Some flower characters, variety features and environmental effects affecting bee pollination of pear (*Pyrus communis* L.): a review of the results of latest research

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Summary: Intensive research has been implemented on different aspects of the bee pollination of pear in Hungary in the past decade, extending to the following topics: the effect of the opening sequence of the flowers within the inflorescence of pear cultivars on the effectiveness of bee pollination; the nectar production of flowers of pear cultivars; intensity of honeybee visitation and their foraging behaviour at the flowers of pear cultivars; flower constancy of honeybees to pear plantations; competition by weeds in bloom for bee pollination in flowering pear orchards; and some aspects to the bee pollination strategies of pear plantations (the effect of the limitation of bee pollination period on the set and the yield, possible compensation of frost damage of flowers by bee pollination in pear orchards, the optimal size of single cultivar block in pear plantations). The results of these studies are reviewed in this paper and some important aspects that need further studies are outlined.

Introduction

Pear is an important fruit crop round the world and so great many research was made to explore its pollination requirements and the compatibility of its cultivars for pollination (reviewed lately by *Nyéki*, 1996). Most cultivated pear varieties are self-sterile and need pollinating insects as pollen vectors to set a commercial crop (*McGregor*, 1976, *Benedek*, 1996). There is a good agreement in the literature that honeybees are the most abundant visitors to blooming pear trees, however, first of all, blowflies can attain considerable densities among other flower visiting insects but they are considered to be of little value as pollinators of pear and their abundance is usually highly surpassed by that of honeybees (*McGregor*, 1976, *Klug & Bunemann*, 1983, 1985, *Choi*, 1987, *Benedek*, 1996).

The role and the activity of flower visiting insects, first of all of honeybees was intensively studied in pear pollination (reviewed by *Free*, 1993, *Benedek*, 1996). In spite of this, little information has been available so far on the flower characteristics of pear cultivars that are known to be decisive on the pollinating efficiency of flower visiting insects to some other temperate-zone fruit tree species (*Benedek & Nyéki*, 1994). In Hungary efforts were made in the past decade to contribute this problem. The aim of this paper is to present an outlook on this knowledge (*Benedek et al.*, 2000a, 2000b, *Benedek, Béres & Nyéki*, 1998, *Benedek, Kocsisné-Molnár & Nyéki*, 2000, *Benedek & Nyéki*, 1997, *Benedek, Ruff & Nyéki*, 1997, *Benedek, Ruff, Nagy & Nyéki*, 2000, *Benedek, Soltész & Nyéki*, 1997, *Dibuz et al.*, 1997, 1998) and to take the opportunity to point out to those features that has not been explored so far to pear and need further research activity.

Effect of the opening sequence of flowers within the inflorescence on the pollination of pear

It is well known long ago that the flowers do not open simultaneously in pear inflorescence. *Ulrich* (1952) stated that pear inflorescence could be characterised by centripetal or in other term acropetal flowering order. *Troll* (1969), however, indicated that another succession order could also be possible with certain pear cultivars. It was *Dibuz* (1991, 1996, 1997) who has made detailed studies in this item and she has shown that there were three types of flowering succession within the inflorescence among pear cultivars. Most cultivars (59%) can be characterised with centripetal opening sequence, while centrifugal succession appears at some 25% and divergent (mixed) type at about 16% of the cultivars. She has suggested that this feature may influence bee visitation and the fruit set of pears.

For this reason she and her co-authors made detailed studies on 47 pear cultivars during four consecutive years (*Dibuz et al.*, 1997). Results have proved her hypothesis because show that the flowering order in pear inflorescence is connected with some other flower characteristics (with the number of flowers per inflorescence and with the longevity of flowers) that has an effect on bee visitation and fruit set.

Dibuz et al. (1997) found that the number of flowers in racemose inflorescence differs according to the type of opening sequence. However, there were some differences between some cultivars of centripetal opening order, most cultivars of this group had fairly similar number of flowers per inflorescence.

