# The effect of rootstock on the nectar production of apple cultivar 'Idared'

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**Nagy Tóth E.[1] and Orosz-Kovács Zs.[2]**

[1]*Berzsenyi Dániel Teachers' Training College, Department of Botany, Szombathely*
[2]*Janus Pannonius University, Department of Botany, Pécs*

***Key words:*** apple, nectar, periodicity

***Summary:*** Approaches based on the daily rhythm of apple flowers provide a new stage in nectar research, where the synchronous functioning of sexual organs is studied. In the flower biological studies the insect attraction of flowers was also studied. The two most important factors of insect attraction are the pollen- and nectar production of the flowers. From 1993 to 1998 we studied the food, that flower had to offer for the pollinating insects at different times of the day.
Studies were carried out on *'Idared'*, one of the hybrids of *'Jonathan'* apple cultivar. The fruit of *'Idared'* is bigger than the fruit of *'Jonathan'*. It is bright red, transportable, has a bigger productivity and is not subject to Jonathan-spots. Concerning its inner characteristics, it is juicy, the flesh consistency is better than that of *'Jonathan'*, but its acid/sugar ratio is worse *(Sansavini* et al. 1981).

## Introduction

The 24-hour nectar production of apple flowers was studied by a number of researchers. According to *Gluhov* (1955) 0.025mg nectar is produced per flower. According to *Sazikin* (1955) an apple flower may produce 3–8 mg nectar during a day.

Based on studies on nectar production of 12 apple cultivars *Szimidcsiev* (1971) claims that the quantity of nectar secreted by one flower during 24 hours is 0.784–3.23 mg in average at the different cultivars. He also described that apple cultivars produce a significant amount of nectar at night, as well.

*Maurizio* (1960) states that apple is an excellent nectar- and pollen producer. According to the studies of *Maurizio & Grafl* (1982) apple flowers produce 2–6 mg nectar.

According to *Crane* (1984) the flowers of various apple cultivars secrete 3.2–7.0 mg nectar daily.

Studying the nectar production of *'Idared'* and *'Wellspur'* apple cultivars, *Krlevska* et al. (1995) claims that a flower produces 2.3–2.7 µl nectar during 24 hours. On the basis of nectar production it was estimated that 35-84 kg nectar and 13.8–32 kg honey per hectare could be expected.

According to *Beutler* (1941) the sugar value of apple nectar is 0.7 mg, according to *Livenceva* (1954) it is 0.41, whereas *Mommers* (1966) calculated 0.584-–0.876 mg for the sugar value of *'Jonathan'* and 0.913 mg for *'Golden Delicious'*, based on his measurements. According to *Simidchiev* (1971) the sugar quantity is 0.408–1.432 mg.

According to *Gluhov* (1955) the dry matter content of apple nectar is about 20–40%. *Vansell* (1952) measured a refraction of 50% at apple. According to the investigations of *Rimasevskij* (1957) the sugar percentage of apple nectar varies between 37–55.7%, whereas *Szimidcsiev* (1971) measured 35.06–56.24%.

According to *Maurizio & Grafl* (1982) sugar refraction varies between 30–65%. In extreme conditions, as e.g. in Israel 87% was measured.

*Crane* (1984) found apple nectar with as high as 30–65% sugar content too. According to *Krlevska* et al. (1995) the dry matter content of nectar varied between 30.5–30.8%.

In Hungary *Halmágyi & Suhayda* (1966) reported 1.0–1.5kg increase in weight per bee family in average years and 2–3kg increase in weight in good years in the apple orchard.

*Szilva* (1969) listed apple as one of the medium-level honey-bearing plants. The flowering period of cultivars studied by *Péter* (1972) lasted for 10–14 days. He measured 1.02 mg nectar with 40–44% (0.4 mg) sugar value in *'Asztraháni piros'* and 1.25 mg nectar with 45.71% (0.6 mg) sugar value in *'Jonathan'*.

*Soltész* (1982) measured 250–300 mg nectar in 100 flowers and the sugar value was 80–120 mg/100 flowers in the average of the cultivars. According to the 1977–1980 investigations of *Soltész* et al. (1983) nectar production was 2.5–3 mg per flower. Differences between cultivars could be detected mainly in sugar value.

*Gulyás* et al. (1989) measured an average of 2–5 mg nectar in the flowers of apple cultivars in the Nyírség region of Hungary. Among the cultivars '*Mutsu*' and '*Jonagold*' proved to be the best nectar producers. According to the above authors these apple cultivars secrete twice as much nectar than locust. The worst nectar producers were '*Idared*' and '*Golden Delicious*' with 2.14–2.93 mg nectar. The sugar percentage varied between 23–29%.

According to *Benedek, Soltész, Nyéki & Szabó* (1989), the nectar production of apple in the rare cultivars or in cultivar collections is poor, whereas in widespread commercial cultivars as e.g. '*Jonathan*' and '*Starking*' it is good or at least medium. '*Idared*' and '*Golden Delicious*' were also classified as cultivars with medium nectar production.

According to *Davary-Nejad, Szabó, Nyéki & Benedek* (1993) nectar production displays a great degree of fluctuation. The highest fluctuation was found in cv. '*Red Jonagold*', which produced 8.9 mg nectar per flower in one year and 3.4 mg in the other. It was also observed that large amounts of nectar occurred with low values of refraction.

*Benedek* et al. (1990) stated that there is a positive correlation between the daily nectar production of flowers and the sugar value of nectar, whereas a negative correlation exists between the quantity of nectar and sugar concentration. *Benedek, Soltész, Nyéki & Szabó* (1989) (1993) justified the negative correlation (r=-0.562) between quantity of nectar and sugar concentration and the positive correlation (r=0.72) between quantity of nectar and sugar production *(Benedek & Nyéki*, 1994).

According to *Soltész* (1996) among apples the triploid flowers produce more nectar than the diploid ones.

According to the investigations of *Péter* (1972) and *Gulyás* (1975) nectar production is largely influenced by air humidity, air temperature and cloudiness.

According to *Polevoj* (1981) *& Zauralov* (1986) the quantity and composition of nectar is determined by the genetic characteristics of the plant together with the outer environmental factors.

Several researchers observed the continuity or periodicity of nectar production. On the basis of the rhythmicity of nectar secretion *Beutler* (1953) classified plants into four groups:

1. nectar production is continuous during the whole day
2. the sugar value has a daily maximum
3. the quantity of nectar has a daily maximum
4. the quantity and quality of nectar have a maximum together.

The periodicity of nectar production was also observed by *Maurizio* (1960). According to him the peak in production differs from species to species.

*Shuel* (1961) *& Lüttge* (1971) supposed that nectar production is regulated by hormones. According to *Zauralov* (1986) in the majority of plants the maximal nectar secretion in flowers is synchronous with the maturing of the reproductive organs, pollen and egg.

*Kartasova* (1965) also formed several groups on the basis of the daily rhythm of nectar production and the opening of the flower.

1. Flowers opening in the morning (before 9 o'clock) – the most nectar can be found in the morning hours (e.g. *Tilia cordata, Lamium album, Prunella vulgaris*)
2. Flowers producing the most nectar in day-time (e.g. *Phacelia tanacetifolia*)
3. Flowers having two secretory maxima: one in the morning, one in the evening (e.g. *Caragana frutescens, Lathyrus pratensis, Vicia cracca, Pulmonaria molissima, Trifolium pratense*)
4. The maximal nectar production occurs in the evening hours (e.g. *Lythrum salicaria, Polemonium coeruleum*).

The rhythm of nectar secretion in fruit cultivars is less known. *Szimidcsiev* (1971) studied the daily rhythm of secretion in several fruit species, e.g. sour cherry cultivars in 1971. He took samples every two hours and for this reason he could not precisely determine the production peaks. He also observed that a significant amount of nectar was produced in the flowers at night as well.

