BEE POLLINATION OF FRUIT TREES: RECENT ADVANCES AND RESEARCH PERSPECTIVES II.

Pál Benedek

University of West Hungary, Faculty of Agricultural and Food Sciences,
H-9201 Mosonmagyaróvár, Vár 4., Hungary.

Summary

Intense research was carried out on the bee pollination of temperate zone deciduous fruit trees during the past decade. Much progress was achieved to explore the flower characters of a great number of cultivars affecting honeybee activity at flowers and their pollinating efficiency. Flower characters were found to be consequently different among apple and pear cultivars in consecutive years but in case of some stone fruits differences between consecutive years were greater than between cultivars in given years. The necessity of bee pollination was clearly demonstrated both at self-sterile and at self-fertile fruit cultivars. The rate of flower constancy of honeybee foragers was different at different fruit tree species but the role of competing plants was found to be much less deleterious than stated in the literature earlier. However, a number of questions arose partly from the results of latest pollination research and partly from practical experiences in commercial plant production. These indicate several research tasks to understand and to solve the problems possibly in the near future. The questions concentrate on the effectiveness of bee visits in the pollination of individual fruit crops and their different cultivars and on the reliable estimate of the overall amount of bees as well as on the control of bee density during the flowering period of fruit orchards for optimal, controlled honeybee pollination. Much less effort was made to manage native wild bees for fruit tree pollination, however, some mason bees seem to be promising for this purpose in Europe, The Far East and North America.

Keyworlds: insect pollination, honeybees, temperate zone deciduous fruit crops.

INTRODUCTION

Almost all temperate zone fruit tree species need insect pollination, the only exception is the horse chestnut, which is wind pollinated, but partly benefits insect pollination, too. The role of insects in fruit crop pollination has been recognized long ago. The information accumulated on this field has been reviewed by Free (1993) in the comprehensive handbook "Insect pollination of crops (second edition)" some ten years ago. After the appearance of this book fruit pollination research has remained intense. Important new information accumulated in this field, however, several new problems arose that needs further research. The aim of this paper is to give an outlook onto the state of knowledge in this field and to point out the need for further research.

RESULTS

Flowers characters and other conditions affecting bee activity

Pollination requirements of temperate zone fruit crops, their pollinating insects, the rewards to attract bees and the foraging behaviour of bees on their flowers as well as the effect of bee pollination on the yield is fairly well known (Free 1993). Lately, intensive studies were carried out on variety features affecting bee activity,

There were some few indications in the

literature that some differences between cultivars, for example the relative position of petals and stamens, or the nectar and pollen production of flowers had a definite influence on bee behaviour and on the pollinating efficiency of bees at some instances (see in Free 1993), this problem, however, has not been not adequately studied and no more than sporadic information was available on very few cultivars of some selected fruit species, first if all of apple and pear. For this reason lately large series of cultivars were inspected for various fruit species, first of apple (Benedek et al. 1989b, Benedek and Nyéki 1996a, Devary-Nejad et al. 1993), thereafter of apricot (Benedek et al. 1991b, 1995), peach and nectarine (Benedek et al. 1991a, Benedek and Nyéki 1996b), sweet and sour cherry (Benedek et al. 1990, 1996) and plum (Szabó et al. 1989, Benedek et al. 1994). Differences were detected among cultivars in flower sizes, in the number of stamens/flower, in the relative position of petals to stamens and to pistils, in the nectar content of flowers, in the sugar concentration in nectars, in the anther size and in the pollen production, and finally in the intensity of bee visitation at the flowers. In case of apricot, flower characteristics varied considerably depending on the year and site, greater differences occurred at the same cultivar in consecutive years than between cultivars in given years. Similarly, no consistent differences were found in the bee visitation at a number of almond cultivars in India; floral preferences varied from year to year (Thakur et al. 1995). Contrarily, at the rest of the mentioned fruit species, the differences in the flower characteristics of cvs were consistent in different years, and consequently, also their bee visitation differed. In the case of pear, the opening order of flowers within inflorescence was different; cvs fell into three types of opening order which also differed in the average number of bee visits per flower; this was explained by the different number of flowers and differences in the longevity of flowers within the inflorescence of the tree types (Dibuz el al. 1997, 1998).

In other studies the nectar content and the bee visitation of several almond (Abrol 1995), peach (Nyéki et al. 2000), pear (Benedek et al. 2000a) and quince cultivars were compared (Benedek et al. 2000d, 2000e); cultivars with higher sugar concentration, i.e. with higher caloric rewards usually attracted more foraging insects compared to other cultivars of the same fruit species, except pear (Abrol 1995, Benedek et al. 1997, 1998b, 2000e, Benedek 2000). Nectar production of pear is generally regarded to be very poor in the literature (Free 1993); in fact, it has been shown lately that pear flowers could produce a plenty of nectar, but the amount of nectar was extremely dependent on the weather (Benedek et al. 2000a). However, pear nectar always contains very little amount of sugar (Benedek et al. 2000a) which is not attractive to bees at all (Free 1993). That is why honeybees collect almost exclusively pollen on pear, even with high nectar production (Benedek et al. 1997, 1998b, Benedek and Nyéki 1997a, Benedek 2000).

