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The effect of nectar production to the gathering behaviour of honeybees and to the foraging activity of wild bees at apple flowers

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Summary: Intensity of bee visitation (honeybees and wild bees), foraging behaviour of honeybees and nectar parameters (nectar production, sugar concentration, sugar content in nectars) were inspected at 18 apple cultivars for three consecutive years. Honeybee visitation was calculated to be some 3.07 bee visits at a single apple flower a day but wild bee activity was very low, only some 0.11 wild bee visits per flower per day.

The nectar production (nectar content) of apple flowers was fairly different according to the cultivars and the nectar production (nectar content) of flowers was negatively correlated with the sugar concentration in nectar. Interestingly, at the majority of the inspected 18 cultivars the nectar production has shown minor or no changes in the morning and at the afternoon. The nectar production (nectar content) of flowers clearly encouraged the total bee activity at the inspected cultivars ($r = 0.54$). Bees visited abundant nectars with greater sugar concentration most intensely than lees abundant nectars with smaller sugar concentration.

Nectar parameters, however, affected the activity of honeybees with different types of gathering behaviour in different way. More intense activity by pollen gatherer and mixed behaviour honeybees was observed at cultivars producing abundant nectar (pollen gatherers: $r = 0.65$, mixed behaviour: $r = 0.79$). The activity of pollen gatherer honeybees and of mixed behaviour bees, on the other hand, was negatively correlated to the sugar concentration in nectar (pollen gatherers: $r = -0.51$, mixed behaviour: $r = -0.73$). This can be explained by the fact that their behaviour was much more affected by the amount of pollen than by any nectar parameters. Accordingly, "mixed behaviour honeybees" should probably rather be called as "pollen gatherers with nectar load" instead of "nectar gatherers with pollen load", as widely used in literature. The activity of ineffective side worker nectar gatherers was greatly encouraged by the sugar concentration in nectar ($p = 0.63$), similarly to the pure (top) nectar gatherer honeybees ($r = 0.72$). There was a negative relationship between the nectar production (nectar content) of flowers and the activity of these behaviour classes (nectar gatherers: $r = -0.47$, side workers: $r = -0.36$).

Concluding the findings we can state that the activity of pollen gatherers and mixed behaviour honeybees is strongly encouraged by greater nectar production (greater nectar content) of apple flowers. Their activity, however, is mostly dependent firstly on the amount of pollen. This is the reason why the sugar concentration is in a negative relationship to the activity of pure pollen gatherers and mixed behaviour bee. On the other hand, pure nectar gatherers and side worker nectar gatherers are greatly encouraged by the sugar concentration of apple nectar the amount of nectar was not a definite influence on their activity.

Side worker honeybees occurred at each cultivar inspected, however, their ratio varied widely among cultivars. So we can draw the conclusion that, in contradiction with earlier believes, side worker nectar gathering is a general phenomenon at apple flowers. The activity of side workers depends first of all on the relative position of stamens and petals; however, low sugar concentration of nectars can probably moderate their activity but probably do not affect pollen gatherers and mixed behaviour bees.

Wild bee visitation was very low; the wild bee species observed (*Osmia cornuta, Andrena flavipes, Anthophora acervorum, Bombus terrestris, Bombus lapidarius and Halictus simplex*) comprised some 3.44 per cent of the total bee visitation at apple flowers only. Wild bee visitation was in a positive correlation with the nectar production (nectar amount) of flowers ($r = 0,4$) and with the sugar content of nectar ($r = 0.46$) but it was negatively correlated with the sugar concentration in nectar ($r = -0,27$).

Our result calls the attention to the importance of nectar parameters in the effective honeybee pollination of apple plantations. Most effective pollinating activity of honeybees can be expected in plantations with cultivars of high nectar production because this feature seem so encourage the activity of those behaviour classes (pure pollen gatherers and mixed behaviour bees) that are the most effective pollinating agents among honeybees.

Key words: apple, cultivars, nectar production, sugar concentration, sugar content of nectar, honeybees, wild bees, foraging activity, gathering behaviour, nectar gatherers, pollen gatherers, mixed behaviour bees, side workers

Introduction

Flowering fruit trees are among the first nectar and pollen sources for flower visiting insects early in the season. Honeybees and wild bees as pollinators exploit both kinds of rewards in fruit tree flowers. The nectar production (nectar content) of apple flowers is fairly abundant usually changing between 3–8 mg and contains some 25–65 per cent sugar depending on cultivar, locality and year but more concentrated nectars are more frequent than more diluted ones (*Vansell,* 1952; *Sazykin,* 1955; *Rymashevskii,* 1957; *Maurizio & Grafl,* 1982; *Crane,* 1984; *Free,* 1993; *Benedek,* 1996; *Benedek & Nyéki,* 1997; *Krlevska* et al., 1998; *Benedek,* 2003).

Apple cultivars are known to be of different value as pollen and even more different as nectar sources for honeybees because their pollen and nectar production and also the sugar concentration in their nectar is more or less different in most cases (*Free,* 1993; *Benedek* et al., 1989; *Devary-Nejad* et al., 1993; *Benedek,* 1996; *Benedek & Nyéki,* 1996; *Benedek,* 2003).

However, soil conditions can induce remarkable variability in the nectar production of the same cultivar in different places (*Beutler,* 1953) and some differences can also be found in the nectar production of flowers within individual trees (*Ryle,* 1954). *Devary-Nejad* et al., 1993) has shown that the nectar production of apple cultivars also depends on the varying conditions of consecutive years and so can be changeable according to the season; when the nectar production of flowers of the same cultivar increases in some years the sugar concentration decreases simultaneously. In fact, nectar production of flowers occurs only above a threshold temperature and the actual nectar production of flowers is also greatly affected by the changing weather, by the changing air temperature, changing relative air humidity as well as by the direct sunshine and cloud cover (*Péter,* 1972).

The most concentrated nectars are usually produced by aged flowers often with fallen petals (*Ewert,* 1940) and so these petal-less flowers are often more attractive to nectar gatherers honeybees than flowers with petals (*Williams & Brain,* 1985). Sadly, insecticide sprays applied immediately after the petal fall of flowers can therefore cause serious bee losses in apiaries in the nearby (*Benedek* et al., 1974; *Courant,* 1994).

Honeybees usually prefer triploid apple cultivars as nectar sources and often visit their flowers more abundantly because these cultivars always produce more nectar than the usual diploid ones (*Soltész,* 1997). *Gulyás* et al. (1989) for example found that among a number of apple cultivars the flowers of two triploid ones, of *Mutsu* and *Jonagold* contained the most abundant nectar, and two diploids, *Idared* and *Golden Delicious* were the worst in their nectar production.

Based on their extensive studies with 35 apple cultivars *Benedek & Nyéki* (1996) have shown that sugar concentration in apple nectars is greatly important because cultivars with more concentrated nectars attract definitely more honeybees than cultivars with more diluted ones. They also found that nectar content of flowers alone, on the other hand, is of no definite influence on the intensity of bee visitation of apple trees. Accordingly, sugar concentration of nectars is greatly important from the point of view successful bee pollination of apple cultivars. Growers are, therefore, recommended to combine cultivars with similar nectar concentrations.

