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Comparison of flower bud development in almond, apricot and peach genotypes

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Summary: The phenological processes of flower bud development of stone fruits during dormancy are not thoroughly known. The yield of these species, especially of almond, apricot and peach is determined basically by dormancy of flower buds, the survival rate of buds during winter frosts and by their ability to develop normal floral organs in the next spring. After the initiation of floral primordia, flower bud development is taking place in continuous space until blooming, though at different speed characteristic to the species. To study flower bud development during dormancy we applied two alternative methods in different genotypes of almond, apricot and peach: (1) examination of pollen development (microsporogenesis), and (2) the measurement of pistil length. The samples were collected from the central part of Hungary during the dormancy period of 2004/2005. The three fruit species differed significantly in the speed of flower bud development, it was the quickest in almond, followed by apricot and peach. In addition to the species, there were significant differences in the process of microsporogenesis and pistil development between genotypes within species and also between the different types of shoots on which the buds were located. On short shoots buds developed at a higher speed, than on long shoots. Based on our observations, on the short shoots the period of endodormancy was shorter with 5–30 days, according to genotypes, compared to the long shoots. This difference, however, decreased to 2–3 days by the time of blooming.

Key words: microsporogenesis, pistil length, almond, apricot, peach

Introduction

The process of flower bud development is a genetically fixed property of the respective genotype or variety, but the environment of the growing site may cause significant changes in the manifestation of the inherited character. Other factors also play significant role in determining the rate of bud development, such as the age and health of the tree, the density and distribution of buds on the shoots, the maturity (lignification) of the shoot tissues, the geographical position, the rootstock, the applied growing technology and level of plant diseases or pest damage (*Pedryc*, 1992; *Szalay*, 2001; *Szabó*, 2002; *Holb*, 2004).

The first step of flower bud development is the phase of floral meristem initiation, when biochemical processes take place without any visual sign to be observed in the light microscope. The first visible sign of flower initiation with light microscope is the flattening of the meristematic cone (*Bubán*, 2003), which is called the "square" or „pflock" phase. Its timing is largely determined by the genotype but environment has a strong modifying effect. Flower initiation and differentiation ensues in stone fruit species around the second part of summer with the shortening of days. In almond this stage takes place at the earliest in May, 50–60 days after blooming date (*Pejovics*, 1976), in sour and sweet cherry at the end of June, early July (*Elekné*, 1990), followed by apricot and peach (*Nyujtó & Surányi*, 1981; *Bubán*, 1992).

After initiation of flower primordial, flower buds continues developing until blooming, though at different speed. Three main periods are distinguished, 1 paradormancy, 2 endodormancy and 3 ecodormancy (*Lang*, 1996). In the first period, the speed of development is high, then it slows down during endodormancy, during which period there are hardly any changes, and it accelerates again until bloom. All temperate zone fruit species develop following this process, and avoid frost damage at variable extent. There is no strong correlation between the time of flower bud initiation and blooming.

Paradormancy is the first period of flower bud development. This expression is somewhat misleading because intense changes ensue during the full vegetation in mid-summer time, except that development stops at a certain stage in spite of the warm weather. The inhibition of sprouting is caused by growth substances produced in the vegetative organs. If that relation is disturbed an early sprouting may occur, but those flowers are unable to develop fruit in the autumn. That type of anomalous sprouting may be triggered by drought stress or by premature defoliation. Paradormancy lasts until the fall of leaves, meanwhile the flower buds develop quickly. Flower organs appear in a centripetal sequence: first the sepals of the calyx then the petals of the corolla, following stamina and as last the pistil.

The development of flower parts in apricot varieties of Hungarian origin was examined by *Nyujtó & Surányi* (1981).