Longevity of the flowers is also different according to the type of the inflorescence. Cultivars belonging to the centrifugal type open consistently for longer time than the same of the remaining two another types. However, no real differences can be established between cultivars belonging to the same groups and the longevity figures varied for individual cultivars during consecutive years.

There were large differences between bee visitation figures to individual cultivars in their studies. However, there are a number of environmental factors affecting bee activity on fruit crops definitely (*Free, 1970, 1993, McGregor*, 1976, *Benedek*, 1996, *Benedek & Nyéki*, 1994). For this reason visitation figures in consecutive years are not comparable. In given years, however, the comparisons are reliable because observations were made parallel with each variety several times during the blooming periods at the same experimental orchard in each of the four consecutive years. Taking this very important condition into account, conspicuous differences can be established between cultivars and first of all between the groups of opening order of flowers (*Dibuz et al.*, 1997, 1998). Some varieties exist within each group that tend to be more intensely visited by honeybees than other cultivars. There is a clear tendency that cultivars of the centripetal opening order are definitely more frequented by honeybees than the cultivars belonging to the another two groups. Cultivars with centrifugal opening order, on the other hand, are less visited by bees and the varieties belonging to the divergent type are somewhat more frequented than the former group but less visited than the centripetal type. Differences in bee visitation seem to be reflected in the fruit set, too. Cultivars and group of cvs most intensely visited by honeybees usually produce greater set than other ones. Varieties of centrifugal types produced much smaller sets. Fruit set of divergent type cultivars was not in such a good accordance with their bee visitation. Disregarding these few exceptions it can be stated that cvs of centripetal type produce greater sets in average significantly, than the cultivars belonging to the other two groups. Divergent group, on the other hand, is characterised by somewhat higher fruit set values than the centrifugal one but this difference is not statistically significant.

The authors (*Dibuz et al.*, 1997) are of the opinion that more intensive bee visitation and better fruit set of cvs of centripetal type of flowering order is connected with the highestnumber of flowers per inflorescence and with the highestlongevity of individual flowers. Namely, highest-number of flowers per inflorescence can increase the flower density and also the number of flowers in pear trees and this can increase their attractiveness to honeybees (c.f. *Free*, 1970, 1993). Increased longevity of flowers, on the other hand, can influence the availability of pollen to honey bees and so it can increase the attractiveness of the trees. Also the flower constancy of honeybees can be influenced by these factors and so increased longevity can contribute to increase bee visitation on pear trees. This type of flowering sequence (centripetal) seems to be typical to the majority of important cultivated varieties. The difference is so large that the fruit set of the centrifugal type is some 40 and that of the divergent type some 30 per cent smaller than that of the centripetal type, when the set of the latter is considered as 100 per cent (*Dibuz et al.*, 1997, 1998).

Nectar production of flowers of pear cultivars

Pear flowers are usually considered to produce rather little amount of nectar (*Free*, 1970) and most authors accept the statement of *Vansell* (1946) that pear nectar is low is sugar content and so it frequently fails to attract honeybees. Other authors, however, report on fairly high mean nectar content of pear flowers (*Glowska*, 1998, *Benedek and Nyéki*, 1997) and also on high sugar content of pear nectar (*Péter*, 1972). Some authors have found that the nectar production of pear cultivars may be different (*Vansell*, 1946, *Simidchiev*, 1970).

Benedek, Kocsisné-Molnár & Nyéki (2000) have shown that pear flowers do not necessarily produce small amount of nectar as stated frequently and accepted widely in world literature (*Free*, 1970, 1993, *Benedek*, 1996). It is evident that pear can produce significant amount of nectar in favourable weather but its nectar production is extremely dependent on weather conditions as indicated in some earlier publications (*Sazykin*, 1955, *Péter*, 1972).