Some one half or one third of honeybees visiting apple flowers usually gather for pollen, but the ratio of pollen gatherers can greatly be different at different sections of the flowering period (*Free,* 1960a; *Benedek* et al., 1974; *McGregor,* 1976; *Hellmich & Rothenbuhler,* 1986; *Benedek,* 1996; *Benedek* et al., 1989; *Free,* 1993; *Benedek,* 2003). Pollen gatherer honeybees approach the flowers from the top and for landing on stamens and pistils they usually get in contact with stigmas and so pollinate them by the pollen grains carried in their body hairs (*Free,* 1960a; *Benedek* et al., 1974; *McGregor,* 1976; *Free,* 1993). Nectar gatherers are also effective pollinating agents when landing on the top of the flowers and pushing their tongue towards the nectar between the pistils and stamens but in other instances they land on petals and approach the nectaries between the sepal and the stamens and so do not get into contact with the stigmas and so do not pollinate the flower. The formers are known to be pure nectar gatherers and the latter as side workers (*Free,* 1960a; *Benedek* et al., 1974; *McGregor,* 1976; *Benedek,* 1996). A number of nectar gatherers also collect some pollen when gathering deliberately for nectar. These bees are called to be mixed behaviour individuals and they are almost as effective in the pollination of apple flower as the pure pollen gatherers (*Free,* 1960a; *Benedek* et al., 1974; *McGregor,* 1976). *Benedek & Nyéki* (1996) has found that the ratio of pure pollen gathers is usually fairly high at apple flowers, being normally between 41–60 per cent at the flowers of different cultivars, but the proportion of mixed behaviour bees and of pure nectar gathers honeybees is rather changeable depending on the cultivar (*Benedek,* 2003).

In spite of this knowledge little information is available how these factors can possibly affect the gathering behaviour and consequently the pollinating efficiency of honeybees or wild bees on the flowers of specific apple cultivars. For the honeybees are the most abundant pollinating agents in commercial apple plantations (*Free,* 1970, 1993; *Benedek* et al., 1974; *Benedek,* 1996) it is greatly important to explore the influence of the parameters mentioned to honeybee behaviour on apple flowers. First of all the effect of differences in the nectar production of apple cultivars and of sugar concentration as well as of sugar content of apple nectars seems to be important and, additionally, it is also interesting if these factors were of any influence on the activity of wild bees that were usually less abundant but much more active flower visitors on flowering apple trees than honeybees. The aim of this study is to analyse these relationships in the case of some selected apple cultivars and to check if these relationships are constant during the day.

Table 1. Comparison of nectar production of apple cultivars (Mosonmagyaróvár)

Cultivar	Mean nectar content of apple flowers (based on the results of series of measurements made in the morning and at the afternoon)								
	Mean nectar content of flowers (mg /flower) n = 864			Sugar concentration in nectar (per cent) n = 864			Sugar content in nectar (mg/flower) n = 864		
	Mean	SD5 %	Confidence intervals at p=5% level	Mean	SD5 %	Confidence intervals at p=5% level	Mean	SD5 %	Confidence intervals at p=5% level
1. Akane	1.81	0.53	0.15	35.37	5.46	1.58	0.63	0.08	0.02
2. Arlet	1.48	0.79	0.22	37.25	6.1	1.96	0.64	0.1	0.03
3. Braeburn	2.15	0.67	0.19	43.79	3.76	1.06	0.92	0.21	0.06
4. Early Gold	1.62	0.54	0.15	37.5	2.43	0.74	0.63	0.15	0.04
5. Florina	1.53	0.42	0.12	42.51	2.69	0.79	0.66	0.11	0.03
6. Freedom	1.45	0.39	0.11	39.56	2.54	0.74	0.58	0.1	0.03
7. Gala Must	1.88	0.54	0.15	45.77	3.55	1.03	0.86	0.17	0.05
8. Gloster	3.42	0.85	0.24	34.94	6.67	1.89	1.15	0.14	0.04
9. Golden B	1.36	0.33	0.1	48.36	2.18	0.64	0.67	0.1	0.03
10. Golden Spur	1.34	0.33	0.1	49.5	2.29	0.68	0.68	0.1	0.03
11. Granny Smith	1.54	0.58	0.16	46.27	3.11	0.92	0.73	0.18	0.05
12. Idared	1.92	0.73	0.21	44.95	4.6	1.35	0.85	0.23	0.07
13. Jonagold	4.96	0.94	0.27	27.79	4.99	1.41	1.33	0.06	0.02
14. Jonagold Wilmuta	4.79	0.68	0.19	27.67	3.59	1.01	1.3	0.04	0.01
15. Jonathan M 41	2.9	0.9	0.25	31.77	5.82	2.05	0.87	0.11	0.04
16. Naményi Jonathan	2.12	0.41	0.12	37.15	3.17	0.9	0.77	0.09	0.03
17. Red Elstar	1.43	0.6	0.17	48.77	2.12	0.66	0.79	0.16	0.05
18. Royal Gala	2.57	0.75	0.22	37.9	5.17	1.49	0.94	0.17	0.05
Means of the 3 years' measurements	*2.24*			*39.92*			*0.83*		
$SD_{5\%}$	*0.23*			*1.51*			*0.05*		

Material and methods

Locality and cultivars inspected

Measurements were taken and field observations were made in the 0.3 ha large experimental garden of the Horticulture Department, Faculty of Agricultural and Food Sciences, University of West Hungary, Mosonmagyaróvár (Hungary) in three consecutive years, between 2001–2003. As much as 18 apple cultivars were inspected in all the tree years as follows: *Akane, Arlet, Braeburn, Early Gold, Florina, Freedom, Gala Must, Gloster, Golden B, Golden Spur, Granny Smith, Idared, Jonagold, Jonagold Wilmuta, Jonathan M 41, Naményi Jonathan, Red Elstar and Royal Gala*. It was a collection of apple cultivars planted in hedging type with trees on M26 type rootstock and so the trees were some 2 metres high only. The plantation was some 10 years old and the rows run from East to West.

Measuring the nectar production of cultivars and sugar concentration in nectars

Nectar production of cultivars was measured by the classical capillary method at two trees per cultivar. Two flowering branches were selected for measurements at the Northern and the Southern side of each tree that is at Northern and the Southern side of the rows. Branches for sampling were selected in the middle level of the crowns that is some 1.5 m above ground. Each selected branch was covered with parchment paper bags on the day prior to the day of nectar sampling. Bags were removed at sampling and nectar was taken from 5 flowers per branch each occasion with capillary tubes weighted together with two tiny beeswax balls with a digital analytical scale previously at room temperature. Capillary tubes were stopped at both ends with pertaining tiny beeswax balls. Stopped tubes with nectar samples were weighted with the same digital analytical scale at room temperature. Measurements were taken at three mornings (between 10:12:00) and in three afternoons (14:00-16:00) during the flowering period on days with weather favourable to the flight activity of bees.

Nectar production (= nectar content) of flowers was calculated as subtracting empty weight of tubes with pertaining beeswax ball from the stopped tubes containing nectar samples. Results were expressed as the amount of nectar mg/flower.

Sugar concentration of nectars (in per cent) was measured with an Abbe-type refractometer for each sample separately.

Sugar content in flowers was calculated as a function of nectar content and sugar concentration as mg/flower.