From the Hungarian researchers, similarly to *Szimidcsiev* (1971), *Pesti* (1976) also studied the daily rhythm of nectar secretion in *Compositae* species in every two hours, and he claimed that the periodicity of nectar secretion is of endogenous origin, not influenced significantly by environmental factors and the daily rhythm is characteristic of the subfamilies in *Compositae*.

*Cruden* et al. (1983) studied the nectar secretion of some flowers with tubular corolla in Mexico. At several species the degree of nectar secretion was constant until a critical point, then stopped. At *Caesalpinia pulcherrima* the secretion was continuous during the whole day. The above authors formed 3 groups on the basis of the beginning and degree of nectar secretion:

1. Nectar secretion is slow: they secrete 5–10% of the maximal value of the secretory product in every hour. The nectary of the slow producers is always covered, protected by the perianth.
2. Fast: they secrete 22–68% of the maximal value of nectar hourly
3. Super producers: they secrete as much nectar as the fast producers during 2-3 hours.

*Cruden* et al. (1983) reported the delay of nectar secretion, where after a cool dewy night the plant started to secrete 1–1.5 hour later than after a dry warm night.

*Belmonte* et al. (1994) found nectar secretion mainly after the opening of the anthers at species of the *Bignoniaceae* family.

*Kartasova* (1965) studied the nectar secretion of some *Rosaceae* species and stated that the most nectar can be found in the flower when the anthers are opening. Also within the *Rosaceae* family, *Orosz-Kovács* (1988, 1989, 1990/a, b, 1991, 1992), *Orosz-Kovács* et al. 1987, *Orosz-Kovács* et al. 1988, *Orosz-Kovács* et al. 1989, *Orosz-Kovács, Faust, Nyújtó & Erdős,* 1993) described the secretory rhythm of *Prunoideae* taxa. According to them taxa with homogamous flowers secrete in every 6 hours synchronously with the function of the reproductive organs, whereas the secretory maximum of dichogamous flowers could be observed every 12 hours, related to the functioning ability of the sexual organs. They also described a form of partial dichogamy: the delayed homogamy at sour cherry cultivars. They carried out their studies for 24–48 hours.

Based on our previous investigations *(Orosz-Kovács* et al, 1991, *Orosz-Kovács* 1989, *Nagy Tóth* 1991, 1994) the maxima in production could be observed in every 4 hours at the apple cv. *'Richared Delicious'*, both at night and during the day. The maxima of nectar production occurred at 2, 6, 10, 14, 18 and 22 o'clock, which were preceded by an hour by the maxima of anther opening.

The effect of the rootstock on the nectar production of apple cultivars was not studied a lot. According to *Nagy-Tóth* (1991) the influence of the rootstock on nectar production depends greatly on the characteristics of the engrafted cultivar on the rootstock. Based on her studies at *Érsekhalma*, most studied cultivars produced the most nectar on the rootstocks *M.9, M.26* and *MM. 104*.

*Gulyás, N. Bíró & Molnár* (1989) concluded from their studies that the more vigorous rootstocks produce more nectar.

According to the studies of N. *Bíró & Gulyás* (1990) in the Nyírség, more nectar is produced on rootstock MM.106 than on M.9.

## Material and method

The floral secretion of the apple cultivar *Idared* on various rootstocks was studied from 1994 to 1998 at the Research and Extension Centre for Fruitgrowing, Újfehértó. The selected rootstocks were *M.9, M.4, M.26* and *MM.106*. The orchard had been planted in 1980-88. The soil is multilayered sand, with a strongly acidic pH. The daily fluctuation of temperature is 6,1C in January and 13.1C in July. The average annual precipitation is 583 mm. The average number of sunny hours is 2000.

The nectar measurement following the 24-hour isolation was carried out by the internationally known and applied methodology *(Demianowicz & Hlyn,* 1960). Using this method our results can be compared with the results of other researchers. However the 24-hour isolation does not give the real parameters of the secretory product that is offered for insects in the flower at a given time, since the nectar becomes concentrated during this period. Nectar may only stay in the flower for 24 hours in the case of cool weather, when the insects do not visit them, but the secretory product can also be retracted. This method can show to the bee-keepers how much honey can be expected, but does not answer the question whether bees can find the food sweet enough during the day or at different stages of blooming and whether they can be expected at all to visit the flowers, i.e. whether the nectar refraction reaches the threshold of bee visits (10%) or to what degree the quantity and refraction of nectar differs at the various cultivars in the given cultivar combinations.

For this reason we also studied the hourly nectar production of the same numbered flowers. Nectar was sucked out of the flowers and its volume was measured by calibrated microcapillaries and refraction was determined by a refractometer. The calculation of sugar value slightly differs from earlier data in literature, because here the volume (µl × refraction % / 100) formula was used, according to *Cruden & Hermann* (1983), instead of the well known mass (mg × refraction % / 100) formula.

## Results

Based on the measurements following the 24-hour isolation it can be stated that the apple cv. *Idared* produced nectar of sufficient amount and good quality in all rootstock combinations in the studied period *(Table 1)*. From an apiarist's point of view the cultivar produced a very significant amount of sugars.

The average sugar value of 1995–1998 shows the influence of rootstocks better. Nectar with highest sugar value (1.12 mg/flower) was produced by *'Idared'* on rootstock *M.4*. Similarly good quality nectar was secreted on *M.9* (1.09 mg). The sugar value of nectar is slightly lower, but still very good (0.99 mg) on *M.26* and finally, the lowest sugar value (0.65 mg) was produced on *MM.106*.

In 1995 and 1997 as a result of the satisfactory, rainy weather in spring nectar production was also abundant. In 1996 and 1998 however the effect of the drier spring could be observed in the quantity of the floral secretory product too, the production decreased by half at some rootstock combinations *(Figure 1–2)*. Refraction was usually higher in the drier years, so there are no significant fluctuations in sugar value.

Comparison of apple cultivars was made in the same stage of blooming (pollen shedding). Having studied the

***Table 1*** Nectar production of apple cv. Idared between 1994–1998

| Cultivar | 1994 | | | 1995 | | | 1996 | | | 1997 | | | 1998 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | nectar/ refr. /sugar | | | nectar/ refr. /sugar | | | nectar/ refr. /sugar | | | nectar/ refr. /sugar | | | nectar/ refr. /sugar | | |
| | µl | % | mg | µl | % | mg | µl | % | mg | µl | % | mg | µl | % | mg |
| Idared M.4 | | | | 4.54 | 20.6 | 0.93 | 3.1 | 40.3 | 1.24 | 4.9 | 26.8 | 1.31 | 3.5 | 29.0 | 1.01 |
| Idared M.9 | | | | 4.68 | 20.4 | 0.95 | 2.68 | 33.1 | 0.88 | 5.7 | 23.8 | 1.35 | 2.27 | 35.2 | 0.79 |
| IdaredM.26 | | | | 5.18 | 23.3 | 1.2 | 4.33 | 34.4 | 1.48 | 4.8 | 20.5 | 0.98 | 1.71 | 41.3 | 0.7 |
| Idared MM.106 | 1.56 | 44.25 | 0.69 | 2.46 | 23.5 | 0.57 | 1.97 | 23.4 | 0.46 | 1.38 | 28.1 | 0.38 | 3.48 | 35.2 | 1.22 |

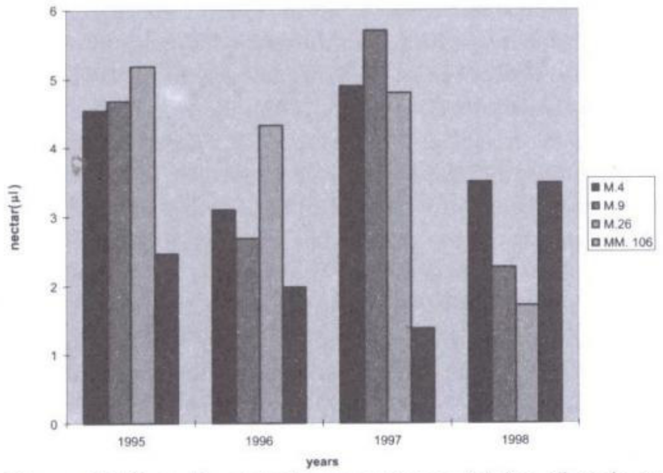



*Figure 1* Effect of rootstocks on nectar produktion of apple cv. Idared (1994–1998)