Based on their results, ambient temperature was considered to be the major governing factor since nectar production was extremely high in the warmest year of their studies but it was much less in the year with much cooler weather (*Benedek, Kocsisné-Molnár & Nyéki*, 2000). On the other hand, the nectar production was completely prevented in a year when weather was very cold with some serious night frost during the blooming period of pear. In most pear growing countries weather can frequently be rather cool during the blooming period of pear and so it can dramatically decrease the nectar production capacity of pear flowers. This may be the explanation of the fact the nectar production of pear flowers is generally regarded to be very low in the literature.

The nectar production of individual pear flowers can be extremely high at some occasions (*Benedek, Kocsisné-Molnár & Nyéki*, 2000), higher than in the flowers of other

temperate-zone fruit trees species (as indicated by *Benedek & Nyéki*, 1997). Highest figures may be sometimes round a 30 mg/flower. This figure can be counted as exceptionally high nectar production even among temperate-zone fruit tree species (see *Benedek & Nyéki,* 1997). The high figures, however, seem to be exceptional and so low nectar production of pear can be much more typical than high figures first of all in most northern, cooler areas where pear production is more common than at southern latitudes.

The studies of *Benedek, Kocsisné-Molnár & Nyéki* (2000) corroborate to the earlier statements on low sugar concentration of pear nectars (e.g. *Vansell,* 1946, *Free,* 1970). However, they demonstrated a highly significant negative correlation between the amount of nectar in pear flowers and its sugar concentration. They state that the sugar concentration can be high at exceptional cages but no doubt the typical sugar concentration of pear nectar seems ta round or below 20%. This was well demonstrated by the average figures that were 15.1% in one year (n = 291) and 17.1% in another year (n = 197), respectively. Accordingly, the mean sugar concentration of pear nectar can be considered to be very low compared to other temperate-zone fruit tree species (*Benedek & Nyéki,* 1997).

They have not found any consequent differences between the nectar production of pear cultivars, however, the number of cvs. inspected was as high as 44, 16 and 18, respectively, in consecutive years. This statement is in contradiction with some earlier reports (*Vansell,* 1946, *Simidchiev,* 1970, *Péter,* 1972) that were based on measurements of much smaller number of cultivars usually in shorter period of time. They say that comparisons made in a single year can show some differences among cultivars but these differences seem not to be consequent during consecutive years. This in not surprising because it has been proved that some flower characters of some fruit tree species can be much more variable during consecutive years than between cvs in given years (*Benedek and Nyéki,* 1994). *Benedek, Kocsisné-Molnár & Nyéki* (2000) established that honeybees fail to gather nectar at pear flowers for its very low sugar concentration even in the case when nectar production of pear flowers is exceptionally high.

Intensity of honeybee visitation and their foraging behaviour at the flowers of pear cultivars

There are some indications in the literature that bee visitation of pears can be different. *Caron* (1973) for example indicated notable differences between the intensity of bee visitation of *'Magness'* pear and its pollinizers and *Choi & Kim* (1988) suggested differences in the foraging behaviour of honeybees between six varieties of Asian pear. That were *Benedek, Ruff & Nyéki* (1997) who have made efforts to compare the intensity of bee visitation of 13 European pear cvs. Their results indicate notable differences between the intensity of bee visitation of pear cultivars. The results show that the differences in the bee visitation seems to be a general phenomenon in the case of pear varieties with 'normal' amount of pollen production, too. However, differences between cultivars with 'normal' pollen production are not so large than between them and the male sterile cultivar. Some cultivars were highly visited by honeybees, while another ones were less visited than the rest of the varieties that were characterised by medium intensity of honeybee visitation. Extreme (very high and low) mean values for bee visitations usually differed significantly from the mean figures for the remaining cultivars of medium intensity of bee visitation. This finding is important from the point of view of pear production because effectiveness of honeybee pollination is greatly influenced by the relative intensity of bee visitation at the main cultivar and at the pollinizer varieties in plantations (*Free,* 1970, 1993).

