The effect of the limitation of insect pollination period on the fruit set and yield of quince cultivars *(Cydonia oblonga Mill.)*

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Summary: The effect of the partial and/or complete limitation of the insect (bee) pollination period was studied in three consecutive years at 6 quince cultivars. Quince is greatly sensitive to the limitation. Complete limitation of insect pollination resulted in no yield and also a partial limitation of the insect pollination period (exclusion of the bees at the first or at the second half of the blooming) depressed the final set and the yield by 60–70% at least or more, sometimes down to no yield. No real correlation was found between the mean mass of fruits and the fruit set. The mass of fruit seems to be rather a character of the cultivars. A loose but significant correlation was established between the intensity of honeybee visitation and the consequent yield of quince. As much as some 4–5 and 8–10 honeybee visits are needed a day on one flower to achieve the required optimal fruit set that has been declared to be 20–25% for quince in the literature. These are extremely high bee visitation figures, accordingly, no doubt the commercial quince plantations require much higher number of honeybee colonies than other temperate zone fruit tree species to supplementary pollination

Introduction

Quince is a far less important fruit tree species than apple or pear. Its growing area ranges first of all to more Southern latitudes and it is cultivated at much less acreage. For this reason very little attention has been paid so far to understand its pollinating requirements. There are two separate questions in this respect. The first is whether the fruit tree species itself or its cultivars are self compatible that is they can or cannot be pollinated with their own pollen or they are self incompatible and so they need foreign pollen from other cultivars to set fruit? The second question is what is the role of the flower visiting insects in the pollination of the flowers? This question should be put because the maturation of the female and the male sexual organs do not overlap in fruit tree flowers. Anther dehiscence takes place earlier than the stigma becomes receptive within individual flowers and this mechanism usually prevents the automatic self pollination within the same flower. *Nyéki* (1996) has reviewed the world literature on the pollinating requirements of quince and concluded that some quince cultivars were highly self-sterile, other ones were party and some of them were almost completely self-sterile. Thus, the first question can be replied.

As far as the second question is concerned he expresses the opinion that at least as much as 20–25% of the quince flowers have to set fruit to achieve a satisfactory yield because the flower density of quince is much lower than that of other temperate zone fruit tree species. The required set is some 2–2,5 times higher than for apple and pear. On the basis of this statement it seems to be clear that quince needs insect pollination as it has been indicated earlier by *McGregor* (1976).

Simidchiev (1967) has stated that quince was very attractive to honeybees because flowering quince trees were abundantly visited by them. *Benedek, Szabó & Nyéki* (2000) also observed intense bee visitation at quince but their experimental area was highly overpopulated with honeybee colonies. They concluded that the bee visitation was greatly variable but the weather and the nectar production of flowers affected definitely the bee visitation and the foraging behaviour of honeybees at quince flowers. For the variable nature of bee activity they concluded that supplementary bee pollination seems to be indispensable in quince orchards to achieve the required high fruit set.

So there are several indications towards the necessity of insect pollination of quince but no experimental evidence has been available so far on the effect of insect pollination on the fruit set and the yield of that (*Benedek*, 1996).

Accordingly, we have decided to study this problem. Experiments were carried out to explore the effect of the partial and the total limitation of insect pollination period on the fruit set and the yield of quince.

Material and methods

The experiment was carried out at a 1 ha large quince orchard consisting of 15–18 years old trees of a number of cultivars. Six cultivars were selected for observations (*Angersi, Bereczki, Bereczki bőtermő, Champion, Konstantinápolyi, Mezőtúri*). The quince plantation belonged to the Fruit Research Station Ujfehértó (Eastern Hungary). It was surrounded by a number of other fruit tree plantations of different temperate zone fruit tree species, first of all of apple, but for the late flowering time of quince nothing else but some late sour cherry cultivars were in flower (at the very end of their blooming period) at the first part of the blooming period of quince. 4–5 strong bee colonies were moved to the quince plantation prior to its flowering had begun in each year of the research. Also some 30–40 bee colonies were placed at the nearby at the sour cherry plantation mentioned that was 20 ha large. As a result of this the area was well overpopulated with honeybees.