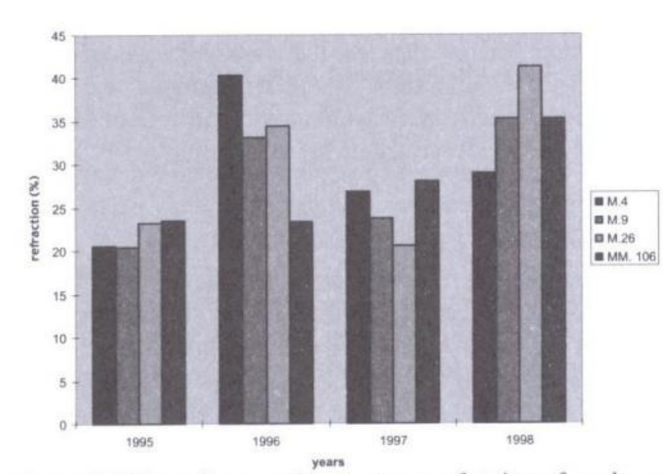



*Figure 2* Effect of rootstocks on nectar refraction of apple cv. Idared (1994–1998)

insect attraction of flowers with focus on the rootstock, the following observations can be made.

Based on studies of nectar production in apple cv. '*Idared*' for 4 years on 4 rootstocks: the quantity of nectar was the highest in 1995 (5.18 µl) and in 1997 (5.7 µl) in connection with the more favourable rain conditions (except for rootstock *MM.106*). The nectar in flowers of trees grown on rootstock *M.26* was between 4.33–5.18 µl in the first three years, which means a very good production, whereas in 1998, being a drier year the least (1.71 µl) secretory product was produced on this rootstock. Refraction was the highest in 1996 and 1998 around 30–43% related to the decrease in the amount of nectar. Having studied the four rootstocks it can be stated that the quantity of the secretory product was the most balanced (3.1–4.9 µl) in the flowers of trees on rootstock *M.4*, which may be related to the fact that M.4 is more drought-resistant. The quantity and refraction of nectar of plants on rootstock *MM.106* was also fairly balanced, while the nectar production in flowers of trees on the other two rootstocks fluctuated to a great degree in different years *(Figure 1)*.

In favourable weather bees visited the flowers of *'Idared'* well on all four studied rootstocks. The reason for this may be that the quantity of nectar can be four or five times higher than that of locust-tree. Also refraction exceeds 10%, the threshold value of bee visitation being about 20% or even higher, which is very attractive for bees *(Figure 2)*. Another advantage of the cultivar is its early blooming, because at this time other apple cultivars do not start blooming yet. Consequently there is not a wide choice for bees and they also collect the more diluted secretory product.

During measuring nectar production, following the 24-hour isolation, differences can be rather big if the nectar samples were collected at various times during the day. At certain times of the day the flowers are empty, at other times however a significant amount of nectar gathers in them.

If nectar is sucked out of the same flowers and measured every hour, the periodicity of secretion can be observed on the basis of which there are differences concerning each rootstock.

*Nagy Tóth* (1991), *Orosz-Kovács* et al. (1991), *Szabó-Mühlenkampf* (1994) observed that the majority of apple cultivars produced nectar at more or less regular intervals. These studies were carried out in *Érsekhalma*, where the climate was much drier than in the Nyírség. It was stated that nectar secretion of apple cultivars is periodical, nectar being produced every 4 hours in most cases or rarely (in too hot weather) every 2–3 hours. Among the peaks of production, secretion ceased completely or only a minimal amount of nectar was produced.

In 1994 the hourly average nectar secretion of '*Idared*' on rootstock *M.9*, having delayed homogamous flowers was nearly continuous almost the whole day from 1pm with a 1 pm peak at the beginning of blooming. The peaks in anther opening could be observed at at 10 am, 1 pm and 3 pm, and at 18 o'clock a smaller scale pollen shedding began. During the main blooming period nectar secretion was also protracted and irregular: two protracted production peaks could be observed at 10–12 am and 4–5 pm. Secretion was quite scarce almost the whole day, so the cultivar ensures a weak but continuous attraction for pollinating insects. Anthers were opening continuously all day, from the noon hours until 6 pm *(Figure 4 and 6)*. '*Idared*' on *MM.106* showed a very regular secretory rhythm this year. The peaks of nectar production occurred at at 10 am, 2 pm and 7 pm, at

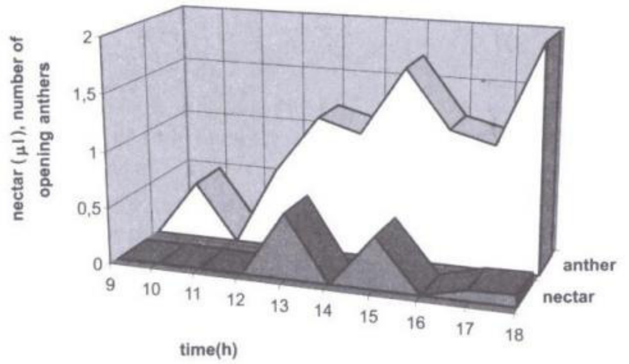



*Figure 3* Hourly mean nectar production and anther dehiscence of apple cv. Idared on rootstock M.4 Újfehértó, 20.04.1994., beginning of bloom

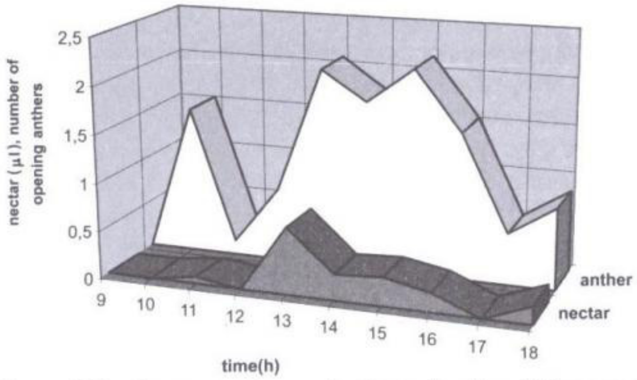



*Figure 4* Hourly mean nectar production and anther dehiscence of apple cv. Idared on rootstock M.9 Újfehértó, 20.04.1994., beginning of bloom

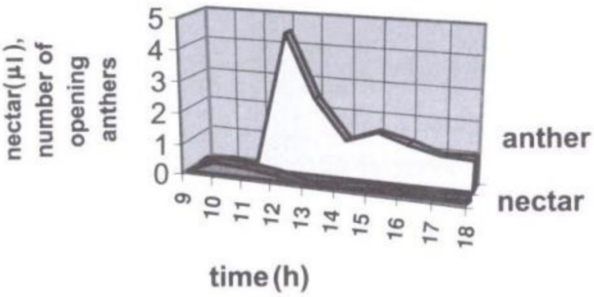



*Figure 5* Hourly mean nectar production and anther dehiscence of apple cv. Idared on rootstock M.4 Újfehértó, 20.04.1994., full bloom

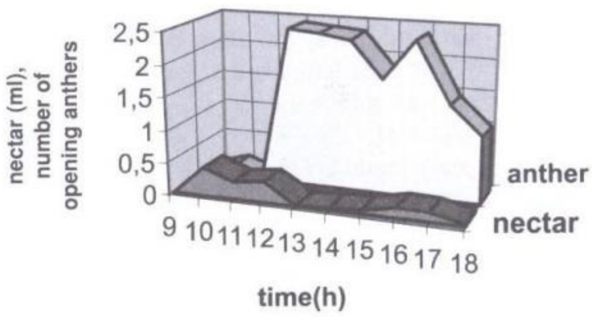



*Figure 6* Hourly mean nectar production and anther dehiscence of apple cv. Idared on rootstock M.9 Újfehértó, 20.04.1994., full bloom

regular 4–5-hour intervals, but secretion was continuous from 9 am to 5 pm *(Figure 6/a)*.