Table 2. Comparison of nectar production of apple cultivars in the morning (Mosonmagyaróvár)

Cultivar	Mean nectar content of apple flowers based on the results of series of measurements made in the morning (10:00 to 12:00)								
	Mean nectar content of flowers (mg /flower) n = 432			Sugar concentration in nectar (per cent) n = 432			Sugar content in nectar (mg/flower) n = 432		
	Mean	SD5 %	Confidence intervals at p=5% level	Mean	SD5 %	Confidence intervals at p=5% level	Mean	SD5 %	Confidence intervals at p=5% level
1. Akane	1.79	0.54	0.22	36	5.55	2.22	0.62	0.09	0.04
2. Arlet	1.82	0.64	0.25	36.1	6.4	2.67	0.66	0.1	0.04
3. Braeburn	2.04	0.53	0.21	44.21	3.15	1.26	0.89	0.18	0.07
4. Early Gold	1.59	0.56	0.23	37.57	2.57	1.12	0.65	0.15	0.06
5. Florina	1.61	0.48	0.19	41.78	3.3	1.35	0.68	0.13	0.05
6. Freedom	1.53	0.44	0.18	39.15	2.71	1.13	0.61	0.12	0.05
7. Gala Must	2.07	0.37	0.15	44.57	2.57	1.03	0.91	0.12	0.05
8. Gloster	3.07	0.72	0.2	37.18	6.74	1.91	1.1	0.15	0.04
9. Golden B	1.37	0.41	0.16	48.2	2.2	0.9	0.68	0.11	0.04
10. Golden Spur	1.39	0.43	0.17	49.03	2.54	1.06	0.72	0.11	0.04
11. Granny Smith	1.61	0.46	0.19	46.06	2.54	1.04	0.75	0.16	0.07
12. Idared	1.53	0.52	0.21	47.5	4.2	1.76	0.74	0.17	0.07
13. Jonagold	4.43	0.75	0.3	30.45	4.27	1.71	1.32	0.08	0.03
14. Jonagold Wilmuta	4.71	0.62	0.25	28.14	3.45	1.38	1.31	0.04	0.01
15. Jonathan M 41	2.7	0.85	0.34	33.13	5.8	2.32	0.85	0.12	0.05
16. Naményi Jonathan	2.09	0.42	0.17	37.29	3.24	1.29	0.77	0.1	0.04
17. Red Elstar	1.38	0.66	0.26	48.77	2.1	0.92	0.78	0.15	0.07
18. Royal Gala	2.47	0.67	0.27	38.8	4.44	1.78	0.93	0.16	0.06
Means of the 3 years' measurements	*2.18*			*40.3*			*0.83*		
$SD_{5\%}$	*0.24*			*1.67*			*0.06*		

Inspecting bee visitation at flowering apple trees and the foraging behaviour of flower visiting bees

Three strong bee colonies were placed in the experimental garden just before the flowering of apple trees has begun. Bee visitation was inspected at two trees per cultivar on two branches with some 50 open flowers each at the Northern and the Southern side of the relevant trees. Branches selected were at the middle section of the crown of the trees, approximately 1.5 m above the ground. Inspections were made at three mornings (between 10–12:00) and in three afternoons (14:00–16:00) during the flowering period on days with weather favourable to the flight activity of bees. Branches were inspected for 20 minutes periods each occasion for registering bee activity. Numbers of pollen gatherer, of nectar gatherer and of mixed behaviour honeybees (that is nectar gatherers with pollen loads) as well as of side of side worker honeybees and of wild bees were registered at each occasion at each branch inspected. Some weather conditions (air temperature, wind velocity, cloud cover) were also inspected for the 20 minutes observation periods. Also the stage of flowering was registered at each date of observations. Figures on bee activity were expressed as bee visits per 100 flowers in 20 minutes periods.

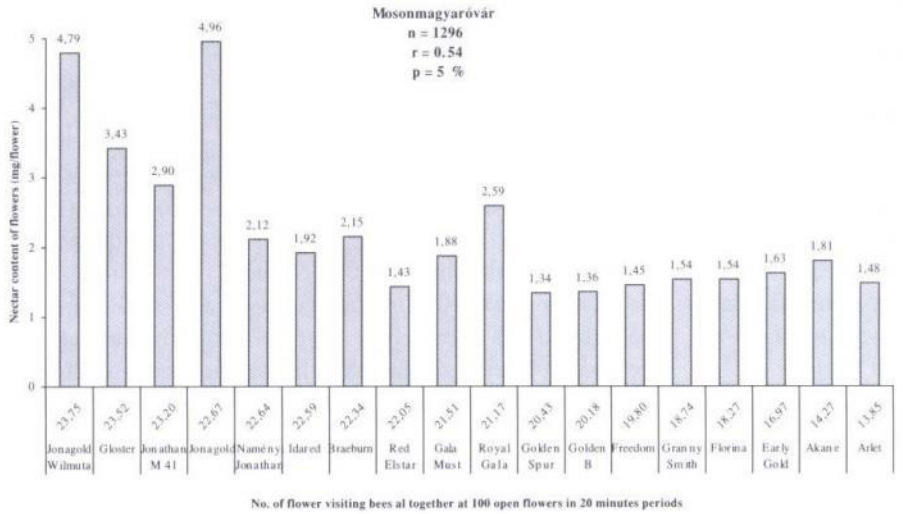

Figure 1. The effect nectar production of apple flowers to the intensity of bee visitation at flowering apple trees (honeybees and wild bees altogether)

Table 2. Comparison of nectar production of apple cultivars at the afternoon (Mosonmagyaróvár)

Cultivar	Mean nectar content of apple flowers based on the results of series of measurements made at the afternon (14:00 to 16:00)								
	Mean nectar content of flowers (mg /flower) n = 432			Sugar concentration in nectar (per cent) n = 432			Sugar content in nectar (mg/flower) n = 432		
	Mean	SD5 %	Confidence intervals at p=5% level	Mean	SD5 %	Confidence intervals at p=5% level	Mean	SD5 %	Confidence intervals at p=5% level
1. Akane	1.83	0.54	0.22	34.68	5.4	2.26	0.64	0.07	0.03
2. Arlet	1.14	0.79	0.32	38.95	5.39	2.56	0.61	0.1	0.05
3. Braeburn	2.26	0.79	0.32	43.36	4.31	1.72	0.95	0.24	0.09
4. Early Gold	1.64	0.52	0.21	37.43	2.36	0.99	0.62	0.15	0.06
5. Florina	1.44	0.33	0.13	43.31	1.51	0.64	0.64	0.1	0.04
6. Freedom	1.38	0.33	0.13	39.96	2.36	0.97	0.56	0.08	0.03
7. Gala Must	1.69	0.61	0.24	47.09	4.04	1.65	0.81	0.2	0.08
8. Gloster	3.78	0.83	0.24	32.7	5.92	1.68	1.19	0.11	0.03
9. Golden B	1.35	0.24	0.1	48.52	2.19	0.92	0.66	0.08	0.04
10. Golden Spur	1.29	0.18	0.08	49.97	1.96	0.82	0.64	0.07	0.03
11. Granny Smith	1.47	0.68	0.27	46.49	3.69	1.58	0.72	0.2	0.09
12. Idared	2.31	0.7	0.28	42.52	3.58	1.46	0.96	0.23	0.09
13. Jonagold	5.49	0.82	0.33	25.12	4.22	1.69	1.35	0.04	0.02
14. Jonagold Wilmuta	4.88	0.74	0.3	27.21	3.74	1.49	1.3	0.04	0.02
15. Jonathan M 41	3.09	0.93	0.37	30.42	5.64	2.26	0.89	0.1	0.04
16. Naményi Jonathan	2.15	0.41	0.16	37.02	3.18	1.27	0.78	0.09	0.04
17. Red Elstar	1.48	0.55	0.22	48.77	2.21	0.97	0.79	0.17	0.07
18. Royal Gala	2.69	0.83	0.35	36.91	5.81	2.43	0.95	0.19	0.08
Means of the 3 years' measurements	*2.3*			*39.58*			*0.83*		
$SD_{5\%}$	*0.28*			*1.87*			*0.06*		