The experiment was repeated in 3 consecutive years, in 1997, 1998 and 1999. Two trees were selected for observation of each of the six cultivars inspected. One with some 50 flowers at the Northern and another at the Southern side of each tree were selected for treatments and measurements. Treatments were applied at both sides of each tree on the selected branches as follows: (1) 0% open (caged) = total limitation of bee pollination, caged with muslin bags during the whole blooming period, (2) 50%open, first = partial limitation, free pollination in the first half of the blooming and caged afterwards with bags of parchment paper, (3) 50% open, second = partial limitation, caged at the first half of the blooming and free pollination afterwards, (4) 100% open = free pollination, no caging. Accordingly, four replicates were applied to each treatment to each of the cultivars investigated (two branches at two trees of each cultivar).

Fruit set was measured three times. The primary set was counted immediately after the petal fall. The counting was replicated after the first drop of fruits and final set was counted late July or early August. Finally, the number of fruits was counted at the time of the harvest. Each fruit on the experimental branches were measured one by one in 1998 and 1999 to calculate their mean mass and also the total yield (g) of the treatments.

Weather conditions during the blooming period of quince were also observed. The weather was fairly good to bee activity in all the three years of the study, however, it was more or less different in the consecutive years.

In 1997: The weather was fairly hot all along the blooming period of quince. Except the first two days of the flowering the daily mean temperatures were around 20 °C and the daily maximums rose up to 30–40 °C. There was very little, practically no rain and it was bright and sunny all along the blooming period of quince.

In 1998: The weather was warm but no so hot as in the previous year. Daily mean temperatures were around 10 or 20 °C and the daily maximums did not surpassed 30 °C except on three days just after the first half of the blooming period. There were three rainy days at the fist quarter of the blooming with fairly good amount of precipitation. It was fairly sunny except some few days at the middle of the blooming period.

In 1999: The weather was warm too but both the daily mean and the daily maximum temperatures remained at a bit lower level than in the previous year. There were few rainy days and no more than one day produced great amount of precipitation in the first quarter and one other day at the very end of the flowering. The weather was usually sunny but there were somewhat less sunny hours at the middle of the flowering.

Honeybee visitation of the trees selected for the experimental treatments was also measured on 3 to 5 days of the blooming period (when the weather was favourable to bee activity). Branches with some 50 flowers were inspected twice a day, late morning (10–12h) and early afternoon (13–15h) for exactly 10 minutes of time each occasion. The mean figures calculated from the bee counts are used in the paper but the detailed results of that have been reported in one another paper (*Benedek, Szabó & Nyéki, 2000*).

Results

1977: Free pollination resulted in a fairly high fruit set (*Table 1*). It was the highest in *Mezőtúri* (44.1%) and the lowest in *Konstantinápolyi* (11.5%). Complete exclusion of bees resulted no fruit set at all at any of the 6 cultivars investigated (*Table 1*). The fruit drop was very low at 5 of the cultivars but it was high at a single variety (*Bereczki*). The set of open flowers was very different of the cultivars. It was low for four cvs (*Konstantinápolyi, Champion, Angersi, Bereczki*) and very high for two ones (*Bereczki bőtermő, Angersi*). Results for the two groups (low and high) were different significantly ($p< 0.01$) but no significant difference was found within the groups. Partial limitation of the bee pollination period (caging at the first or at the second half of the blooming period) drastically affected the set of fruits. Exclusion of bees at the second half of the blooming period (50% second) was resulted in stronger effect at most of the cultivars and it was so strong at some instances that no set and yield detected (at 2 cvs of the six ones) but at two occasions the exclusion of bees at the first half of the blooming (50% first) was the strongest. There was one cultivar (*Champion*) that gave no yield when the bees were excluded in the first or the second half of the blooming period. In fact, the reduction of the fruit set was very strong for the limitation of the insect pollination period at most of the six cultivars but no reduction was detected at a single cvs (*Angersi*) when the bees were excluded at the first half of the blooming (*Table 1*).