Floral nectar secretion of *'Idared'* on *M.4* could be observed at 1 pm, 3 pm and 5–6 pm at the beginning of blooming. The opening of anthers preceded the beginning of secretion at 10 o'clock, then a double peak could be seen at 1 and 3 pm finally at 5–6 pm. In the main blooming period there was little secretion all day (with a break at 1–2 pm), which ensures a continuous insect attraction and is advantageous in attracting pollinating insects *(Figure 3 and 5)*.

In 1995 the nectar secretion of *'Idared'* on *M.4* showed a fairly regular rhythm: with smaller peaks at 9 am, 1 pm and

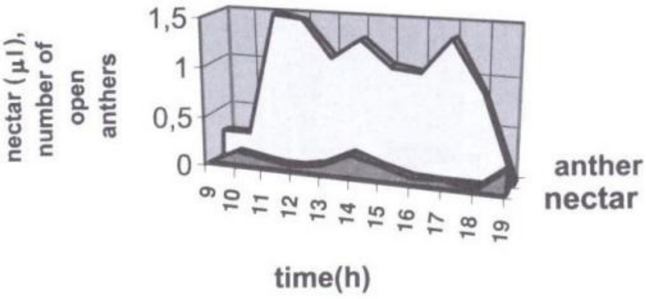



*Figure 6/a* Hourly mean nectar production and anther dehiscence of apple cv. Idared on rootstock M.106 Újfehértó, 20.04.1994., full bloom

between 5–6 pm. Opening of anthers shows peaks at 11 am, 1 pm and 4 pm, quite irregularly *(Figure. 7)*. The nectar secretion of *'Idared'* on *M.9* was continuous but scarce during the whole day *(Fig. 8)*. In the flowers of the tree on *M.26* peaksof nectar production can be observed at 9, 1 pm and 5–8 pm, similarly to those on *M.4 (Fig. 9)*. Also in 1995 on the rootstock *MM.106* during the main blooming period, the morning production peak occurred at 9 am, and two smaller peaks can be observed in the afternoon, at 1 and 6 pm *(Figure 10)*.

In 1997 the rhythm of nectar secretion in apple cv. *'Idared'* was studied on three rootstocks. In the flowers of trees on rootstock *M.26* there was very little (0.01 µl in average) secretory product at 10 and 11 am in the morning at 26 °C. Maxima at 2 and 4 pm indicate that the maxima of

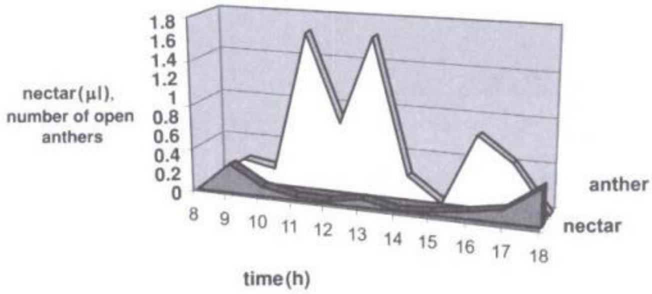



*Figure 7* Hourly mean nectar production and anther dehiscence of apple cv. Idared on rootstock M.4 Újfehértó, 28.04.1995.

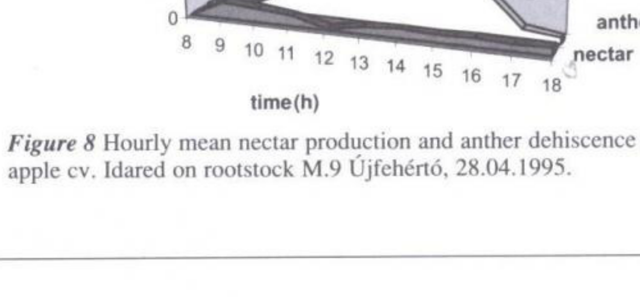



*Figure 8* Hourly mean nectar production and anther dehiscence of apple cv. Idared on rootstock M.9 Újfehértó, 28.04.1995.

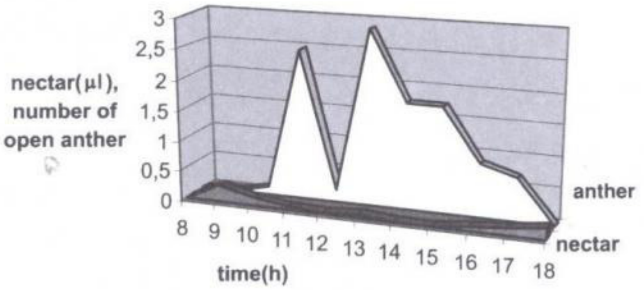



*Figure 9* Hourly mean nectar production and anther dehiscence of apple cv. Idared on rootstock M.26 Újfehértó, 28.04.1995.

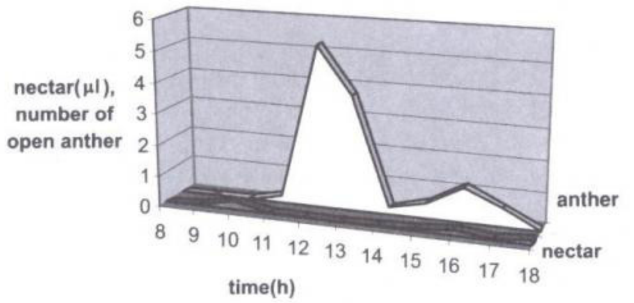



*Figure 10* Hourly mean nectar production and anther dehiscence of apple cv. Idared on rootstock M.106 Újfehértó, 28.04.1995.

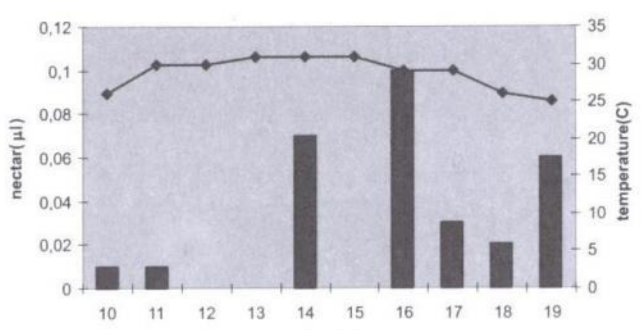



*Figure 11* Hourly mean nectar production and anther dehiscence of apple cv. Idared on rootstock M.26 Újfehértó, 05.05.1997., full bloom

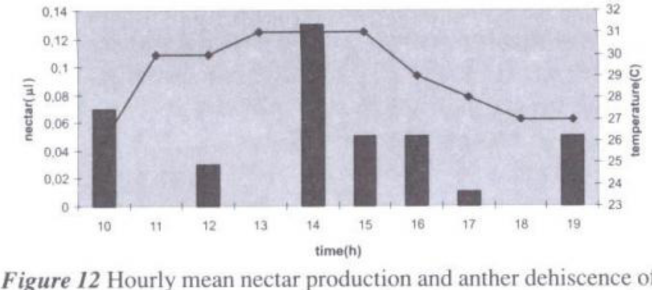



*Figure 12* Hourly mean nectar production and anther dehiscence of apple cv. Idared on rootstock M.4 Újfehértó, 05.05.1997., full bloom

the 4-hour secretory rhythm well known from previous studies appear at shorter intervals, at extreme temperatures (31 °C) they occur every 2 hours and at a slightly lower temperature – at 7 pm – every 3 hours *(Figure 11)*. On the same day at trees on rootstock *M.4* the first peak appeared already at 10 am, the next one at 2 pm and afterwards a continuous secretion of low intensity could be observed *(Figure 12)*. In the flowers of trees on rootstock *M.9* the maxima of nectar production occurred at 10–11 am then at 3 and 7 pm, i.e. almost precisely every 4 hours *(Fig. 13)*. Concerning the quantity of the secretory product there was more nectar at rootstock *M.9*. It seems that plants grown on this rootstock are the most capable of tolerating high temperature influences.