Results

Nectar production of apple cultivars

Results on the nectar production of cultivars inspected are shown in *Tables* 1–2 and in *Figures* 1–3. Apple flowers produced 2.3 mg nectar in average, but the nectar production of individual cultivars ranged between 1.34 to 4.46 mg/flower. Some cultivars produced much less than average (*Golden Spur, Golden B, Red Elstar, Arlet, Early Gold*) while others produced much more (*Jonagold, Jonagold Wilmuta, Gloster*). As clearly shown triploid cultivars (*Gloster, Jonagold, Jonagold Wilmuta*) that produced the greatest amount of nectar attracted fairly great number of bees (*Fig.* 1). Other cultivars, e.g. *Akane, Arlet,* produced much less abundant nectar but with greater sugar concentration. Honeybees, however, less visited the latter cultivars, than the ones with more nectar in their flowers (*Fig.* 1). Interestingly, two other cultivars with the smallest nectar production, *Golden Spur* and *Red Elstar* were abundantly visited by bees (*Fig.* 1).

Evaluating the sugar concentration of apple nectars we found that the grand mean was close to 40 per cent (39.92 %) and the extremes were 27.67 and 49.50 respectively (*Table* 1).

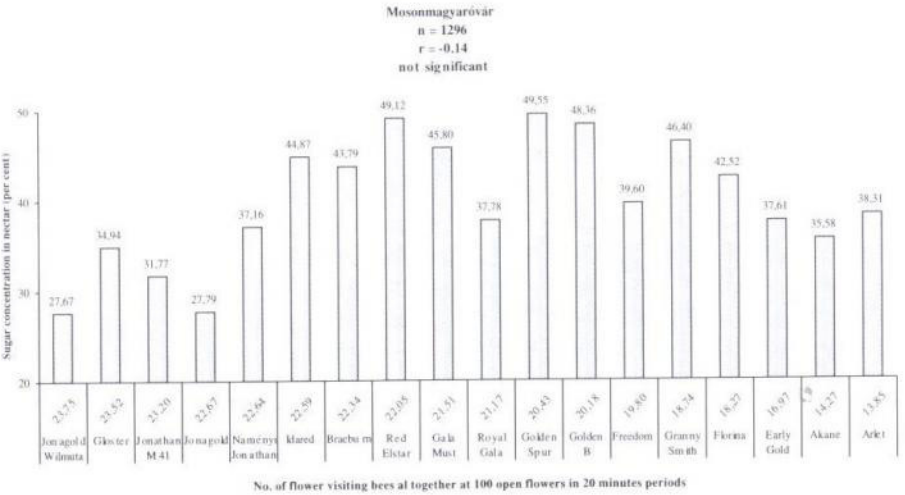

Figure 2. The effect sugar concentration in nectar of apple flowers to the intensity of bee visitation at flowering apple trees (honeybees and wild bees altogether)

Table 3. Comparing bee visitation and foraging behaviour of bees at the flowers of apple cultivars (Mosonmagyaróvár)

Culivar		Number of flower visiting bees on 100 open flowers in 20 minutes periods (n=1296) (based on the results of series of measurements made in the morning and at the afternoon)											
		Flower visiting bees in total			Honeybees							Wild bees	
					Pollen gatherer honeybees		Mixed behaviour honeybees		Nectar gatherer honeybees		Side worker honeybees		
		Mean	$SD_{5\ \%}$	Confidence intervals at p=5% level	Mean	Per cent to all honey bees	Mean	Per cent to all honey bees	Mean	Per cent to all honey bees	Mean	Per cent to all honey bees	Mean	Per cent to all flower visiting bees (100 % = 20.44)
1.	Akane	14.26	5.55	1.28	7.45	54.24	2.65	19.21	2.8	20.36	0.72	5.14	0.64	2.85
2.	Arlet	13.86	7.5	1.73	6.64	49.78	1.98	14.73	2.52	18.90	2.17	15.91	0.54	2.41
3.	Braeburn	22.34	6.7	1.55	12.01	55.83	3.11	14.38	6.08	28.24	0.42	1.91	0.72	3.21
4.	Early Gold	16.96	7.97	1.84	8.73	53.48	2.75	16.73	3.71	22.70	1.29	7.72	0.48	2.14
5.	Florina	18.27	8.18	1.89	9.34	53.11	2.75	16.52	3	17.04	2.44	13.52	0.75	3.34
6.	Freedom	19.8	6.58	1.52	11.13	58.39	3.34	17.40	3.19	16.73	1.32	6.76	0.83	3.70
7.	Gala Must	21.51	5.95	1.37	8.73	41.91	2.45	11.67	6.61	31.88	3.02	14.24	0.71	3.16
8.	Gloster	23.51	5.74	1.33	11.24	49.66	5.87	25.81	3.03	13.37	2.23	9.64	1.14	5.08
9.	Golden B	20.19	5.85	1.35	8.91	45.87	1.6	8.24	4.84	24.90	4.23	21.25	0.6	2.67
10.	Golden Spur	20.42	7.18	1.66	9.67	49.18	1.42	7.21	4.19	21.31	4.57	22.70	0.58	2.58
11.	Granny Smith	18.74	6.32	1.46	6.57	36.39	3.63	20.10	4.94	27.37	3.04	16.38	0.57	2.54
12.	Idared	22.59	6.81	1.57	11.22	51.58	3.67	16.84	4.67	21.51	2.02	9.05	1.02	4.54
13.	Jonagold	22.67	6.24	1.44	13.06	59.84	5.04	23.11	2.38	10.90	1.38	6.08	0.81	3.60
14.	Jonagold Wilmuta	23.75	6.18	1.43	12.84	56.14	7.26	37.09	1.75	7.65	1	4.28	0.9	4.01
15.	Jonathan M 41	23.19	6.65	1.54	13.53	60.59	5.03	22.38	3.21	14.40	0.34	1.50	1.08	4.81
16.	Naményi Jonathan	22.64	6.48	1.5	12.43	57.00	3.84	17.61	4.18	19.17	1.27	5.70	0.92	4.09
17.	Red Elstar	22.05	7.1	1.64	9.9	46.63	1.46	6.87	6.5	30.61	3.15	14.48	1.05	4.68
18.	Royal Gala	21.17	6.34	1.46	10.14	49.76	5.17	25.24	3.66	17.97	1.62	8.05	0.57	2.54
Means of the 3 years' measurements		**20.44**			*10.2*	*51.64*	*3.5*	*17.85*	*3.96*	*20.28*	*2.01*	*10.23*	**0.77**	**3.44**

Some cultivars (*Jonagold, Jonagold Wilmuta*) produced remarkably less than average while others (*Golden Spur, Golden B*) produced much more (*Table* 1). As far as the bee activity at the flowers of the inspected cultivars is concerned some cultivars with high sugar concentrations (*Braeburn, Idared, Red Elstar*) attracted more bees than other cultivars with similar sugar concentrations in their nectars (e.g. *Florina, Granny Smith*) *Fig.* 2).