In the variety 'Ceglédi bíborkajszi', flower bud differentiation started during the last third of July, in 'Kécskei rózsa' during the first part of August. Between the starting date and the speed of development there was a negative correlation. The later the differentiation started the higher was the speed of development. The pistil appeared in all varieties about the same time, at the end of September. In some peach varieties, *Bubán* (1992) observed the first signs of flower bud formation during the last days of July, sepals and petals were initiated in early August, stamina in the second part of August, the pistil appeared in September. There was but little difference between the varieties observed. No data are available on the paradormancy of Hungarian almond varieties.

After leaf fall, the development seemingly stops completely and that is the beginning of endodormancy for the winter. During endodormancy, sprouting cannot be induced. That type of rest period is determined biochemically. Metabolic processes are reduced to a minimum. The growth and development of flower parts stops almost completely. Frost tolerance of flower buds reaches its maximum at that time. Until the autumnal leaf fall, all flower organs appear in the flower primordium, however, the differentiation of tissues within the organs did not ensue yet. In the embryonal phase of anthers, a homogenous tissue, the archesporium is visible. In the inner part of the pistil, no trace of embryo sac or generative cells could be detected. Endodormancy is finished by the accumulation of a set number of chilling hours, which is genetically determined in species and in different varieties. In stone fruit species, the chilling temperature is between 0 and +9 °C, which is much more effective than temperatures below zero (*Richardson* et al., 1974; *Lang*, 1996; *Timon*, 1998, 2000; *Pénzes & Szalay*, 2003).

The third period of dormancy is determined essentially by environmental conditions. The buds are very susceptible to the temperature, which means that they do not move until the warm weather did not allow sprouting. During mild weather, the growth and development continues where it stopped during endodormancy, and subsequently sprouting ensues.

The experimental study of dormancy is confronted with two difficulties. First, the dynamic nature of the system which displays dormancy, and second, the phases through which it transitions. The periods of dormancy are not completely distinct and the development of buds on different tree parts may also differ considerably, therefore chilling requirement of individual genotypes cannot be easily determined (*Faust*, 1989; *Lang*, 1996).

Researchers use different models to describe the developmental processes of perennial woody plants. In the lifelong helix model (*Seeley*, 1996) the helix is divided into arcs, representing periods of development, while the degree growth stage model (*Fuchigami* et al., 1982) describes numerically the various developmental stages of plants, including dormancy. Some arcs, developmental phases have been studied extensively, others only superficially. Vegetative growth, with its driving photosynthetic and respiratory functions, has been characterized in depth. Endodormancy and ecodormancy inceptions and also the phenological processes of stone fruits have been studied to a much smaller extent. Although the yield of almond, apricot and peach is determined basically by dormancy of flower buds, the survival rate of buds during winter frosts and by their ability to develop normal floral organs in the next spring (*Pedryc* et al., 1999; *Szabó*, 2001; *Szabó & Nyéki*, 1988a, 1988b, 1991).

Shoots collected during ecodormancy start sprouting soon at room temperature leaf buds producing shoots and flower buds flowers, thus the end of endodormancy can be easily detected. This method is however not accurate enough, and it is not possible to follow the phases of development. Two alternative methods are available to carry out more accurate study of flower bud development during endodormancy and ecodormancy. One of them is the examination of pollen development (microsporogenesis), and the other is the measurement of the pistil length.

The flower bud development of almond, apricot and peach varieties was investigated in different geographical regions (*Draczinsky*, 1958; *Bubán*, 1992; *Ramina* et al., 1995; *Nyujtó & Banai*, 1975, *Bailey* et al., 1978). Based on these results, significant differences could be detected between genotypes, years, and locations.

In our work microsporogenes and pistil length of 3–3 genotypes of almond, apricot and peach were studied in Central Hungary in the winter of 2004–2005.

Materials and methods

Samples for the experiments were collected from our germplasm collections (Szigetcsép and Soroksár), which are situated in the Centre of Hungary, near south of Budapest, during the dormancy period of 2004–2005. Samples were collected weekly in the sampling period spanned from leaf falling in the autumn to the blooming time next spring. Different types of shoots were collected: short shoots (10–15 cm), and long shoots (50–60 cm) observing the flower buds of the central section of both types.