Number of flowers visited by honeybees at a single branch with opening flowers seems also to be different among cultivars (*Benedek, Ruff & Nyéki,* 1997). These differences, however, do not seem to be in accordance with the intensity of bee visitation at the same cultivars. Intensity of bee visitation is probably governed first of all by the pollen and nectar production of varieties but some another factors have an impact on that, too. *Benedek, Ruff & Nyéki* (1997) have found that the intensity of bee visitation is negatively correlated with the wind speed and positively correlated with the intensity of blooming and the air temperature. Correlation coefficients were significant in all cases. This finding is in contradiction with the statement of *Choi* (1987) who said that temperature had not a significant effect on the foraging activity of honeybees. He stressed the positive effect of the solar radiation. There is no doubt on the strong effect of that but also air temperature is of a strong influence on bees first of all in cloudy weather. This conclusion corroborates the finding of *Lee et al.* (1988) because they argue for the strong effect of air temperature on the foraging activity of honeybees among other physical factors. Bee visitation tends to be more intense in the morning than at the afternoon and it seems to be more numerous at the Northern side of the trees than on the Southern one (*Benedek, Ruff & Nyéki,* 1997).

Most authors agree that honeybees prefer to gather pollen at pear trees (*Vansell,* 1946, *Stephen,* 1958, *Free,* 1963, *Choi & Kim,* 1988) because their flowers produce plenty of pollen but usually only small amount of nectar always with low sugar concentrations. *Benedek, Ruff & Nyéki* (1997) also found that vast majority of foragers scrabbled deliberately for pollen and thus contributed to the pollination of pear flowers effectively. No more than very few bees gathered for nectar only and mixed behaviour (gathering both pollen and nectar) could be regarded as exceptional. In their study there were no more than two cultivars of the 13 ones inspected on the flowers of which there were more than 10 per cent nectar gatherers seen. Their results show that there are not so much differences between cultivars (probably except male sterile ones) in the foraging behaviour of honeybees than it was suggested by *Choi & Kim* (1988). However, some authors are of the opinion that

the proportion of pollen gatherers can show variation across the day (*Vansell,* 1946, *Free & Smith,* 1961).

Flower constancy of honeybees to pear plantations

Pear does not have any specialised flower visitors (c.f. *Free,* 1970, 1993, *Benedek et al.*, 1974, *McGregor,* 1976, *Benedek,* 1996) and thus its flowers are frequented by polylectic and widely oligolectic pollinators. Accordingly, their behaviour and fidelity towards pear is greatly important from the point of view of its pollination and also of commercial fruit set.

In the case of honeybees, however, constancy is largely different at the level of the individual forager bee and at the level of the colony, respectively. Individual foragers visit much more limited number of pollen and nectar sources than all the field bees of the colony together (*Free* 1970, 1993). Thus flower constancy of honeybee foragers is an important factor in pear production. Previous studies on the flower constancy of honeybee foragers were based on the composition of pollen loads of individuals collected at the hive entrance when they were returning back from their foraging trips (*Betts,* 1920, *Percival,* 1947, *Maurizio,* 1953, *Free,* 1963 and others). This kind of study provides a very good picture on the general pattern of flower constancy of all foragers of the honeybee colony. Individual foragers, however, can be and usually are constant at different plant species simultaneously. Pollinating efficiency of honeybees visiting a specific crop does not depend on the fact that they come together from different bee colonies. Therefore, the approach mentioned does not give a reliable information on the relative constancy of bees visiting a specific plant species. For this reason *Benedek & Nagy* (1995) as well as *Benedek, Ruff, Nagy & Nyéki* (2000) made attempts to explore the fidelity of honeybees towards pear when visiting the flowers of blooming pear trees in commercial plantations independent of the fact whether they came from different bee colonies at the nearby. They found that fairly high proportion of the pollen loads of honeybee foragers captured when visiting pear flowers were free of any contaminating pollen species and the few mixed loads contained less then two per cent contamination of other pollen species than pear. Considering the ratio of the pure loads and those ones together that contained only minor (>2%) contamination the percentages are very high (round 90%) for all of the cases studied showing a high rate of fidelity. Smaller amount of contamination were always more frequent than the higher ones. The average contamination of mixed loads was rather low. Major contaminating pollen species were more or less different at the cases investigated. Composition of pollen loads of honeybee foragers captured at pear flowers corroborates to the earlier statements that flower constancy of honeybees seems be fairly high at blooming pear trees, higher than at some another temperate zone fruit trees, at apple, sour cherry and apricot (*Benedek & Nagy,* 1995).