Sugar content in apple nectars was found to be 0.83 mg/flower in average with extremes between 0.58 and 1.33 mg/flower (*Table* 1). Sugar content seemed to be less different between cultivars than the amount of nectar and its sugar concentration. Some cultivars, however, produced somewhat less (*Freedom, Akane, Early Gold, Arlet*) and others produced remarkably more (*Jonagold, Jonagold Wilmuta, Gloster*) than average (*Table* 1). Cultivars with more sugar production per flower tended to be more intensely visited by bees than the same with less sugar in their nectar (*Fig.* 3).

Comparing the nectar production of cultivars in the morning and at the afternoon most cultivars has show minor or no changes. This was the reason while the mean values for the morning and for the afternoon were

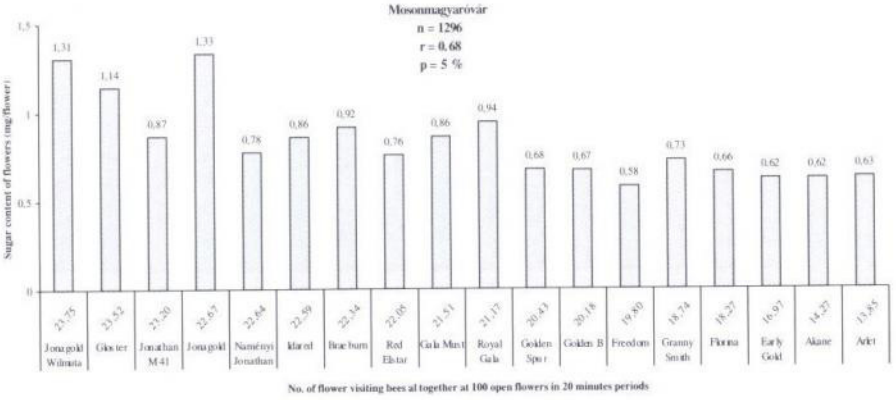

Figure 3. The effect sugar content in nectar of apple flowers to the intensity of bee visitation at flowering apple trees (honeybees and wild bees altogether)

Table 4. Bee visitation and foraging behaviour of bees at the flowers of apple cultivars in the morning: 10:00-12:00 (Mosonmagyaróvár)

Culivar		Number of flower visiting bees on 100 open flowers in 20 minutes periods based on the results of series of measurements made in the morning (n=648)											
		Flower visiting bees in total (all bee visits)			Pollen gatherer honeybees		Mixed behaviour honeybees		Nectar gatherer honeybees		Side worker honeybees		Wild bees	
		Mean	$SD_{5\%}$	Confidence intervals at p=5% level	Mean	Per cent to all honey bees visits	Mean	Per cent to all honey bees visits	Mean	Per cent to all honey bees visits	Mean	Per cent to all honey bees visits	Mean	Per cent to all honey bees visits
1.	Akane	11.53	3.61	1.18	5.92	51.3	2.46	21.31	2.74	23.77	0.28	2.46	0.13	1.16
2.	Arlet	10.45	5.13	1.67	4.67	44.67	1.73	16.54	2.48	23.7	1.38	13.22	0.2	1.87
3.	Braeburn	18.95	5.38	1.76	9.79	51.67	3.34	17.61	5.05	26.63	0.31	1.65	0.46	2.44
4.	Early Gold	13.33	5.95	1.94	6.98	52.4	2.21	16.61	3.25	24.38	0.78	5.83	0.11	0.79
5.	Florina	13.54	4.68	1.53	6.73	49.67	2.36	17.42	2.61	19.25	1.53	11.27	0.32	2.39
6.	Freedom	16.86	5.32	1.74	9.16	54.31	3.17	18.82	3.35	19.85	0.77	4.55	0.42	2.46
7.	Gala Must	17.8	4.09	1.33	7.19	40.38	2.47	13.86	5.39	30.27	2.26	12.68	0.5	2.81
8.	Gloster	20.36	5.2	1.7	9.03	44.35	4.98	24.46	4.19	20.57	1.51	7.42	0.65	3.2
9.	Golden B	16.73	4	1.31	7.4	44.22	1.44	8.59	4.16	24.88	3.2	19.15	0.53	3.16
10.	Golden Spur	15.53	4.35	1.42	7.42	47.81	0.74	4.75	3.67	23.65	3.42	22.02	0.27	1.77
11.	Granny Smith	14.51	4.25	1.39	4.84	33.39	3.09	21.31	4.22	29.08	1.94	13.37	0.41	2.85
12.	Idared	18.93	5.58	1.82	8.94	47.22	2.94	15.55	5.27	27.86	1.27	6.71	0.51	2.67
13.	Jonagold	18.92	4.53	1.48	10.11	53.44	3.43	18.12	3.92	20.71	0.8	4.24	0.66	3.48
14.	Jonagold Wilmuta	18.84	3.6	1.18	9.74	51.71	5.73	30.4	2.12	11.23	0.72	3.82	0.54	2.84
15.	Jonathan M 41	18.64	5.05	1.65	10.31	55.28	4.09	21.96	3.4	18.24	0.23	1.25	0.61	3.27
16.	Naményi Jonathan	18.18	4.37	1.43	9.43	51.85	3.36	18.47	4.29	23.61	0.51	2.8	0.59	3.27
17.	Red Elstar	16.47	3.9	1.27	6.83	41.46	1.14	6.91	5.78	35.07	2.14	12.99	0.59	3.57
18.	Royal Gala	15.93	3.2	1.04	6.57	41.26	4.5	28.28	4.09	25.65	0.71	4.45	0.06	0.36
Means of the 3 years' measurements		16.44			7.84	47.65	2.95	17.97	3.89	23.63	1.32	8.03	0.45	2.72

fairly similar (nectar production: 2.18 and 2.30, sugar concentration 40.30 and 39.58, sugar content 0.83 and 0.83 mg/flower) as show in *Table* 2. There were some cultivars only that produced remarkably more (*Idared*: 1.53 and 2.31, *Jonagold*: 4.43 and 4.88 mg/flower) or less nectar at the afternoon (*Arlet*: 1.82 and 1.14). Other cultivars produced similar amount in the morning and at the afternoon (*Table* 2). Even less differences were detected in the sugar concentration of nectars and the sugar content in that. At least half of the cultivars produced almost completely similar values in the morning and at the afternoon (*Table* 2). There was a single cultivar, *Idared,* the nectar of that contained remarkably more sugar at the afternoon than in the morning (0.74 and 0.96 mf/flower, respectively).

