered (too) late for annually sufficient overlap with ‘Conference’. So, local climatic conditions in winter and spring have to be taken into account.

Pollinya® 1, Pollinya® 2, Pollinya® 3 and Pollinya® 4 showed a growth level comparable with that of ‘Conference’. These 4 genotypes, with different flowering periods and good healthiness, were selected for commercial use. To ensure maximal overlap of the flowering period of the main cultivar every year, a mix of 2 or 3 different pollinizers will be advised for practical orchards.

For ‘Conference’, a combination of Pollinya® 4 or Pollinya® 3 with Pollinya® 1 or Pollinya® 2 seems optimal. With other cultivars other combinations can be applicable, such depending on compatibility and flowering overlap. To enlarge the use of the ornamental pollinizer series, some extra accessions will be tested. With all pollinizers, especially with Pollinya® 3 because of its tendency to biennialism, pruning (directly) after flowering is advisable. It is also advisable to bend some shoots to a more horizontal position in the year of planting, in order to stimulate early flower bud formation.

In 2006, another *Pyrus communis* cultivar, Xenia, was pollinated too with the same series of pollinizers. The obtained results were promising. To gain more accurate and reliable information on the compatibility of the pollinizers with Xenia and other cultivars, the experiments should be continued. Also additional investigations on S-alleles and susceptibility to important diseases and pests like *Stemphylium vesicarium, Erwinia amylovora*, pear decline, and pear psylla are required.

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Tables

Table 1. Pollen germination (2005) percentages at 12ºC and 20.5ºC, the fruit set percentages and numbers of good seeds per fruit with *Pyrus communis* 'Conference' pollinated by *Pyrus communis* Gieser Wildeman and 8 ornamental *Pyrus* accessions in Randwijk (2005, 2006).

Accessions/	Germination (%)		Fruit set (%)		Good seeds per fruit	
Cultivars	12ºC	20.5ºC	2005	2006	2005	2006
Conference	72.7 d	83.3 e	*	66.0 a	*	0.0 a
P9935	55.2 c	60.9 bcd	17.9 a	79.4 ab	0.6 a	3.2 de
G. Wildeman	63.6 cd	48.7 ab	12.4 a	84.1 bc	0.5 a	1.4 b
Pollinya® 3	40.3 b	47.2 a	18.2 a	89.1 bc	0.9 a	1.7 bc
P0232	58.5 c	35.6 a	8.0 a	90.0 bc	1.2 a	3.4 e
P9939	54.3 c	70.8 d	16.4 a	90.6 bc	0.9 a	2.4 cde
Pollinya® 1	73.5 d	69.9 d	13.0 a	90.7 bc	0.8 a	2.1 bcd
P337-41	22.2 a	38.1 a	16.0 a	93.2 bc	1.0 a	0.9 ab
Pollinya® 2	88.5 e	68.3 cd	10.4 a	94.1 bc	1.5 a	2.1 bcd
Pollinya® 4	54.5 c	59.1 bc	18.4 a	95.0 c	0.5 a	2.6 cde

Values followed by the same letter(s) do not differ significantly (P=0.05). * = no data.

Figures

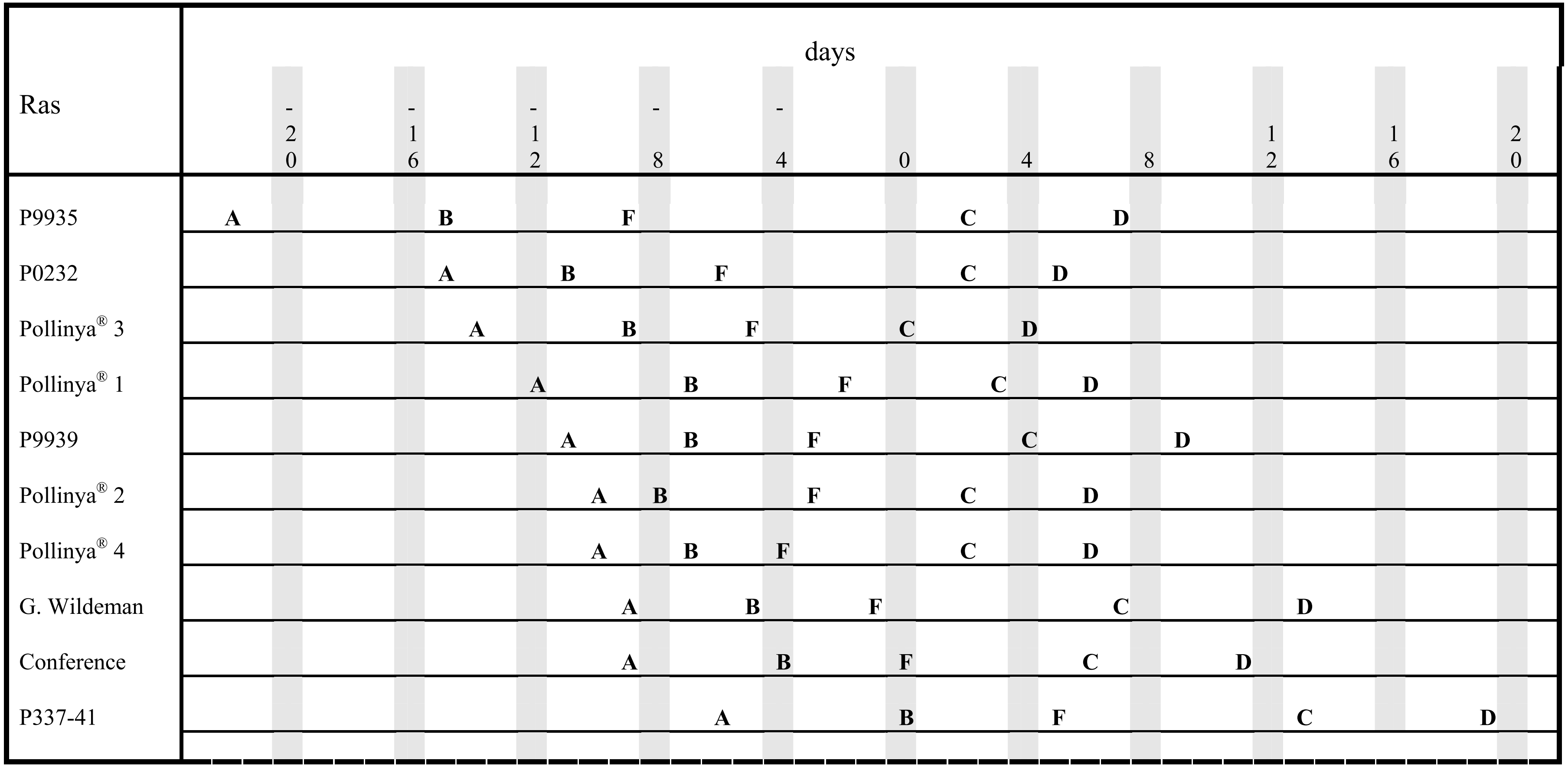

Fig. 1. Flowering period and overlap of *Pyrus communis* cv. Conference and some pollinizers, Randwijk, 2002–2007*. Flowering stages related to day of full bloom of 'Conference', A = 1st open flower, B = 20% open flowers, F = 80% open flowers (full bloom), C = 80% worn flowers, D = 100% worn flowers. *P0232, Pollinya® 1 and 2 2003–2007 and Pollinya® 3 2002–2007 excepted 2003.