Table 1 Fruit set and yield of quince as affected by the effective duration of the insect pollination period (Újfehértó, 1997)

Cultivar	Effective duration of the insect pollination during the blooming period	Primary set immediately after petal fall (n=4)	Set after the first drop of fruit (n=4)	Final set (per cent) (n=4)	No of fruits from 100 flowers (n=4)
Agersi	(1) 0%open (caged) (2) 50%open (first) (3) 50%open (smecond) (4) 100%open	0 27.0±8.9 1.7±1.7 17.9±6.9	0 19.9±6.3 1.7±1.7 14.9±7.1	0 19.9±6.3 1.7±1.7 14.9±7.1	0 15.8±4.1 1.7±1.7 14.9±7.1
Bereczki	(1) 0%open (caged) (2) 50%open (first) (3) 50%open (second) (4) 100%open	0 2.3±2..3 4.4±4.4 46.7±7.8	0 0 2.9±2.9 17.0±3.6	0 0 2.9±2.9 16.6±3.3	0 0 2.9±2.9 16.6±3.3
Bereczki bőtermő	(1) 0%open (caged) (2) 50%open (first) (3) 50%open (second) (4) 100%open	0 7.5±3.6 14.4±5.6 47.7±5.0	0 6.4±2.7 4.5±3.0 37.5±3,1	0 6.4±2.7 4.5±3.0 37.5±3.1	0 6.4±2.7 3.1±3.1 36.9±3.1
Champion	(1) 0%open (caged) (2) 50%open (first) (3) 50%open (second) (4) 100%open	0 0 0 15.3±4.2	0 0 0 13.7±4.2	0 0 0 13.7±4.2	0 0 0 13.7±4.2
Konstantiná-polyi	(1) 0%open (caged) (2) 50%open (first) (3) 50%open (second) (4) 100%open	0 1.2±1.2 0 10.7±5.2	0 1.2 ±1,2 0 11.5±3,4	0 1.2±1.2 0 11.5±3.4	0 1.2±1.2 0 11.5±3.4
Mezőtúri	(1) 0%open (caged) (2) 50%open (first) (3) 50%open (second) (4) 100%open	0 4.1±2,6 20.0±5.8 50.4±8.3	0 2.7±1,6 17.4±6.1 44.1±7.2	0 2.7±1.6 17.4±6.1 44.1±7.2	0 2.7±1.6 15.8±4.7 44.1±7.2

Explanation:

(1): 0% open (caged) = caged during the whole blooming
(2): 50% open (first) = open in the fist half, caged during the second half of blooming
(3): 50% open (second) = caged in the first half, open during the second half of blooming
(4): 100% open = no caging, open pollination

1998: Fruit set from free pollination was the highest in *Angersi* (17.4%) and the lowest in *Bereczki bőtermő* (2.6%). Complete limitation of bee pollination was resulted in no yield and free pollination also produced smaller set than in the previous year (*Table 2*) except at one cvs (*Angersi*) the set of that was a bit higher. Partial limitation of the bee pollination period both at the first and the second half of the blooming period completely prevented the fruit set at many cases (at 4 cvs of the 6 ones) or was resulted in a very small set compared to the open pollination (2 cvs of the 6 ones). The exclusion of the bees in the first half of the pollination period reduced the set at a much greater extent than the exclusion in the second half (*Table 2*). Also the yield (mass of fruits set at 50 flowers) reflected the differences found in the final fruit set (*Table 4*). Much stronger fruit drop was detected between the initial and the final fruit set in case of some cultivars (*Konstantinápolyi, Champion*) than of others (*Table 2*). No relationship was detected between the fruit set (%) and the mean mass of individual fruits (*Table 2*). The mean mass of fruits was negatively correlated to the final set at the branches, because fruits were smaller as the set was greater ($r = -0.57$, $p < 0.1$, $n = 9$).

1999: Final fruit set at free pollination was as moderate as in the previous year (*Table 3*). That was the greatest of *Bereczki bőtermő* (15.8%) and the smallest of *Bereczki* (1.9%). Complete limitation of insect pollination gave no yield at all at any of the cultivars (*Table 3*). Also the exclusion of bees during the first half of the blooming period (50% first) was of a detrimental effect on the fruit set but the limitation of the bee pollination in the second half of the flowering was resulted in some yield at most cases. The final set, however, was not more than some 1/3 of the same for open pollination at any of the cultivars inspected (*Table 3*). There were few cultivars only the effect of the limitation of the bee pollination period in the first and the second part of blooming can be compared to each other. The effect was stronger at all the four cases when the bees were excluded during the first half of the flowering (*Table 3*).