The following varieties representing a wide scale both in winterhardiness and in chilling unit requirements within their species were involved in the experiments:

- Almond: 'Tétényi bőtermő', Tétényi rekord' and 'Tétényi keményhéjú'
- Apricot: 'Ceglédi bíborkajszi', 'Gönci magyar kajszi' and 'Bergeron'
- Peach: 'Venus', 'Redhaven' and 'Piroska'.

Microsporogenesis was observed in bud tissue preparations coloured with aceto-carmin by microscope. The following stages of microsporogenesis were distinguished:

- Archesporium – undifferentiated sporogenic tissue
- Premeiotic conditions – development of pollen mother cells
- Tetrads – after meiosis
- Microspores – development of pollen grains

The transition between these stages occurs gradually, with an interval of 5–6 days on the same fruiting structure of

an individual tree (*Viti & Monteleone*, 1991; *Sebők*, 1993). For comparisons and analyses the transition was dated, when half of the cells in the anthers observed represented the earlier and the other half the later developmental stage (*Szalay*, 2001). Length of pistils was measured by micrometer. The blooming time of the observed varieties were also recorded in the experimental orchard.

Results and discussion

Microsporogenesis

We found significant differences in the developmental rate of microsporogenesis not only between the three fruit species and between the genotypes within species, but also between the different types of shoots of the same tree (*Figure 1*).

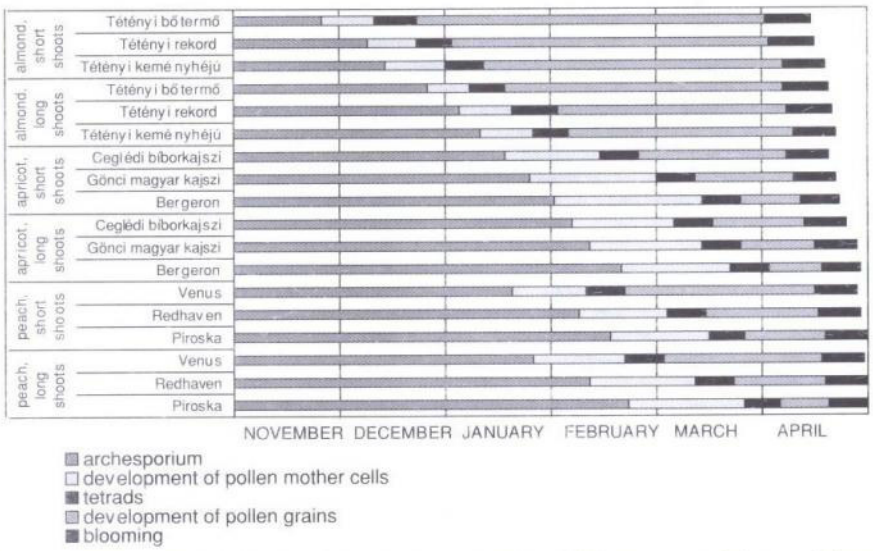

Figure 1 Microsporogenesis in flower buds on central section of different types of shoots of almond, apricot and peach varieties (Szigetcsép, Soroksár, 2004–2005)

It is hypothesised that the chilling units of flower buds necessary for the termination of endodormancy are saturated by the end of archesporium stage, which is then followed by ecodormancy. During ecodoromancy the pollen mother cells develop, then divide leading to the formation of pollen grains through microspores. Our findings that there is significant difference between the shoot types would then mean, that the chilling requirements of flower buds might show large variation on shoots with differing length. Of the three fruit species, the end of archesporium stage and the beginning of pollen mother cell stage took place in almond at the earliest, first in the flower buds located on short shoots, irrespective of the genotype. On short shoots this developmental phase could already be observed at the end of November, beginning of December. On the long shoots, however the same developmental phase took place almost one month later. In the end of archesporium stage the difference between the three almond genotypes was 8–12 day; Tétényi bőtermő was the earliest, while Tétényi keményhéjú the latest. The pollen mother cell stage took 12–16 days, the following tetrad stage 10–12 days in these almond genotypes (*Figure 1*).