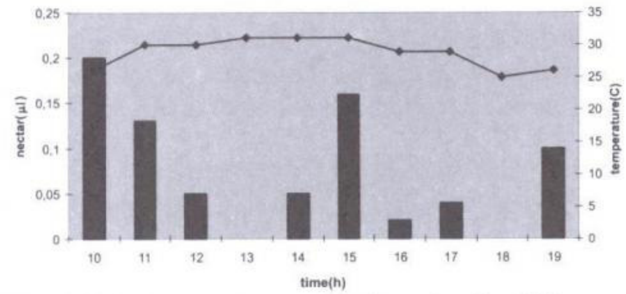



*Figure 13* Hourly mean nectar production and anther dehiscence of apple cv. Idared on rootstock M.9 Újfehértó, 05.05.1997., full bloom

In 1998 the nectar production of the apple cv. '*Idared*' was also studied on three rootstocks in the main blooming period. On rootstock *M.26* maxima could be observed at 1 pm and 6 pm *(Figure 14)*. Below temperatures of 20 °C there is hardly any secretion in the morning hours. At temperatures of about 22 °C the morning maximum shifted to 1 am. At the 6 pm peak, the amount of the secretory product was 0.3 µl with temperature approaching 25 °C. Nectar refraction was quite balanced, 20–23% *(Figure 15)*. At trees on rootstock *M.4* there was no morning peak either, but two other peaks could be detected at 1 pm and at 6 pm *(Figure 16)*. At trees on rootstock *M.9* the maxima occurred at 12 am, 2 pm and 5 pm *(Figure 18)*.

Our studies reinforce previous data in literature, according to which *(Cruden, Hermann & Peterson,* 1983) the daily rhythm of nectar secretion may shift forwards or backwards as a result of the influence of weather. According to our previous results concerning apple *(Nagy Tóth,* 1991), high temperatures results in more frequent and earlier peaks in secretion, whereas low temperatures cause later and less frequent secretory maxima.

At the studied cultivar delayed homogamy always starts with protogyny. At the time of pollen shedding the style has not started becoming brown yet, which means that the stages of style activity and pollen shedding are not totally separated, but overlap to a certain degree. On the basis of our studies the apple cv. '*Idared*' is delayed homogamous on each rootstock studied by us, which means that the rootstock does not influence the flower biological type. Delayed homogamy differs from delayed autogamy described by *Cruden & Lyon* (1989) by the fact that at apple cultivars self-

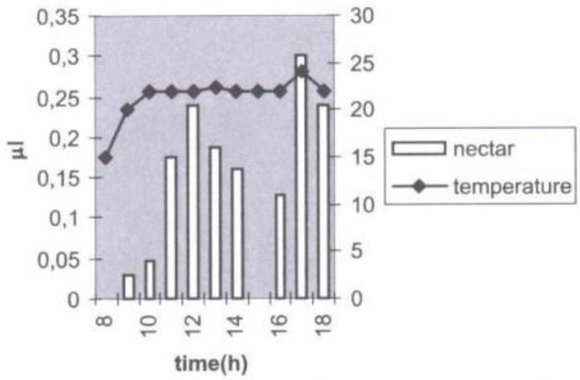



*Figure 14* Nectar production of flowers in apple cv. Idared on rootstock M.26 as a function of temperature, Újfehértó, 23. 04. 1998., full bloom

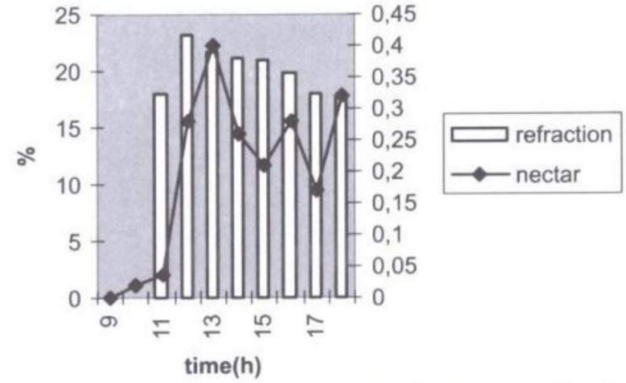



*Figure 17* Nectar production of flowers in apple cv. Idared on rootstock M.4: amount of nectar (µl) and refraction (%), Újfehértó, 23. 04. 1998., full bloom

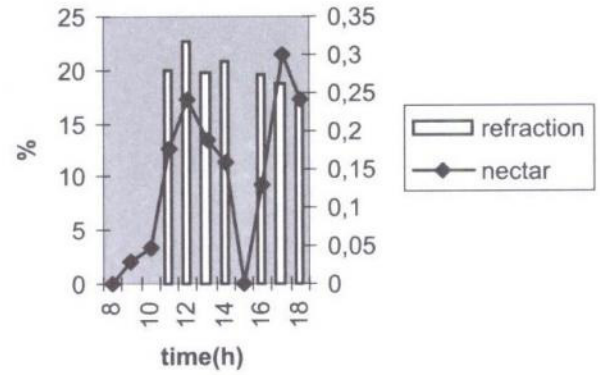



*Figure 15* Nectar production of flowers in apple cv. Idared on rootstock M.26: amount of nectar (µl) and refraction (%), Újfehértó, 23. 04. 1998., full bloom

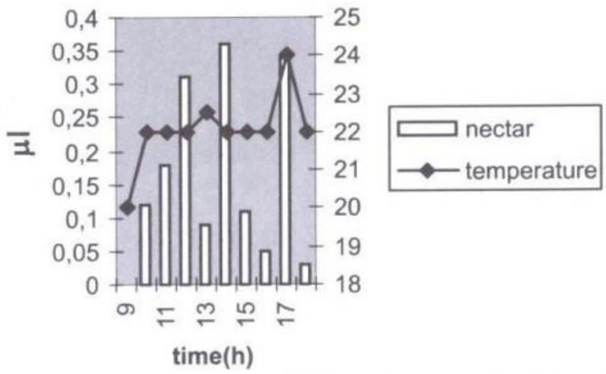



*Figure 18* Nectar production of flowers in apple cv. Idared on rootstock M.9 as a function of temperature, Újfehértó, 23. 04. 1998., full bloom

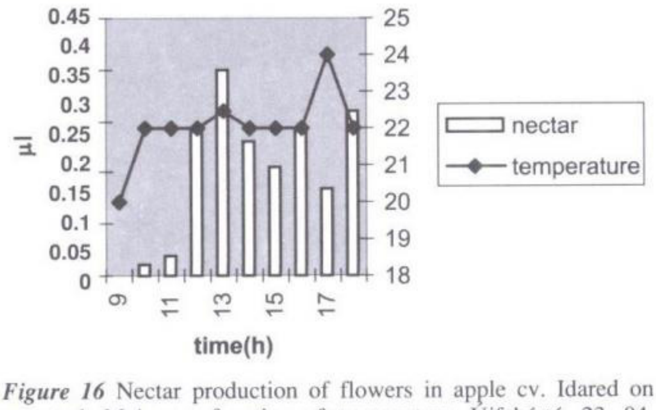



*Figure 16* Nectar production of flowers in apple cv. Idared on rootstock M.4 as a function of temperature, Újfehértó, 23. 04. 1998., full bloom