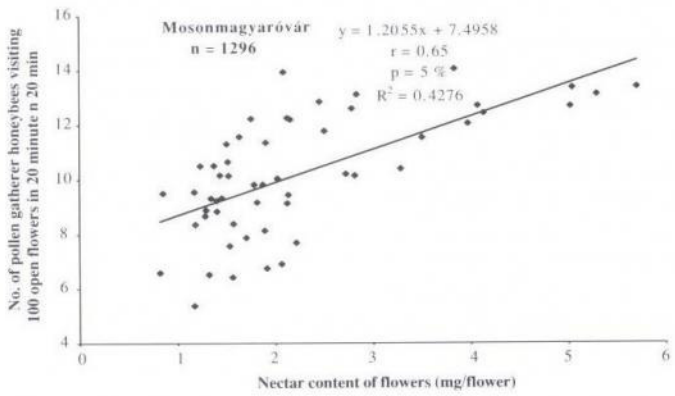

Figure 4. The effect of nectar production of apple flowers to the intensity of visitation by pollen gatherer honeybees at flowering apple trees

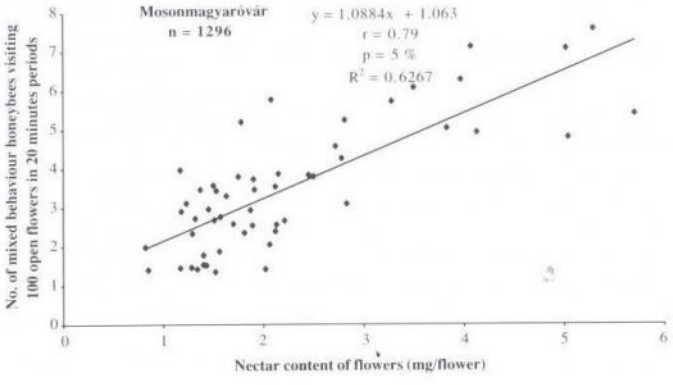

Figure 5. The effect of nectar production of apple flowers to the intensity of visitation by mixed behaviour honeybees at flowering apple trees

Table 5. Bee visitation and foraging behaviour of bees at the flowers of apple cultivars at the afternoon: 14:00–16:00 (Mosonmagyaróvár)

Culivar		Number of flower visiting bees on 100 open flowers in 20 minutes periods based on the results of series of measurements made in the morning (n=648)											
		Flower visiting bees in total (all bee visits)			Pollen gatherer honeybees		Mixed behaviour honeybees		Nectar gatherer honeybees		Side worker honeybees		Wild bees	
		Mean	$SD_{5\ \%}$	Confidence intervals at p=5% level	Mean	Per cent to all honey bees visits	Mean	Per cent to all honey bees visits	Mean	Per cent to all honey bees visits	Mean	Per cent to all honey bees visits	Mean	Per cent to all honey bees visits
1.	Akane	17	5.83	1.9	8.98	52.84	2.85	16.75	2.86	16.82	1.16	6.84	1.15	6.75
2.	Arlet	17.27	8	2.61	8.62	49.9	2.23	12.9	2.57	14.9	2.97	17.17	0.89	5.13
3.	Braeburn	25.72	6.2	2.02	14.22	55.28	2.88	11.22	7.11	27.62	0.53	2.06	0.98	3.82
4.	Early Gold	20.59	8.14	2.66	10.48	50.9	3.28	15.95	4.17	20.27	1.8	8.75	0.85	4.13
5.	Florina	23.01	8.23	2.69	11.96	51.99	3.14	13.64	3.39	14.72	3.35	14.55	1.17	5.1
6.	Freedom	22.73	6.48	2.12	13.1	57.62	3.5	15.38	3.0.3	13.33	1.87	8.22	1.24	5.45
7.	Gala Must	25.23	5.16	1.69	10.26	40.68	2.44	9.68	7.82	31.01	3.79	15.01	0.92	3.63
8.	Gloster	26.67	4.38	1.43	13.45	50.45	6.75	25.33	1.87	7	2.96	11.08	1.64	6.13
9.	Golden B	23.65	5.36	1.75	10.43	44.11	1.76	7.46	5.52	23.36	5.25	22.22	0.68	2.86
10.	Golden Spur	25.32	6.02	1.97	11.92	47.06	2.1	8.27	4.71	18.59	5.72	22.59	0.88	3.48
11.	Granny Smith	22.98	5.1	1.67	8.29	36.08	4.16	18.11	5.67	24.68	4.14	18.02	0.72	3.12
12.	Idared	26.25	5.94	1.94	13.5	51.42	4.4	16.74	4.07	15.49	2.76	10.52	1.53	5.83
13.	Jonagold	26.42	5.44	1.78	16.01	60.6	6.66	25.2	0.84	3.19	1.96	7.41	0.95	3.61
14.	Jonagold Wilmuta	28.65	3.86	1.26	15.93	55.59	8.79	30.69	1.38	4.81	1.28	4.48	1.27	4.42
15.	Jonathan M 41	27.74	4.67	1.53	16.75	60.38	5.96	21.48	3.0.3	10.92	0.45	1.62	1.55	5.6
16.	Naményi Jonathan	27.1	5.03	1.64	15.43	56.91	4.32	15.93	4.07	15.01	2.04	7.52	1.25	4.63
17.	Red Elstar	27.63	4.8	1.57	12.97	46.96	1.78	6.43	7.21	26.11	4.16	15.04	1.51	5.46
18.	Royal Gala	26.4	3.85	1.26	13.71	51.92	5.84	22.1	3.24	12.28	2.54	9.62	1.08	4.08
Means of the 3 years' measurements		24.47			12.56	51.32	4.05	16.54	4.03	16.48	2.71	11.06	1.13	4.6

Table 6. Relationship between the nectar parameters of apple flowers and the gathering behaviour of bees (Mosonmagyaróvár)

Gathering behaviour of bees at apple flowers	The effect of …								
	nectar production of flowers (mg/flower)	sugar concentration in nectar (per cent)	sugar content in nectar (mg/flower)	nectar production of flowers (mg/flower)	sugar concentration in nectar (per cent)	sugar content in nectar (mg/flower)	nectar production of flowers (mg/flower)	sugar concentration in nectar (per cent)	sugar content in nectar (mg/flower)
	during the whole day (n = 1296, at each column)			in the morning (10.00:-12:00) (n = 648, at each column)			at the afternoon (14:00-16:00) (n = 648, at each column)		
	… on the foraging behaviour of bees (correlation coefficients)								
pollen gatherer honeybees	**0.65***	**-0.51***	**0.64***	**0.54***	-0.37 n.s.	**0.54***	**0.7***	**-0.58***	**0.68***
mixed behaviour honeybees	**0.79***	**-0.73***	**0.74***	**0.74***	**-0.67***	**0.68***	**0.89***	**-0.84***	**0.83***
nectar gatherer honeybees	**-0.47***	**0.72***	-0.25 n.s.	-0.28 n.s.	**0.63***	0.02 n.s.	**-0.61***	**0.82***	-0.41 n.s.
side worker honeybees	-0.36 n.s.	**0.63***	-0.22 n.s.	-0.39 n.s.	**0.71***	-0.2 n.s.	-0.46 n.s.	**0.73***	-0.34 n.s.
flower visiting activity of wild bees	0.40 n.s.	-0.27 n.s.	**0.46***	0.27 n.s.	0.01 n.s.	0.36 n.s.	0.32 n.s.	-0.35 n.s.	0.36 n.s