Almond varieties were followed by apricot in the rate of flower bud development. In this fruit specie, the formation of pollen mother cells started also on the short shoots first, between the middle of January and the beginning of February. The earliest was Ceglédi biborkajszi, followed by Gönci Magyar kajszi and Bergeron. The same genotypic order was characteristic to the flower bud development on the long shoots, but the formation of pollen mother cells began 20 days later than on short shoots. Pollen tetrads could be detected one to one and half month after the formation of pollen mother cells first on short shoots, then on long shoots. In apricot the difference was smaller between the shoot types reaching tetrad stage, than it was found in almond (*Figure 1*).

Of the three fruit species, the slowest flower bud development was characteristic to peach varieties. Variety Venus was the first to reach the end of archesporium stage in the second half of January, followed by Redhaven in the beginning of February, and by Piroska in the second half of February. The length of pollen mother stage was approximately one month, followed by the beginning of tetrad stage taking place in February in Venus, and in March in the other two peach varieties. Among the three fruit species the difference in bud developmental rate on short and long shoots was the smallest in peach, being 8–10 days only.

In the growing period of 2004/05 all three fruit species flowered in April, first almond, then apricot, followed by peach varieties. Flowers on short shoots started to bloom 2–3 days earlier, than on long shoots, irrespective to species or genotypes.

On short shoots, buds develop at a higher speed, than on long shoots. Based on our observations, the period of endodormancy is shorter by 15–20, occasionally by 30 days in the short shoots, whereas the blooming dates display only 2–3 day differences among the parts of the tree. The rhythm of microsporogenesis is closely correlated with frost resistance / susceptibility of the flower buds (*Szalay*, 2001; *Pénzes & Szalay*, 2003).

Length of pistils

The last floral organ, which appears in the primordium is the pistil, the continuous growth of which lasted until the endodormancy started. In the autumn at leaf fall the pistils of almond varieties were 1–1.2 mm long, while the pistils of apricot and peach varieties were 0.7–0.9 mm long. During endodormancy, there was hardly any detectable sign of pistil growth. We examined the growing rate of pistils on short

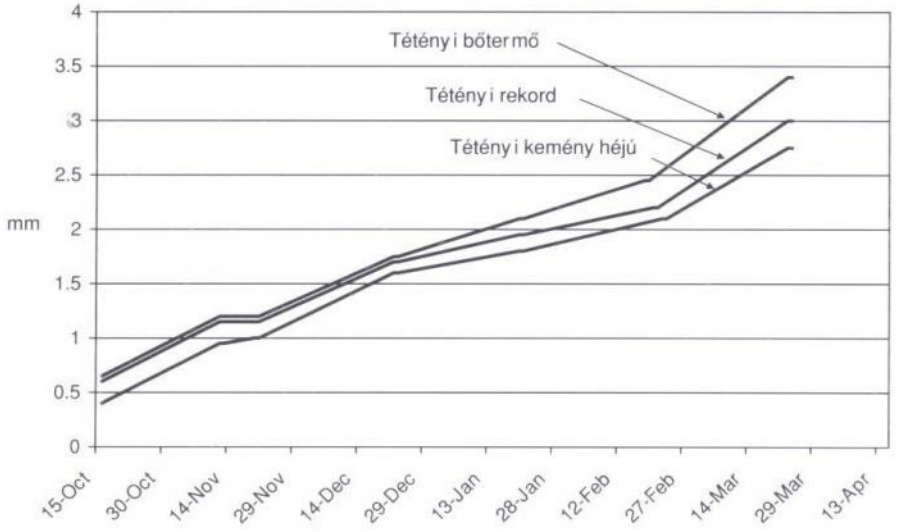

Figure 2 Changes of the pistil length in flower buds on the central section of short shoots of different almond varieties (Szigetcsép, Soroksár, 2004–2005)