High fidelity of honeybee foragers towards pear flowers is of great practical importance in pear growing because honeybees can be much more important and more effective pollinating agents of pear than generally believed. Pollen gatherers usually approach the flowers form the top and so no one pollen gatherer can be ineffective side-worker forager like at apple (*Free,* 1970, 1993, *Benedek & Nyéki,* 1996). This is very important because there is a large gap between anthers and petals in the flowers of several pear cultivars, too, and that structure encourages honeybees to land here and for this reason foragers can lean in a short time to be side worker nectar gatherers.

The high fidelity of honeybees to pear flowers has not been influenced even by the great overpopulation of pear orchard with honeybees (*Benedek, Ruff, Nagy & Nyéki,* 2000). Though, very intense bee visitation was expected to encourage foragers to explore and exploit another sufficient pollen and nectar sources abundant in the proximity the opposite has happened (at least with pollen gatherers, since their proportion was overwhelming). This picture, however, is not an exceptional case with pear. Also *Free & Smith* (1961) observed that in bee colonies moved to pear orchards 47 to 91 per cent of pollen grains carried into the hive had come from pear. Thus, though as a source of nectar, pear is not attractive to honeybees (*Benedek, Kocsiné-Molnár & Nyéki,* 2000), it is very attractive to them as a pollen source even when there are a great number of foragers present gathering large amount of pollen in a short time. Since, pollen presentation of the pear plantations has not found to be decreasing notably during the day by *Benedek, Ruff, Nagy & Nyéki* (2000), pollen production of pear trees seems to be abundant enough to attract a high number of honeybees and provide enough pollen to them visiting the pear trees in bloom. For this reason, it is worth to take this advantage and move honeybee colonies to pear orchards for supplementary pollination because they probably would not be influenced very much by the competing effect of the blooming weed flora, of blooming fruit trees or of other crops blooming simultaneously, except winter rape (e.g. *Benedek & Nagy,* 1995) or of other related cruciferous crops (*Free* 1970). This is an exceptionally favourable condition that is not typical to other temperate zone fruit trees at all (c.f. *Free,* 1970, 1993, *McGregor,* 1976, *Benedek,*1996). For this reason it should be exploited by pear growers much better in the future than it has been made so far.

Competition for bee pollination by weeds in bloom

There are several indications in the literature stating that a number of other plant species can be serious competitors to fruit trees for honeybee visits (*Butler,* 1945, *Free,*1968, 1993, *Benedek et al.,* 1974, *McGregor,* 1976). Among weeds dandelion (*Taraxacum officinale)* has long been regarded as a major competitor of fruits (*Brittain,* 1933; *Filmer,* 1941, *Butler,* 1945, *Percival,* 1955, *Free,* 1968). Also *Stellaria* species have been called to be strong competitors to pear (*Stephen,* 1958). *Kremer* (1950) was the only author who expressed contradictory opinion stating that honeybee visits to dandelion and fruit trees were greatly influenced by