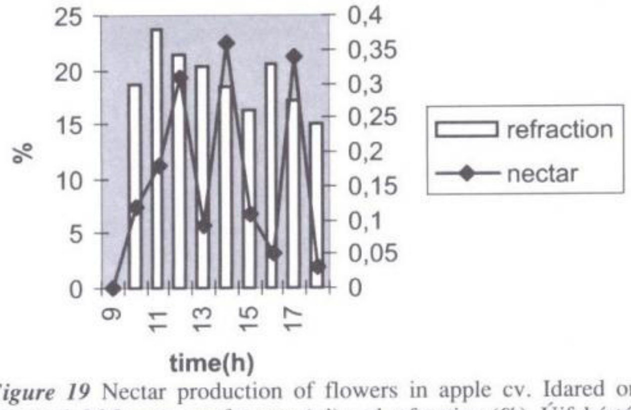
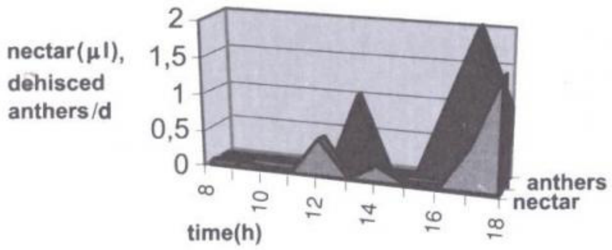



*Figure 19* Nectar production of flowers in apple cv. Idared on rootstock M.9 amount of nectar (µl) and refraction (%), Újfehértó, 23. 04. 1998., full bloom

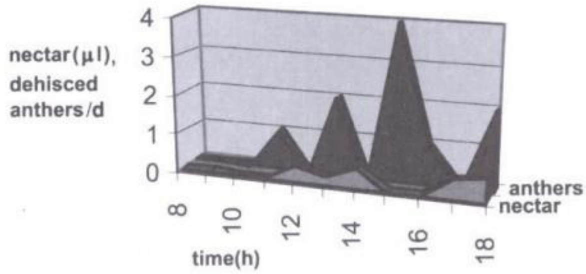
pollination does not occur at the end of blooming either, since apple is an autosterile species.

By studying the flowers hourly we also tried to answer the question whether the flowers differ in their individual secretory rhythm or not. The daily rhythm of nectar secretion and anther opening of *'Idared' M.26* was studied on 23rd April, 1998, between 8 am and 6 pm *(Figure 20).*

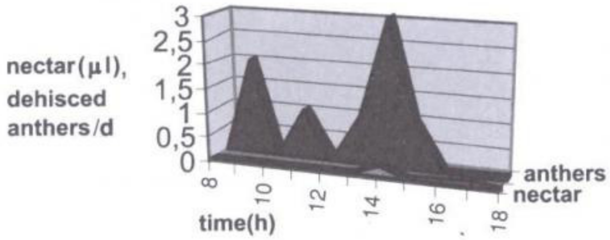
Flowers 1–3 started from half-blown flowers. Flower 1 opened at 10 o'clock and started secreting at 12 am, 2 and 6 pm. Flower 2 also opened at 10 am, and nectar secretion began at 12 am, while flower 3 opened at 10 am, but secretory product could only be found in it at 2 pm. In flowers 2 anther opening started at 11 am, in flower 1 only at 1 pm. Stigma secretion could be observed from 9 o'clock in flower 1