The yield on the branches investigated was completely proportional with the final fruit set (*Table 4*). The coefficient of correlation between the fruit set and the mean mass of fruits was not significant at all ($r = -0.025$, $p < 0.9$, $n = 9$). Thus the mean mass of the fruits did not show any relationship to the fruit set. It seemed to be rather different at

Table 2 Fruit set and yield of quince as affected by the effective duration of the insect pollination period (Újfehértó, 1998)

Cultivar	Effective duration of the insect pollination during the blooming period	Primary set immediately after petal fall (n=4)	Set after the first drop of fruit (n=4)	Final set (per cent) (n=4)	No of fruits from 100 flowers (n=4)	Mass of a single fruit (g)
Agersi	(1) 0% open (caged) (2) 50% open (first) (3) 50% open (second) (4) 100% open	7.5±2.6 12.3±5.7 12.3±4.3 39.6±4.6	0 5.5±3.2 9.2±8.1 26.4±5.0	0 1.5±1.5 5.7±2.0 17.4±0.4	0 1.5±1.5 5.7±2.0 17.4±0.4	– 152 (n=1) * 141±8 (n=43)
Bereczki	(1) 0% open (caged) (2) 50% open (first) (3) 50% open (second) (4) 100% open	0 1.8±1.8 3.2±2.1 14.0±0.2	0 1.8±1.8 3.2±2.1 6.0±3.5	0 1.8±1.8 2.3±2.3 6.0±3.5	0 1.8±1.8 2.3±2.3 6.0±3.5	– 245 (n=1) 278 (n=1) 282±23 (n=9)
Bereczki bőtermő	(1) 0% open (caged) (2) 50% open (first) (3) 50% open (second) (4) 100% open	0 0 0 3,9±1,6	0 0 0 2,6±1,4	0 0 0 2,6±1,4	0 0 0 625±296	– – – 359±32 (n=6)
Champion	(1) 0% open (caged) (2) 50% open (first) (3) 50% open (second) (4) 100% open	3.3±3.3 4.8±4.8 4.1±2.6 23,0±8.0	0 0 0 7.0±3.4	0 0 0 6.5±3.6	0 0 0 6.5±3.6	– – – 211±26 (n=9)
Konstanti-nápolyi	(1) 0% open (caged) (2) 50% open (first) (3) 50% open (second) (4) 100% open	2.5±2.5 0 1.5±1.5 14.3±0.9	0 0 0 9.0±1.5	0 0 0 4.5±1.5	0 0 0 4.5±1.5	– – – 137±14 (n=13)
Mezőtúri	(1) 0% open (caged) (2) 50% open (first) (3) 50% open (second) (4) 100% open	1.5±1.5 3.0±3.0 6.7±0.6 14,0±7.0	0 1.5±1.5 5.1±1.8 14,0±7.0	0 0 0 13.3±6.1	0 0 0 13.3±6.1	– – – 85±18 (n=28)

Explanation:

(1): 0% open (caged) = caged during the whole blooming
(2): 50%open (first) = open in the fist half, caged during the second half of blooming
(3): 50%open (second) = caged in the first half, open during the second half of blooming
(4): 100%open = no caging, open pollination
* = destroyed

the cultivars than for the extent (per cent value) of the final set (*Table 3*).

Relationship between the honeybee activity and the fruit set: Mean numbers of honeybees visiting 50 opening flowers at the cultivars and the average numbers of flowers visited by them at the branches were related to the mean figures of the initial and the final fruit set at the open pollinated branches of the same cultivars. Bee visitation figures were taken from one another paper reporting on the activity of honeybees at quince flowers as observed at the same plantation and at the same time when the bagging experiment were made (*Benedek, Szabó & Nyéki,* 2000). All the mean figures from the three years of the experiment were treated together. There was a positive but loose correlation between the number of honeybee visits and the fruit set (*Table 5*). The correlation was somewhat better expressed for the initial than for the final set showing that the latter was also affected by a number of factors other than the honeybee visits at the flowers of the trees at the blooming period only. The correlation between the fruit set and number of flowers visited by bees at the branches during the flowering period was even less well expressed than with the number of honeybees visiting the branches (*Table 5*).