changing weather. However, most statements in the literature are against him, high fidelity of pollen gathers on pear flowers (see above) also seems to be in a good accordance with his findings. For this reason, *Benedek, Béres & Nyéki* (1998) have made field studies to check the effect of competitor plants against pear plantations in bloom for honeybee visitation. They found some 16 entomophilous weed species in bloom during the flowering period of pear orchards in Hungary. However, the competing weed flora, both its specific composition and density seems to be different at different places and changeable under the influence of changing weather in different years. Flowers of most of the potential competitors start to open at about the same time early spring when pear trees commence to bloom but changing weather can speed up or can retard the flowering of the plant species concerned. There are no more than two weed species, *Taraxacum officinale* and *Stellaria media*, that always seem to bloom simultaneously with pear trees probably at all the times at all places. The same two weed species have been mentioned as most common competing weeds for honeybee visits of pear in North America (*Brittain,* 1933, *Filmer,* 1941, *Kremer,* 1950, *Stephen,* 1958) and in Britain (*Free,* 1968), too. At some instances, however, also *Capsella bursa-pastoris*, *Trifolium repens* and *Senecio vulgaris* were abundantly flowering during the blooming period of pear orchards in the studies of *Benedek, Béres & Nyéki* (1998). They found, however, that competing effect of flowering weeds did not seem to be so strong at all instances as stated in earlier publications because no flowering weeds were affective competitors against pear to bee visits during two years of their study. Even dandelion (*Taraxacum*) was scarcely visited by honeybees as long as the flowering of the experimental pear orchard was intense and the honeybee visitation of *Taraxacum* patches rose remarkably when the blooming period of the pear trees had finished *(Figure 1)*. Accordingly, their results show that the competing effect of flowering weeds can be much less important for pear as previously indicated. The reasons of the contradictory conclusions in the literature have not exactly been understood. One possible explanation can be the changing nectar flow of pear and of competing plant species under the influence of changing weather as it was supposed by *Butler* (1945). Also the relative pollen production can be important from this point of view (*Free,* 1968). The situation, however, is probably much more complicated. Presentation of nectar and pollen can be vitally important during the day (*Percival,* 1955) because this phenomena definitely affects the foraging behaviour of honeybees visiting relevant weeds and pear trees being in bloom simultaneously (*Kremer,* 1950).

Contribution to the bee pollination strategies of pear plantations

Weather can frequently be unfavourable to bee activity during the blooming period of pear. Therefore, it is a major question how strong is the effect of the limitation of the bee pollination period to the fruit set and the yield of pear cultivars. *Benedek et al.* (2000b) have made several experiments to explore the effect of that on some temperate zone fruit tree species including pear, too. They found that the total limitation of bee pollination (exclusion of bees all along the blooming period) gave no set and yield of pear and also the partial limitation of the bee pollination period was conspicuous. They investigated 4 cultivars of pear. No yield was set at one cultivar also when the bee pollination period was partially limited. On the other hand, at the other cultivars tested partial limitation of the bee pollination period resulted in a smaller set and yield than at open pollination but the reduction was no so strong because at least one of the two treatments of the partial limitation of the bee pollination period gave at least half as much set and yield as free pollination. At two cases partial limitation of the bee pollination period in the first half of the blooming gave more yield than in the second half of bloom but the opposite happened at the other two cases. This means that the effect of the partial limitation was influenced rather by the weather than by the different sensitivity of pear cultivars against the limitation of bee pollination period at different part of their blooming. So the limitation of the period of the effective bee pollination can significantly influence the fruit set and the yield of pear plantations.

Figure 1 Even dandelion was scarcely visited by honeybees in the experimental pear orchards of Benedek, Béres & Nyéki (1998) as long as the flowering of the pear orchard was intensive

The weather can be so cold during the blooming period of pear that completely prevents bee activity in fruit tree plantations and, what is more, the air temperature can drop below the freezing point. Spring frost is know to be of very strong effect on the yield of temperate zone fruit tree species because trees can suffer serious bud and flower damage. In spite of these facts, there is no information in the literature what is the effect of spring frost on bee behaviour on pear trees and on their pollinating efficiency in general. A seriously cold spring with some severe early morning frosts provided an opportunity to study this problem. *Benedek et al.* (2000a) studied the effect of frost and its possible compensation with 5 pear cultivars that suffered significant