* = values with an asterisk are significant at p=5 % level
n.s. = not significant

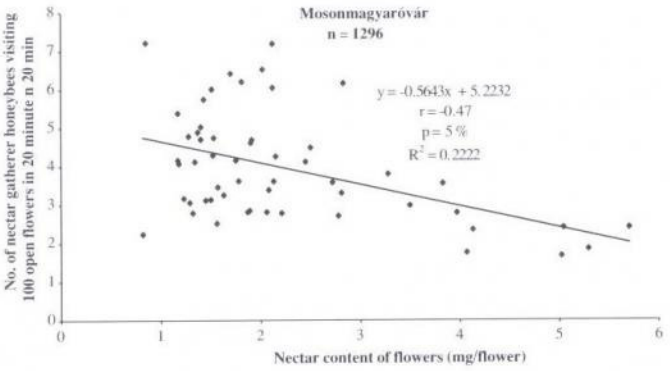

Figure 6. The effect of nectar production of apple flowers to the intensity of visitation by nectar gatherer honeybees at flowering apple trees

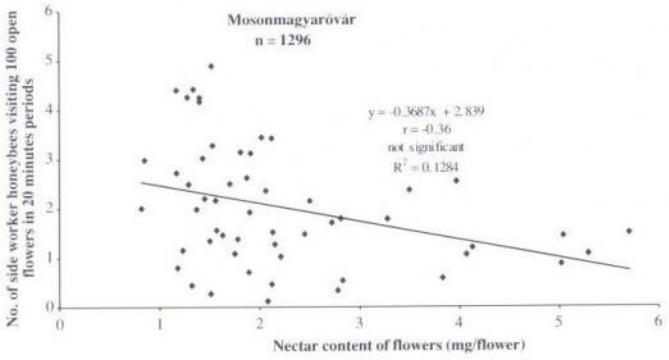

Figure 7. The effect of nectar production of apple flowers to the intensity of visitation by side worker honeybees at flowering apple trees

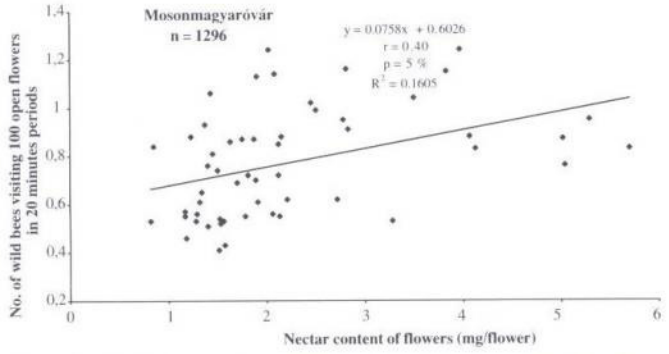

Figure 8. The effect of nectar production of apple flowers to the intensity of wild bee visitation at flowering apple trees

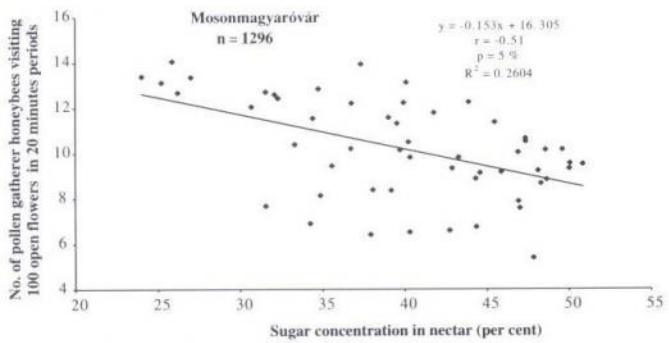

Figure 9. The effect of sugar concentration in apple nectar to the intensity of visitation by pollen gatherer honeybees at flowering apple trees

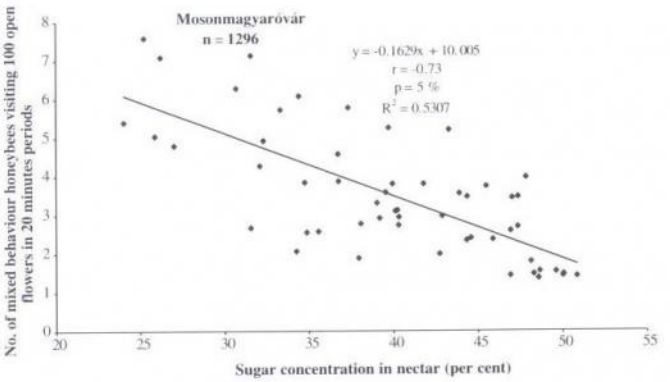

Figure 10. The effect of sugar concentration in apple nectar to the intensity of visitation by mixed behaviour honeybees at flowering apple trees

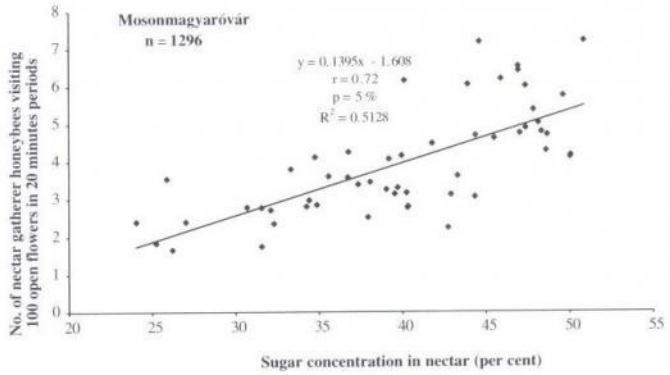

Figure 11. The effect of sugar concentration in apple nectar to the intensity of visitation by nectar gatherer honeybees at flowering apple trees

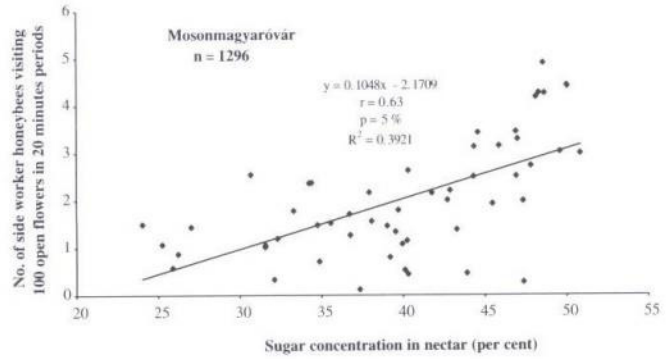

Figure 12. The effect of sugar concentration in apple nectar to the intensity of visitation by side worker honeybees at flowering apple trees

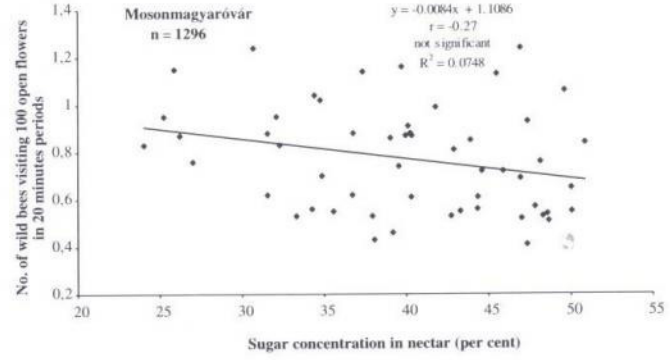

Figure 13. The effect of sugar concentration in apple nectar to the intensity of wild bee visitation at flowering apple trees