Discussion and conclusions

Results clearly show that quince is greatly sensitive to the limitation of the insect pollination period (this is valid to all the 6 cultivars tested). It is much more sensitive to that than some other important temperate zone fruit tree species, apple, pear, sour cherry and plum (c.f. *Benedek & Nyéki,* 1996a, 1996b, *Benedek et al.,* 2000). Accordingly, our result has clearly proved the earlier believes of *McGregor* (1976) who has supposed that bee activity was important at quince to set fruit. No doubt any more that the insect pollination, first of all the activity of honeybees on quince flowers, is absolutely indispensable to he fruit set. Complete limitation of the bee pollination was resulted in no yield and also the partial limitation of the insect pollination period was detrimental because the final set and the yield was depressed

Table 3 Fruit set and yield of quince as affected by the effective duration of the insect pollination period (Újfehértó, 1999)

Cultivar	Effective duration of the insect pollination during the blooming period	Primary set immediately after petal fall (n=4)	Set after the first drop of fruit (n=4)	Final set (per cent) (n=4)	No of fruits from 100 flowers (n=4)	Mass of a single fruit (g)
Agersi	(2) 50% open (first)	0	0	0	0	–
	(3) 50% open (second)	0	0	0	0	–
	(4) 100% open	14.85±3.73	13.8±3.21	13.4±2.72	12.85±2.3	234±10 (n=24)
Bereczki	(1) 0% open (caged)	0	0	0	0	–
	(2) 50% open (first)	0	0	0	0	–
	(3) 50% open (second)	0	0	0	0	–
	(4) 100% open	4.74±2.23	1.87±1.08	1.87±1.08	1.87±1.08	459±11 (n=4)
Bereczki bőtermő	(1) 0% open (caged)	0	0	0	0	–
	(2) 50% open (first)	11.5±4.72	3.85±2.0	3.85±2.0	3.85±2.0	167±23 (n=2)
	(3) 50% open (second)	12.8±2.063	6.08±3.52	6.08±3.52	6.08±3.52	245±48 (n=4)
	(4) 100% open	21.0±2.77	15.82±3.19	15.82±3.19	15.82±3.19	215±10 (n=32)
Champion	(1) 0% open (caged)	0	0	0	0	–
	(2) 50% open (first)	3.33±3.33	0	0	0	–
	(3) 50% open (second)	5.0±2.18	3.72±2.51	3.72±2.51	3.72±2.51	*
	(4) 100% open	15.92±2.44	12.42±2.74	12.42±2.74	12.42±2.74	*
Konstanti-nápolyi	(1) 0% open (caged)	1.05±1.05	0	0	0	–
	(2) 50% open (first)	1.47±1.47	0	0	–	–
	(3) 50% open (second)	3.25±3.25	3.25±3.25	3.25±3.25	3.25±3.25	163±17 (n=3)
	(4) 100% open	12.2±2.92	10.73±3.64	10.25±1.5	10.25±1.5	187±7 (n=20)
Mezőtúri	(1) 0% open (caged)	2.47±1.18	0	0	0	–
	(2) 50% open (first)	0	0	0	0	–
	(3) 50% open (second)	6.55±2.95	4.17±1.45	2.97±1.74	2.97±1.74	175±50 (n=2)
	(4) 100% open	13.5±5.32	13.5±5.32	10.7±4.07	10.7±4.07	164±11 (n=21)

Explanation:

(1): 0% open (caged) = caged during the whole blooming
(2): 50% open (first) = open in the fist half, caged during the second half of blooming
(3): 50% open (second) = caged in the first half, open during the second half of blooming,
* = destroyed

by at least 60–70% or more, sometimes down to 100% (no yield) (*Tables 1–3*). So intensive bee visitation is vitally important during the whole blooming period of quince.

Mean mass of fruits seemed to be negatively correlated to the fruit set in one year but no reliable relationship between the set and the fruit weight was established in the other year. So, the mean weight of fruits seemed to be rather a variety character than the result of the extent of the fruit set. The significant relationship observed in one of the years, however, showed that this relationship also could occur, probably first of all in those years when the per cent ratio of the fruit set was greater than in the two years when it has been observed in this study. At most of the cases (8 of the 11) the reduction of the fruit set and the yield was the greatest when the bee pollination was prevented at the first half of the blooming period (50% first in *Tables 1–4*) than at the second half of it (50% second), but at other instances (3 of the 11) the opposite happened. So the limitation of the insect pollination period tends to have a somewhat greater impact on the set and the yield in the first half of the blooming as it has been indicated at other fruit tree species, earlier (*Benedek & Nyéki,* 1996b). However, this tendency can not be observed at each occasion probably for the impact of the changing weather.