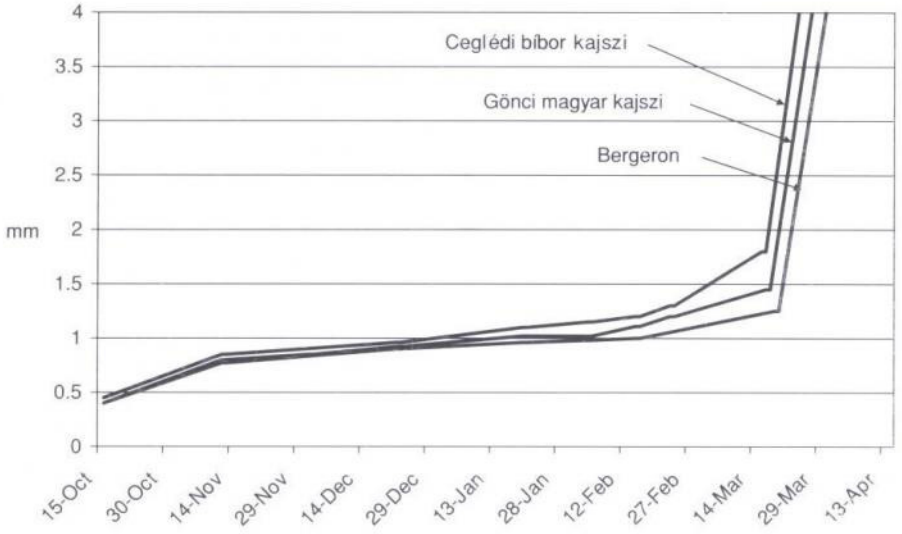

Figure 3 Changes of the pistil length in flower buds on the central section of short shoots of different apricot varieties (Szigetcsép, Soroksár, 2004–2005)

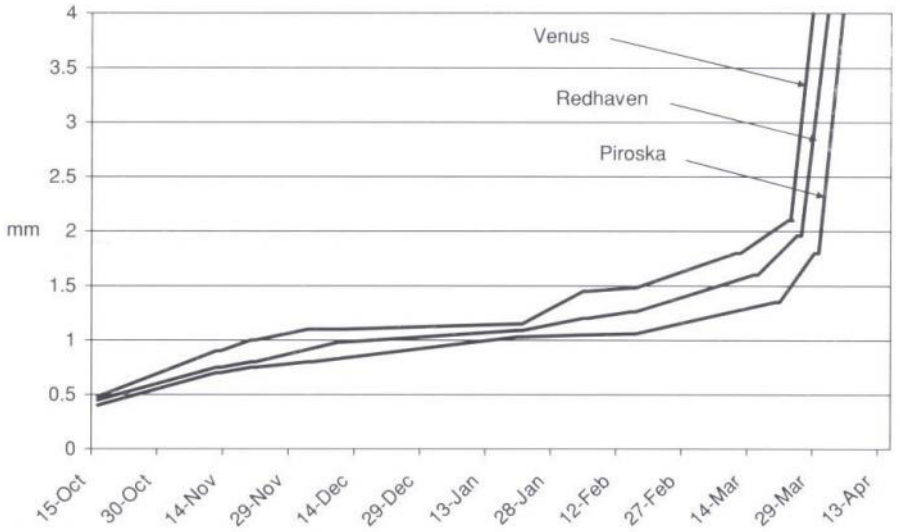

Figure 4 Changes of the pistil length in flower buds on the central section of short shoots of different peach varieties (Szigetcsép, Soroksár, 2004–2005)

shoots. In the case of almond varieties the longitudinal growth of pistils continued after a short pause from the end of November (*Figure 2*). There was no significant difference in the growing rate of the almond varieties, although this rate was quicker compared to the other varieties. Due to the steady increase the length of pistils was approximately 3 mm by the end of March. This was followed by a few days of highly intense growing before blooming.