Comparing the nectar production and the bee visitation of fruit tree flowers at the species level, the amount of nectar/flower was the highest at sour cherry, followed by apricot, apple, plum, peach and nectarine; pear always produce very small but sometimes can produce very high amount of nectar (Benedek and Nyéki 1997a). The mean sugar concentration of pear nectar was always very low, regardless the amount, and the sugar concentration of nectar was the highest at sour cherry, followed by apple, plum, peach and nectarine (Benedek and Nyéki 1997a). Mean intensity of bee visitation was also different according to the fruit species, and again, it was clearly related to the sugar concentration of the nectar (except pear), but the amount of nectar had no effect on the bee visitation at the species level (Benedek and Nyéki 1997a).

Different factors, weather conditions first of all, can restrict pollinating insects to work the flowers of fruit trees during their blooming period. In spite of this, very little information has been available in the literature on the rate of limitation that affected the fruit set and yield. For this, reason experiments were made on this issue lately with apple (Benedek et al. 1989a, Benedek and Nyéki 1996c, 1997b), with pear (Benedek et al. 2000b), with quince (Benedek et al. 2000f), with sour cherry (Benedek et al. 1990), with plum (Szabó et al. 1989, Benedek et al. 1994) and with apricots (Benedek et al. 2000b). Summarizing the results of relevant experiments, the main conclusion was, that in the case of self-sterile fruit species and cultivars (apple, pear, quince, some plums, some sour cherries) even partial limitation of the effective duration of the bee pollination period significantly reduced the fruit set and the yield; in the case of self-fertile fruits (some plums, some sour cherries, some apricots), on the other hand, the effect of partial limitation was usually small, and the complete (or incomplete but strong) limitation resulted in a strong reduction of yields; it means that not only self-sterile, but also self-fertile fruit cultivars definitely need insect pollination (Benedek and Nyéki 1995, 1996d, Benedek et al. 2000b).

Lately flower constancy of honeybees at fruit trees was investigated by analysing the pollen loads of pollen gatherer honeybees captured at fruit tree flowers (Benedek and Nagy 1995, Benedek et al. 2000c); the fidelity of bees was fairly high for pear, but it was smaller for apricot, much smaller for apple and even smaller for sour cherry. Competing plants influenced the flower constancy of honeybees and the influence was greatly different for fruit species; it was very little at pear (Benedek et al. 1998a, Benedek 2000). High fidelity of pollen gatherers was also observed towards cultivars, since bees returning to the hives had 80-90% of their loads from only one cultivar out of the 5 or 6 in an almond orchards (Vezvaei and Jackson 1997, DeGrandi-Hoffman et al. 1992). However, bees with high amount of pollen from a single cultivar usually had some pollen from other cultivars, too (DeGrandi-Hoffman et al. 1992).

The gene flow, as investigated with isozyme markers, was quite restricted in almond orchards in Australia, being the strongest between neighbouring halves of cross-compatible pairs of trees (Jackson and Clarke 1991, Vezvaei and Jackson 1997). However, the nut set on branches adjacent to compatible pollen sources did not differ significantly from the set on branches adjacent to the trees of the same cultivar in one other experiment in the US (DeGrandi-Hoffman et al. 1992).

Managing wild bees and other insects for fruit tree pollination

Managing and utilizing wild bees as pollinators attract more and more interest, because some wild bees are relatively easy to manage and they posses several advantages as pollinators compared to honeybees. Wild bees, some solitary bees and bumblebees, however, have been exploited for field crop pollination and for insect pollination under cover because (Richards 1993, Cane 1997, Ruijter 1997) because the managed species are not specialised visitors of the Rosaceae plant family.