frost damage ranging from 21 to 68% at the bloom stage. They found that the cold weather during the blooming period completely prevented the nectar secretion of the flowers. There were few day when bees could fly at all and that time they intensely worked at flowers. All of them were pollen gatherers on pear. Nectar gatherers had to explore and exploit other plant species, however, cold weather also prevented nectar secretion of other (wild) plants, too. The result of the intensive bee visitation was reflected in the fruit set and the yield, and thus intense bee activity could partly compensate the negative effect of sereve frost damage of the flowers. They found that intense bee visitation can result in as high set of surviving flowers that can compensate the loss of frozen ones, more or less. Compensation needs a very high pollinating insect density that can easily be produced by moving honeybee colonies to the crop. Much more bee colonies are necessary to this specific purpose than generally proposed under usual conditions. The number of necessary colonies was some 4 to 10 times more in their experiment. Accordingly, similar high bee densities can be recommended in the practice to compensate the effect of spring frost on yield. The question is what is the extent of bud and/or flower damage by frost? When a good deal of the flowers survive bee pollination can be a useful tool to compensate the unwanted effect of frost on the yield.

When interplanting compatible pear cultivars, the optimal size of single variety blocks is a vital point, greatly discussed in the literature and practice. The variety-specific cultivation (pruning, plant protection, harvest) would need more wide single cultivar blocks and for this reason growers would prefer this kind of arrangement. However, cross pollination between cultivars would need completely intermixed arrangement of the main and the pollinizer cultivars. This item is most critical in most intense pear plantations where the trees are very close to each other within rows and so they form a 'closed wall' along the rows. The effect of the distance of the pollinizer variety on the yield was studied by *Benedek, Soltész & Nyéki* (1997) in a number of commercial pear plantations with large single curtivar blocks surrounded usually by single rows of pollinizer varieties. The rowspacing of the investigated plantations was traditional, some 7 metres. Evaluating the experimental results they found that the yield in the central rows of the single cultivar blocks decreased rapidly as the number of rows increased within the blocks. The yield was the highest when the block was as narrow as 1 to 3 rows only. This case the central row of the block is at a fairly close vicinity of the pollinizer variety. In the contrast, the yield at central rows decreased with some 80 to 90 per cent when the block was as wide as more than 10–12 rows and so the central row was some 5–6 rows away from the pollinizer variety. The decrease of the yield seemed to be rather significant even when the block was not wider than three to four rows only. Accordingly, they concluded that the maximum acceptable distance between the main cultivar and the pollinizer variety may be not more than 2 or at least 3 seven metres rows that is not more than 15 to 21 metres.This means, there is no reason to plant wider single cultivar blocks in traditional large crown pear plantation than 15 to 20 metres and so single cultivar blocks may not be wider than some 30 to 40 metres at the maximum. Their recommendation is in a good accordance with most of the relevant publications in the literature (reviewed by *Soltész*, 1996).

Conclusions and the need of further research

Comparing the available knowledge on the flower characters affecting bee pollination of several temperate zone fruit tree species and of their cultivars, *Benedek & Nyéki* (1994) concluded that there was a number of flower features that had a definite influence on the effectiveness of honeybees in pollination. These covered the nectar and the pollen production of flowers evidently that has been known from this respect for a long time, but additionally there were also other characteristics, flower shape, size of flowers, relative position of flowers organs and also flower density of the trees that were of definite effect on the bee activity and on their pollinating efficiency, too. They emphasised, however, that individual factors were of different importance for individual fruit tree species and cultivars. They did not evaluated pear because very few information was available on the flower characters of its cultivars that time. The research result having been published so far has widened our knowledge on this item but, naturally, there are some aspects that seem to require further research activity.

It has been understood that the structure of flowers, that is the relative position of petals, stamens and stigmas *(Figure 2)* fails to have a significant importance at pear (however, these are vitally important for example in apple: see *Benedek & Nyéki, 1996*) because very few honeybees collect nectar on pear flowers and the foraging behaviour of pollen gatherers is not influenced by factors like this. Also the nectar production of pear flowers is of little value from the point of view of insect pollination, because its very low sugar concentration is not really attractive to honeybees. In spite of this, pear trees are abundantly visited by honeybees and they seem to prefer some varieties much better than others.