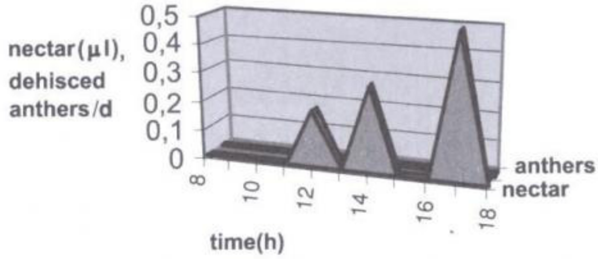

flower 2



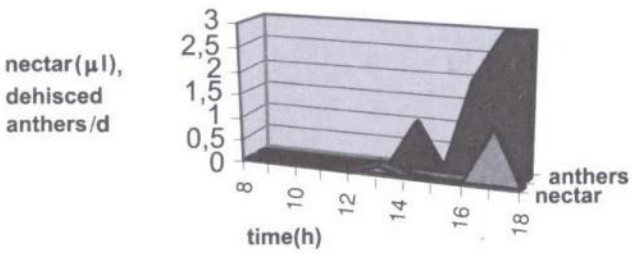

flower 3



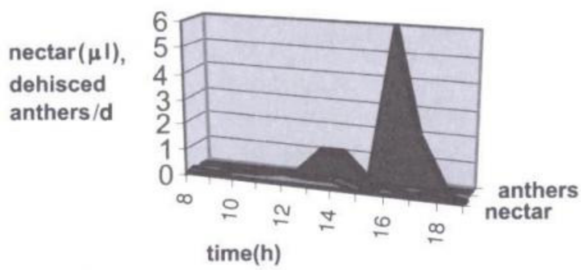

flower 4



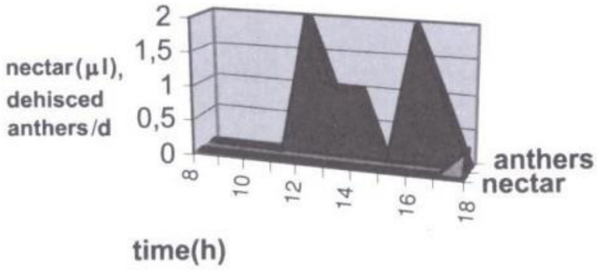

flower 5



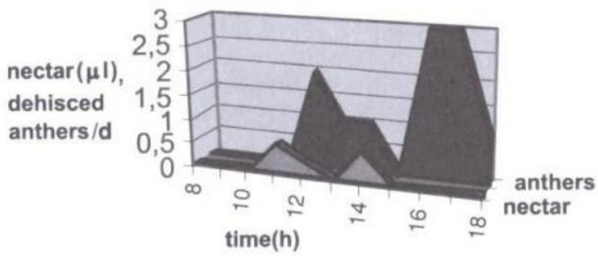

flower 6




flower 7




flower 8



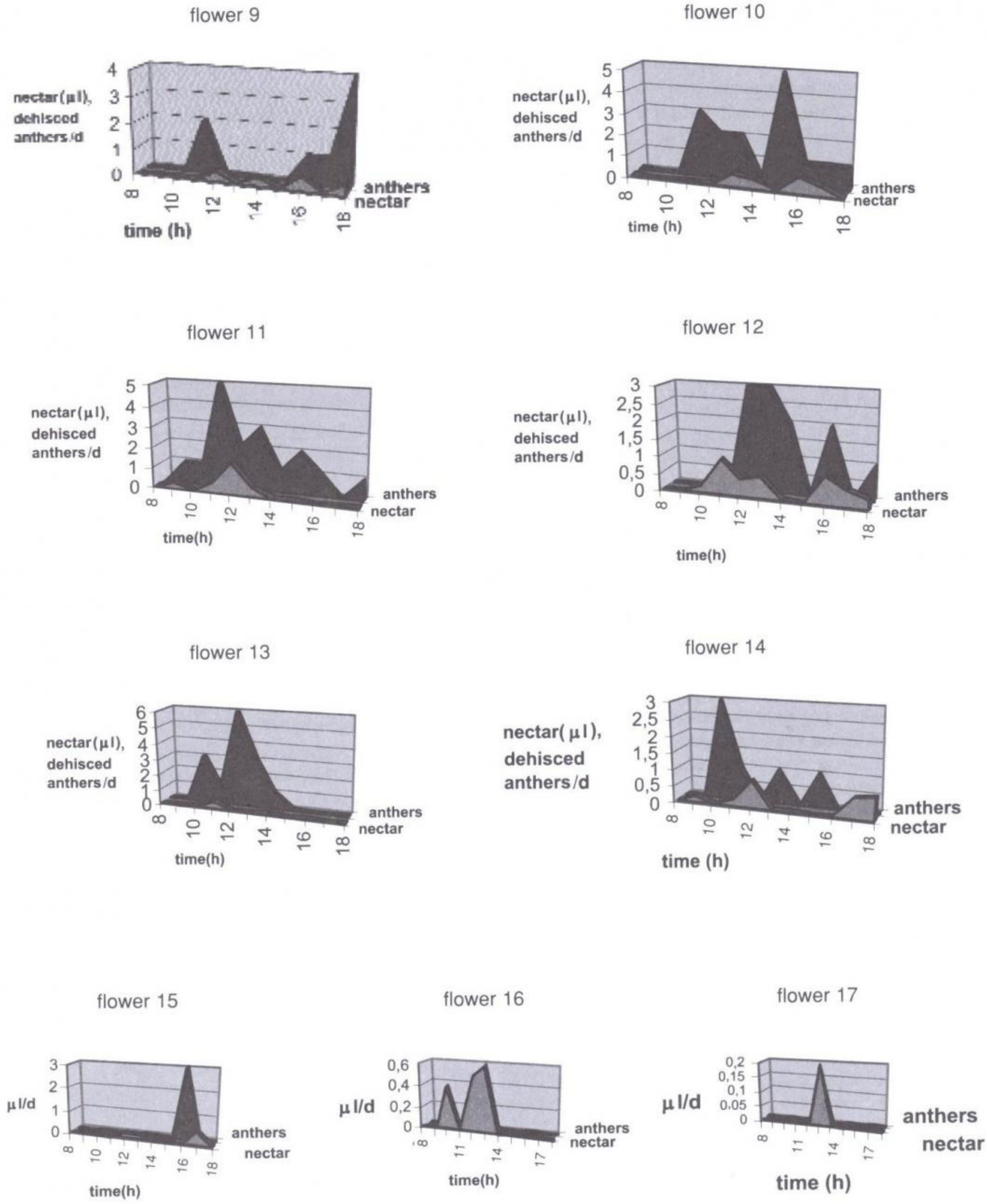



*Figure 20* Nectar production and anther dehiscence of apple cv. Idared on rootstock M.26, Újfehértó, 23. 04. 1998., full bloom

the half-blown and blown flowers, which means that the activity of the style could be detected already at the beginning of flower opening.

Among the young flowers with their anthers shut (4–10), in flower 4 no anther opened during the day, but stigma secretion was continuous and the other factor of insect attraction, nectar secretion started at 12 o'clock, which means that protogyny is expressed in the young flower. In other flowers that opened on the previous day nectar secretion appeared first, followed by the opening of anthers (e.g. flower 5 and 8) or pollen shedding was followed by the first peak of nectar secretion (e.g. flower 7, 9 and 10). Nectar production was protracted in some of the flowers, lasting for several hours (e.g. flower 9); others have breaks in secretion which can last for some hours. Maxima of nectar production appeared most frequently at 11 am, 2 and 5 pm.

Flowers that started pollen shedding the previous day, mostly opened their anthers continuously, not just at a few times during the day (flowers 11–14). Most anthers opened in the noon hours, between 11 am 2 pm, while in the case of flower 14 a certain rhythm can also be observed (at 10 am, 1 and 3 pm).

Anthers are opening continuously during the whole day at apple cv. *'Idared'*, ensuring a continuous insect attraction for the flowers, which is highly advantageous from the viewpoint of primary attraction of the cultivar.

In flowers 11 and 12 the stigma became brown at the end of the day, at 5 and 6 pm, simultaneously with the opening of the last anthers. It means that following the initial protogyny, the sexual organs have functioned synchronously from the beginning of anther opening.

In the old flowers that have already shed most of their pollen (e.g. flowers 15–17) there was no other activity than nectar secretion, except for flower 15, where the last anthers opened at 4 pm. It is interesting that in flower 15 the stigma continued secreting for another 12 hours after the anthers have opened and started getting brown only after this.

Concerning hourly nectar production and refraction, in 1998 on rootstock *M.26* there was a peak in nectar production at 1 pm and 6 pm. *'Idared' M.4* ensures nectar almost continuously all day for the visiting insects, while in the flowers of trees on rootstock *M.9* a smaller peak in nectar secretion can be observed at 12 am, 2 and 5 pm, but the amount of secretory product does not drop to zero between the peaks, either. Refraction varied between 15–20%, there was only a slight increase at 12 o'clock, with 23%. Temperatures were between 21–24 °C from 9 o'clock the whole day *(Fig. 14–19)*.

## Conclusions

The flowers of apple cv. *'Idared'* produced nectar of sufficient amount and good quality in all four rootstock combinations. Sugar value reached or exceeded 1mg on three rootstocks, the flowers of trees on rootstock *MM.106* produced the least (0.65 mg) sugar. In rainy years there was more and diluted floral secretory product, whereas in drier periods there was less and concentrated nectar.

Taking into account the four years of studies it can be stated that the quantity of the secretory product was the most balanced, 3.1–4.9 µl, in the flowers of trees on rootstock *M.4*, which may relate to the fact that this rootstock is rather drought-resistant. The nectar production and refraction of plants grown on rootstock *MM.106* was also fairly balanced, while the nectar production in the flowers of trees grown on the other two rootstocks fluctuated a lot in the different years.

The flowers of apple cultivar *'Idared'* were delayed homogamous in all rootstock combinations each year. Protogyny appearing on the day of flower opening usually shifts to homogamy on the second day. The stigma is still active during anther opening. Wind pollination with protogyny is followed by insect attraction by means of nectar secretion and finally by homogamous attractiveness offering both nectar and pollen. In the course of the rhythmic nectar secretion, which is more or less synchronous with the activity of the sexual organs, nectar is secreted every 4 hour in most cases. However, cool weather may slow, while hot weather may quicken the pace of nectar production. Apple cv. *'Idared'* can also be characterised by a smaller scale secretion between the production peaks, ensuring continuous insect attraction.

## References


**Belmonte, E., Cardemil, L. & Arroyo, M.T.K. (1994):** Floral structure and nectar composition in Eccremocarpus scaber (Bignoniaceae), a hummingbird-pollinated plant of central Chile. Amer. J. Botany 81, 4: 493–503.

**Benedek P. & Nyéki J. (1994):** Comparison of flower characters affecting bee pollination of temperate zone fruit trees. Horticult. Science 26(2): 32–37.

**Benedek P., Soltész M. & Nyéki, J. (1990):** Az alma irányított méhmegporzásának alapjai és üzemi technológiája. Kertgazdaság. 22.(1):1–19.

**Benedek P., Soltész M., Nyéki J. & Szabó Z. (1989):** Almafajták virágainak rovarmegporzást befolyásoló tulajdonságai. Kertgazdaság. 21(6): 41–64.

**Beutler, R. (1941):** Neues über die Bienenweide. Dtsch. Imkerf. 15:42–44.

**Beutler, R. (1953):** Nectar. Bee World 34: 106–116, 128– 136.

**Crane, E. (1984):** Directory of important world honey sources. International Bee Research Assosiation London.

**Cruden, R.W., & Hermann, S.M. (1983):** Studying nectar? Some observationson the art. In: The biology of Nectaries – Ed.by B. Bentley & T.Elias Columbia University Press, New York, 223–241.

**Cruden, R.W., Hermann, S.M., & Peterson, S. (1983):** Patterns of nectar production and plant-pollinator coevolution. In: The biology of Nectaries – Ed.by B. Bentley & T. Elias Columbia University Press, New York, 80–125.

**Cruden, R.W. & Lyon, D.L. (1989):** Facultative xenogamy: examination of a mixed mating system.171–207.( In:The evolutionary ecology of plants. Ed.: Jane H. Bock & Yan B.