In the case of apricot, the length of pistils was 0.7–0.8 mm by the middle of November, an in the following weeks the development considerably slowed (*Figure 3*). During endodormancy there was only a slight increase, thus the length of pistils was 1.0–1.1 mm by the second half of January. The growth rate then showed variation between the apricot genotypes. The strongest growth rate was measured in Ceglédi biborkajszi, followed by Gönci Magyar kajszi and Bergeron. This developmental order is in complete agreement with the order found in the developmental rate of microsporogenesis. The pistils reached a length of 1.3–1.8 mm by the middle of March, which was followed by a very intensive growing period till the beginning of blooming. These results are in good agreement with previously published results observed in Hungarian apricot varieties (*Molnár & Túri*, 1974; *Molnár*, 1992; *Molnár & Vágó*, 1999).

The tendency of the pistil growth detected in peach varieties was very similar to that of apricots (*Figure 4*). The pistils were 0.9–1.1 mm long by the end of November, beginning of December, then their growth stopped. Their length was still between 1.0–1.1 mm at the end of January. The pistils of Venus started first to continue growing; the pistil length was 1.5 mm in the middle of February. The pistil growing rate was slower in Redhaven, and in Piroska, in the latter variety the length of pistil did not change much till the middle of February. From the end of February the rate of growth also increased in the peach varieties resulting in 1.8– 2.1 mm pistil length

by the end of March. The intense growing period just before blooming was also characteristics to peach.

The synchrony of microsporogenesis and the growth of pistils would require closer examination. Hitherto, it is accepted that after endodormancy the appearance of pollen mother cells in the anthers coincides with the restart of growth in the pistil as contemporary events in flower bud development. For the purpose of determining the end of endodormancy, the length of the chilling period, or to predict frost resistance in the respective varieties, microscopic examinations are considered to be accurate methods.

Conclusions

We examined the flower bud developmental processes of three stonefruit species (almond, apricot, peach) during the dormancy period in Central-Hungarian growing locations.

As Hungary is situated on the Northern border of the production area of these species the floral bud developmental processes during winter and their suitable winterhardiness are crucial factors in the safety of production. Within each fruit species three different genotypes with differing degree of winterhardiness were involved in the experiments.

The rate of floral bud development was characterized with studying both microsporogenesis, and pistil growth. We identified significant differences in the floral bud development located on short or long shoots. Between the two shoot types the largest difference of approximately one month was found in almond, while this difference was 20 days in apricot and only 4–5 days in peach. In almond the endodormancy of flower buds on short shoots was terminated by the beginning of December. Similar tendencies were apparent in the occurrence of the tetrad stage, while the difference between the two shoot types decreased to 2–3 days by the beginning of blooming each fruit species.

The measurement of pistil length characterises the floral bud development less accurately, than microsporogenesis, but the differences between species and between genotypes within species remains still apparent. The length of pistil did not change during endodormancy, and then there was a steady, though slow growth during late winter, which was followed by a very intensive growing period just before flowering irrespective to the fruit species.

There are a relatively few result available on this aspect both in Hungary (*Nyujtó & Banai*, 1975; *Banai*, 1981; *Molnár & Vágó*, 1999; *Szalay*, 2001) and abroad (*Bailey*, 1978; *Ramina* et al., 1995), and it is difficult compare these results due to the different environmental conditions and to the different varieties studied. The results of one dormancy seasons are suitable mostly to compare different genotypes, as there can be tremendous differences between years due to the changeable environmental factors. Thus we are planning to continue these experiments to dissect the rhythm of floral bud development characteristic to a given growing location.

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