Managing mason bees for fruit tree pollination: It is a fairly new development to try managing different mason bees for pollination. In temperate regions, Osmia cornuta seems to be the most promising mason bee to this purpose. Its normal seasonal activity starts very early spring, and coincides well with the flowering period of fruit trees (Bosch et al. 1993). There are some serious parasites that can restrict its population size (Bosch 1992, Bosch et al. 1993). Pollen collected for provisions show that the species prefers to collect Prunus pollen, and switches to Malus pollen when it is more readily available (Márquez et al. 1994). It is calculated that during almond flowering, each female potentially visit as much as 9.5 to 23 thousand flowers, and therefore 3 females/tree are sufficient for almond pollination (Bosch 1994a). Cocoons were exposed to different overwintering and incubating temperatures trying to manipulate the time of emergence but with little success so far (Bosch and Blas 1994). Suitable nesting material was searched for (Bosch 1994b, 1995), but further research is needed. Osmia cornuta has been tried to be used for blackberry pollination in plastic tunnel with success (Pinzauti et al. 1997). Very probably it will be suitable to pollinate other fruit crops too, hence this issue also needs further studies. Some other mason bees, Osmia lignaria propinqua, O. californica, O. Montana, were also successfully managed for mobile orchard pollination in the US (Torchio 1991), and O. cornifrons for Japanese pear and apple pollination in the Far East (Maeta et al. 1993, DooHyun et al. 1996, Sekita 2001). There are some additional proposals to manage some other solitary bees for crop pollination; Andrena flavipes - which also occurs in Europe - was proposed to manage in India (Abrol 1993) and Anthophora pilipes villosula in Japan (Batra 1994).

An other European early spring mason bee species, Osmia rufa, closely related to O. cornuta, is regarded as unsuccessful for orchard pollination because this species exploits much wider range of pollen sources and no pollen preference exists towards fruit trees (Ricciardelli d'Albore et al. 1994).

CONCLUSIONS

Based on the above discussion there seem to be a number of topics that greatly needed intense research in the near future to improve the knowledge on as well as the technology of the insect pollination of crop plants cultivated in temperate zone regions. These are partly related to the pollination requirements of selected crops and to managing some solitary wild bee species for crop pollination. The problems, however, concentrate on the effectiveness of bee visits in the pollination of individual fruit crops (and their different cultivars) and on the reliable estimate of the stocking rates of bees for crop pollination as well as on the management of actual bee density during the flowering period of fruit orchards for optimal controlled bee pollination. The following topics are proposed as the subject of further research in the coming years:

1. Flowers characters and other conditions affecting bee activity
   - Further studies are needed on the flower constancy of honeybees on fruit trees as related to their pollinating efficiency.
   - The pollinating efficiency of honeybees on self-incompatible fruit tree species should be re-evaluated by investigating the gene flow with isozyme markers.
2. Managing wild bees for orchard pollination
   - Further research is needed to develop rearing techniques for commercial usage of the European orchard mason bee, Osmia cornuta, for fruit tree pollination. One other closely related species, Osmia rufa, might be successful for a number of crops under cover.

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ZAPYLANIE DRZEW OWOCOWYCH PRZEZ PSZCZOŁY: OSTATNIE POSTĘPY I PERSPEKTYWY BADAŃ II.

Benedek P.

Streszczenie

Podczas minionej dekady prowadzono wiele szczegółowych badań dotyczących zapylania przez pszczoły drzew owocowych strefy umiarkowanej. Wielki postęp został osiągnięty kiedy odkryto, że kwiaty wielu odmian posiadają cechy oddziałujące na aktywność pszczół miodnych na kwiatach i ich wydajność jako zapylaczy. Odnalezione cechy kwiatów były zdecydowanie różne w przypadku odmian jabłoni i gruszy w poszczególnych latach ale w przypadku niektórych odmian gruszy różnice między kolejnymi latami były większe niż między odmianami w danych latach. Konieczność zapylania przez pszczoły została wyraźnie wykazana zarówno w przypadku obcopylnych jaki i samopylnych odmian owoców. Stopień wierności kwiatowej zbieraczek pszczoły miodnej był różny na poszczególnych gatunkach drzew owocowych ale rola pożytków konkurencyjnych okazała się być mniej szkodliwa niż stwierdzano to wcześniej w literaturze. Jednakże, pewna liczba pytań powstała częściowo w wyniku najnowszych badań nad zapylaniem i częściowo z praktycznych doświadczeń w polowej produkcji roślin. Pytania te wskazują kilka zagadnień do badania, by zrozumieć i rozwiązać problemy prawdopodobnie w najbliższej przyszłości. Koncentrują się one na skuteczności wizyt pszczół w zapylaniu poszczególnych upraw owoców i różnych ich odmian oraz na wiarygodnej ocenie całkowitej liczby pszczół jak również na kontroli zagęszczenia pszczół podczas okresu kwitnienia sadów owocowych dla optymalnego, kontrolowanego zapylania ich przez pszczoły. Dużo mniej wysiłku zrobiono, by wykorzystać rodzime dzikie pszczoły samotnice dla zapylania drzew owocowych, jednakże, niektóre murarki wydają się być odpowiednie do tego w Europie, na Dalekim Wschodzie i Ameryce Północnej.

Słowa kluczowe : zapylanie przez owady, pszczoły miodne, plonowanie owoców w strefie umiarkowanej.