Linhart), Westview Press.1989. Boulder, San Francisco London

**Davary-Nejad G.H., Szabó Z., Nyéki J. & Benedek P. (1993):** Almafajták virágtulajdonságai és méhmegporzása. Kertgazdaság. 25(2): 73–88.

**Demianowicz, Z., & Hlyn, M. (1960):** Porownawcze badania nad nekarowaniem 17 gatunkow lip. Pszczel. zesz. Nauk. 4.133–151.

**Gluhov, M.M. (1955):** Vazhneyshie medonosnye rasteniya i sposoby ih zarvedeniya. 6. ed. Selskohozyaystvennoy Literatury Moskva.

**Gulyás S. (1975):** A méhlegelő. (In: Halmágyi L. & Keresztesi B.: A méhlegelő.) Akadémiai Kiadó, Budapest. 21–92.

**Gulyás S., Nagyné Bíró M. & Molnár Á.-né (1989):** Nyírségi almafajták nektártermelése és az almaméz összetétele. Méhész Újság. 2(1): 18–20.

**Halmágyi L. & Suhayda J. (1966):** Fontosabb gyümölcsfajaink virágzása. Méhészet 14: 85–86.

**Kartasova, N.N. (1965):** Stroeniye i funkciya nektarnikov cvetka dvudolnyh rasteniy. Izdatelstvo Tomskogo Universiteta, Tomsk.

**Krlevska, H., Kipriyanovski, M. & Naumovski, M. (1995):** Research on nectar-bearing capacity of apples. Macedonian Agricult. Review 42. (2):115–118.

**Livenceva, E.K. (1954):** O metodike opredelenija nektaroproduktivnosti rasteniy. Pchelovodstvo 30.(4): 42–45.

**Lüttge, U. (1971):** Structure and function of plant glands .- Ann. Rev. Plant Physiol. V. 22: 23.

**Maurizio, A. (1960):** Biene und Bienenzucht. Kapitel Bienenbotanik. München.

**Maurizio, A. & Grafl, I. (1982):** Das Trachtpflanzenbuch. München.

**Mommers, J. (1966):** Die Nektarabsonderung bei verschiedenen Rassen der Obstbäume. Z. Bienenforsch. 6:203–204.

**Nagy Tóth E. (1991):** Almafajták nektáriumszerkezete és nektárprodukciója. Egyetemi doktori disszertáció. 1991. Pécs.

**Nagy Tóth E. (1994):** A Mutsu nektártermelése. Kertészet és Szőlészet. 43. (18):23.

**Nagyné Bíró M. & Gulyás S. (1990):** Almafajták virágainak aszimmetriája és nektárprodukciója. A Magyar Biológiai Társaság és a Bessenyei György Tanárképző Főiskola XIX. Vándorgyűlése. Nyíregyháza 1990.

**Orosz-Kovács Zs. (1988):** Nectary structure and nectar production of sour cherries. -XXIII-th Congress of the Hungarian Biological Society-, Keszthely, Abstract 70.

**Orosz-Kovács Zs. (1989):** Nectary structure and nectar production of apple varieties. V.th . Symposium of the Hungarian Plant Anatomy Szeged. Abstract of Papers 29.

**Orosz-Kovács Zs. (1990/a):** Correlation between the periodicity of nectar secretion and the fertilization ratio in the Pándy sour cherry clones. Kertgazdaság, 22.(5): 25–31.

**Orosz-Kovács Zs. (1990/b):** The endogenous rhythm of flowering and chemisation. 19 th Cong. Hung. Biol.Soc., 1990. 63.

**Orosz-Kovács Zs. (1991):** The histology of floral nectary Prunoideae taxa. VI.th. Symposium of the Hungarian Plant Anatomy. Keszthely. Abstract of Papers.

**Orosz-Kovács Zs. (1992):** A cseresznye és a meggy nektáriumstruktúrája és nektárprodukciója. Kandidátusi disszertáció, Pécs.1992.

**Orosz-Kovács Zs., Faust M., Nyújtó F. & Erdős Z. (1993):** New considerations for cultivar combinations in sour cherry. Acta Horticult. 410:527–535.

**Orosz-Kovács Zs., Gulyás S. & Halászi Zs. (1989):** Periodicity of nectar production of spur cherry cv. "Pándy". Acta Bot.Hung. 35.(1–2):237–244.

**Orosz-Kovács Zs., Gulyás S. & Inhóf L. (1987):** Regulatories in nectar-production of sour cherry cv. "Pándy 31".– Working Papers, Pécs, Osijek 1. 59–72.

**Orosz-Kovács Zs., Gulyás S., Sötét F. & Horváth Sz. (1988):** Periodicity of nectar production of sour- cherry "Pándy 114". Osijek, Pécs, Working Papers 2. 297–308.

**Orosz-Kovács Zs., Nagy Tóth E., Csatos A. & Szabó A. (1991):** A nektáriumszerkezet és a nektárprodukció összefüggése néhány almafajtánál. Bot. Közl. 77.(1–2):127–132.

**Pesti J. (1976):** Daily fluctuations in the sugar content of secretion in the Compositae. Acta Agr. Ac. Sci.Hung.25. (1–2): 5–17.

**Péter J. (1971):** Florális nektárszekréciós vizsgálatok szántóföldi növényeken. – Agrártud. Egyetem Mosonmagyaróvári Mg. Kar Növénytani és Növényélettani Tansz. Közl. 14.(8): 5–35.

**Péter J. (1972):** A gyümölcsfák mézelési értékelése nektártermelésük alapján. Agrártud. Egyetem Keszthely, Mosonmagyaróvári Mg. Kar Növénytani és Növényélettani Tansz. Közl. 15.(8): 5–32.

**Polevoj, V.V. (1981):** Sistemy regulacii u rasteniy. Vestn. LGU. Biologiya 4. 105.

**Rimasevskiy, V.K. (1957):** O nektaroproduktivnosti i saharistosti nektara plodovo yagodnyh kultur. Pchelovodstvo 34 (5): 39–41.

**Sansavini, S., Rosati, P. & Grandi, M. (1981):** Cultivar di melo. Scelte Varietali in Frutticoltura. Ferrara, 38–48.

**Shuel, R.W. (1961):** The influence of calcium and magnesium supply on nectar production in red clover and snapdragon. Repr. Can. J. Plant. Sci. 41:50–58.

**Soltész M. (1982):** Almaültetvények fajtatársítása. Kandidátusi értekezés. Budapest.

**Soltész M. (1996):** The placement of different cultivars in apple orchards. Horticultural Science 28(3–4):38–40.

**Soltész M., Nyéki J. & Benedek, P. (1983):** Variety features affecting insect pollination in apple flowers (Preliminay study). Proc. 29th Internat. Congress of Apiculture, Apimondia Verlag, Bucuresti:286–289.

**Szabóné-Mühlenkampf E. (1994):** Spur típusú almafajták nektárium-szerkezete és nektártermelése. Egyetemi doktori disszertáció. Pécs.

**Sazikin, Ju.V. (1955):** Effektivnosty ispolzovaniya pchel na opylenii sadov mozhno povysty. Pchelovodstvo, 32.(2):14–18.

**Szilva Á. (1969):** Gyümölcstermesztésünk és a méhészet. Méhészet. 17:63–66.

**Szimidcsiev, T. (1971):** Izsledovaniya virhu nektaroproduktivnosta i medoproduktivnosta na jablkata. Nauchno Trudova, VSI Selskotopanski Institut "Vasil Kolarov" -Plovdív 20.(5):71–86.

**Vansell, G.H. (1952):** Variations in Nectar and Pollen Sources, Circ. Utah agric. Exp.Stn. 124:28.

**Zauralov, O.A. (1986):** Reguljacija processa vydeleniya nektara. Seriya Biologicheskaya 1: 77–84.