Very intense bee visitation was detected in the experimented quince orchard because both the orchard and its close vicinity was greatly overpopulated with honeybee colonies as reported in one another paper (*Benedek, Szabó & Nyéki,* 2000). In spite of this fact, much less fruit set was observed at the most cases than the required 20–25% set (*Tables 1–3*) that was the condition of a good yield at quince as having been indicated by *Nyéki* (1996). A loose but significant correlation was established between the fruit set of quince and the intensity of honeybee visitation (*Table 5*). The coefficients of the correlations were significant (except one single case), so the equations can be used for orientation. Based on the calculations with the equations as much as some 5.2–7.4 honeybees and even more flower visits at 50 flowers in 10 minutes can promote as high initial set as 20 – 25% and much more can result in 20–25% final fruit set (*Table 5*). These bee visitation figures equal to 4–5 and 8–10 honeybee visit per flower per day to achieve the required 20–25% initial or final set, respectively! These were extremely high bee visitation figures that we were unable to

Table 4 Yield of quince as affected by the effective duration of the insect pollination period (Újfehértó, 1998–1999)

Cultivar	Effective duration of the insect pollination during the blooming period	Yield from 50 flowers (g) (n = 4, per treatment) 1998	1999
Agersi	(1) 0% open (caged) (2) 50% open (first) (3) 50% open (second) (4) 100% open	0 98±98 0 1529±215	0 0 0 1411±247
Bereczki	(1) 0% open (caged) (2) 50% open (first) (3) 50% open (second) (4) 100% open	0 61±61 320±320 777±449	0 0 0 269±208
Bereczki bőtermő	(1) 0% open (caged) (2) 50% open (first) (3) 50% open (second) (4) 100% open	0 0 0 625±296	0 80±80 245±156 1721±501
Champion	(1) 0% open (caged) (2) 50% open (first) (3) 50% open (second) (4) 100% open	0 0 0 474±229	0 0 * *
Konstanti-nápolyi	(1) 0% open (caged) (2) 50% open (first) (3) 50% open (second) (4) 100% open	0 0 0 445±98	0 0 122±122 991±351
Mezőtúri	(1) 0% open (caged) (2) 50% open (first) (3) 50% open (second) (4) 100% open	0 0 0 816±339	0 0 88±55 911±313

Explanation:

(1): 0% open (caged) = caged during the whole blooming
(2): 50%open (first) = open in the fist half, caged during the second half of blooming
(3): 50%open (second) = caged in the first half, open during the second half of blooming,
* = destroyed

Table 5 Relationship between the number of honeybee visits and the fruit set of quince (Újfehértó, 1997–1999)

Honeybee activity at 50 opening flowers in 10 minutes		Relationship between the initial fruit set (per cent) and the honeybee activity	Relationship between the final fruit set (per cent) and the honeybee activity
Number of honeybees visiting the 50 flowers		**r = 0.52 n = 18 p<0.02 y = 8.0 + 2.3x**	**r = 0.38 n = 18 p<0.1 y = 7.3 + 1.2x**
Number of flowers visited by bees of the 50 ones		**r = 0.44 n = 18 p<0.05 y = 11.9 + 0.9x**	**r = 0.32* n = 18 p>0.1* y = 89.2 + 0.5x***
Required figures to achieve 20% fruit set	No. of bees visiting 50 flowers	**5.2**	**10.6**
	No. of flowers visited of the 50 bees	**9.0**	**21.6**
Required figures to achieve 25% fruit set	No. of bees visiting 50 flowers	**7.4**	**14.8***
	No. of flowers visited of the 50 bees	**14.5**	**31.6***

***not significant**

achieve at our experimental plantation, however, it was overpopulated with honeybees. Accordingly, no doubt the commercial quince plantations require much greater number of honeybee colonies to supplementary pollination than generally recommended to other temperate zone fruit tree species.

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