The opening order of the flowers within pear inflorescence has been discovered to be an important factor in bee pollination because cultivars with centrifugal opening sequence within inflorescence attract more honeybees and receive higher fruit set because they have more flowers per inflorescence and the longevity of their individual flowers is greater that at pear cultivars with other types of opening sequence in their inflorescence (*Dibuz at al.*, 1997, 1998). This indicates that the flower density of trees may be an important factor in pear pollination. Flower density may be one of the factors that can cause the differences in the honeybee visitation of pear that was detected by *Benedek, Ruff & Nyéki* (1997), too. This item, however, has not been studied so far and thus it requires further research in the future.

Fidelity of pollen gatherer honeybees visiting the flowers of pear trees has been found to be surprisingly high, higher that at other temperate zone fruit tree species investigated so far (*Benedek & Nagy,* 1995, *Benedek, Ruff, Nagy & Nyéki,* 2000). This is an exceptional advantage in commercial pear production that is worth to be exploited by the growers, since the pollen gatherers of bee colonies moved to blooming pear plantations would remain at the site *en masse* even in the presence of other blooming honey plants. This may be the reason of the fact that the competitor plant species blooming simultaneously with pear failed to have a measurable effect on the bee visitation of flowering pear plantations even in the case when pear was overpopulated with honeybee colonies (*Benedek, Béres & Nyéki,* 1998). This means that, fortunately, competing plants (weeds and fruit trees) seem not to be so important in pear pollination as it has been suggested previously. This problem, however, would need further detailed studies at other pear growing areas with different ecological conditions and other types of competing weed flora than that of the area where it has been carefully studied so far.

Pollen production of pear seems to be even more important than of other temperate zone fruit tree species. At some other fruits, at apple for example, pollen production of flowers of cultivars was found to be more or less different (*Benedek & Nyéki,* 1994, 1996), however, in the case of pear cultivars this feature has not been studied so far. It is very probable that there are some differences in the pollen production of pear cultivars because this may be one of the reasons of the differences having been found between the bee visitation of pear cultivars. Accordingly, the pollen production of the flowers of pear cultivars greatly needs further research in the future.

It has been clearly proved that the limitation of the effective bee pollination period significantly influences the fruit set and the yield of pear plantations (*Benedek et al.,* 2000b). Intense bee visitation can also be used to compensate partial bud and/or flower damage coused by spring frosts when it is not too high, because the surviving flowers can receive much more higher set consequently (*Benedek et al.,* 2000a). This case 4 to 10 times more honeybee colonies are recommended to move to the pear plantations than at the usual situations.

For supplementary pollination, the optimal number of honeybee colonies required should be estimated on a realistic basis. This, however, has not been possible so far because no information has been available on the number of bee visits that would be needed to a good crop at the flowers of pear cultivars. Accordingly, the relationship between the number of bee visits per flower and the subsequent fruit set and yield of pear should be investigated in the future because this can be the only reliable estimate on the need of additional supplementary bee pollination, that is on the need of moving some more honeybee colonies to or perhaps to remove some of them from the flowering fruit plantations for optimal pollination (*Free,* 1993, *Benedek,* 1996).

Figure 2 The relative position of stamens and petals would encourage nectar gatheres honeybees to be side workers at the flowers of most pear cultivars but, fortunately, very few honeybees collect nectar at pear trees

At traditional large crowned plantations (where row spacing is some 7 m) the with of the single cultivars blocks is recommended to be not more than 30–40 metres at the maximum because the fruit set has been found to decline fast at the central rows of blocks wider than this (*Benedek, Soltész & Nyéki,* 1997). In the case of high density (so called "superintensive") pear plantations this relationship can be greatly different but no relevant information has been available on this item so far, so this problem also needs further research

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