Foraging activity of bees and the behaviour of honeybees at the flowers of apple cultivars

Fairly abundant bee visitation was detected on flowering apple trees during our studies. Grand mean of bee visitation was as much as 20.44 at 100 open flowers in 20 minutes periods (*Table* 3). Taking not more than 5 hours as the period of intensive bee activity during the day this figure equals at least 3.07 bee visit at a single apple flower a day. Great majority of flower visiting insects were honeybees and not more than some 3.44 per cent of the total number of bee visits was made by wild bees (*Table* 3). Some *Osmia cornuta, Andrena flavipes, Anthophora acervorum, Bombus terrestris, Bombus lapidarius and Halictus sipmlex* were observed during the investigations but their abundance was very lo and so their flower visits were evaluated together. The mean number of wild bee visits was only some 0.77 per 20 minutes at 100 open flowers that equals approximately not more than 0.11 wild bee visits per one flower a day.

Intensity of bee visitation slightly differed among cultivars. Some of them (*Braeburn, Akane, Early Gold*) were less visited than others but the total bee visitation of other inspected cultivars was fairly similar (*Table* 3). Some cultivars were slightly more visited by wild bees (*Gloster, Jonathan M 41, Red Elstar, Idared, Naményi Jonathan, Jonagold Wilmuta*) than the rest of the cultivars (*Table* 3). Most honeybees were pollen gatherers on apple flowers; their mean ratio was as much as 51.64 per cent in flower visiting bee population at the experimental apple plantation. Ratio of pollen gatherers was fairly uniform among most of the cultivars, it ranged between 36.39 and 60.59 per cent but was round 50 per cent at most cultivars inspected (*Table* 3). Mixed behaviour bees (nectar gatherers with pollen loads) gave some 17.85 per cent of the total honeybee population visiting our apple trees. The extremes were more different than in the case of pollen gatherers, the extreme values being 6.87 and 37.09 per cent, respectively (*Table* 3). Much less mixed behaviour honeybees occurred at some cultivars (*Red Elstar, Golden Spur, Golden B, Gala must*) and more at others (*Jonagold Wilmuta, Gloster, Royal Gala*) than at the rest of cultivars. Pure nectar gatherer honeybees were much les frequent than pollen gatherers but slightly more abundant than mixed behaviour bees, their mean ratio was 20.28 per cent and the extremes were 6.87 and 37.09 per cent, respectively. Some varieties were much less frequented (*Jonagold Wilmuta, Jonagold, Gloster, Jonathan M 41*) and some other cultivars were much more visited by them (*Gala Must, Red Elstar, Braeburn*) than the majority of cultivars (*Table* 3). Interestingly, side worker honeybees occurred at each cultivar inspected (*Table* 3). Their mean ratio was rather high, as much as 10.23 per cent of the total honeybee visitation but the extremes were much more different of each other than at other behaviour classes, namely, the minimum ratio was only 1.50 but the maximum was 22.70 per cent (*Table* 3). Their ratio was very low at a number of cultivars (*Jonathan M 41, Jonagold Wilmuta, Akane, Naményi Jonathan, Jonagold*) but it was rather high at some others (*Golden Spur, Golden B*).

Comparing the intensity of bee visitation and the occurrence of behaviour classes in the morning and at the afternoon slight differences were detected (*Tables* 4–5). Somewhat more bees visited the flowering apples trees at the afternoon than in the morning (16.66 and 24.47 bee visits at 100 opening flowers during 20 minutes observation periods, respectively). The ratio of pollen gatherers and mixed behaviour bees honeybees was very similar at the two parts of the day but slightly more bees tended to gather deliberately for nectar as top worker nectar gather in the morning and more tended to be side worker nectar gatherers at the afternoon that at the other half of the day. Wild bee visitation tended to be somewhat more intense at the afternoon than in the morning (*Tables* 4–5).

The effect of nectar production to the intensity bee visitation and the gathering behaviour of honeybees at apple trees

Fairly great number of measurements was made parallel on the nectar parameters of apple cultivars and on the bee visitation at their flowers at the same trees; therefore, relationship between nectar production and bee activity was correlated to each other. It was found that nectar production (= nectar content) of flowers, sugar concentration in nectar and sugar content in flowers had a definite influence on bee activity (*Table* 6). Nectar production (= the amount of nectar) in flowers encouraged the activity of pollen gatherers (*Fig.* 4) and mixed behaviour bees (*Fig.* 5) at all instances. The correlation was positive and significant for the whole day as well as for the morning hours and the afternoon period (*Table* 6). In the case of nectar gatherers, on the other hand, the effect of the amount of nectar was negative (*Fig.* 6) at all instances and this relationship was significant for the whole day and for the afternoon (*Table* 6). Side worker nectar gatherer honeybees were also negatively (*Fig.* 7) while wild bees (*Fig.* 8) were positively correlated with the amount of nectar but the coefficient of correlation was not significant at any case (*Table* 6). Sugar concentration in nectar negatively affected the pollen gatherers (*Fig.* 9) and the mixed behaviour honeybees (*Fig.*10) and the correlation coefficients were significant statistically at most cases (*Table* 6). On the other hand, significant positive correlation was detected among the sugar concentration of nectars ant the activity of nectar gatherers (*Fig.* 11) as well as of side worker nectar gatherer honeybees (*Fig.* 12), the correlation coefficients have proved this for the whole day as well as for the morning and for the afternoon hours (*Table* 6). Interestingly, intensity of wild bee visitation was negatively correlated with the sugar concentration in nectars (*Fig.* 13) at all instances (*Table* 6) but the correlation coefficient was not significant at any case. The effect of sugar content in flowers was identical with that of the nectar content in flowers. Namely, the activity of pollen gatherers (*Fig.* 14) and mixed behaviour honey bees (*Fig.* 15) was in a significantly positive relationship with that but the activity of nectar gatherers (*Fig.* 16) as well as of side worker nectar gatherer honeybees (*Fig.* 17) was negatively affected by the sugar content in flowers, however these

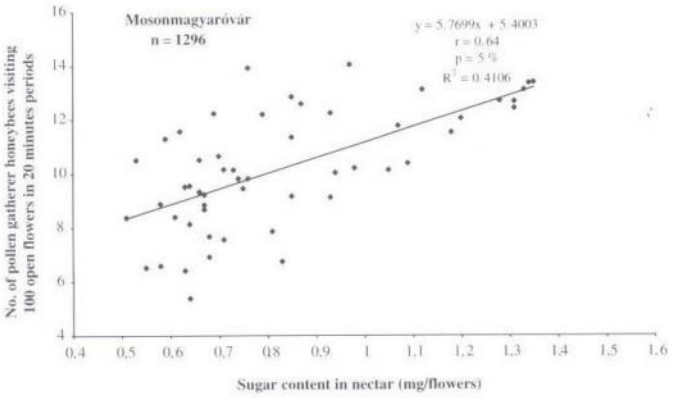

Figure 14. The effect of sugar content in apple nectar to the intensity of visitation by pollen gatherer honeybees at flowering apple trees

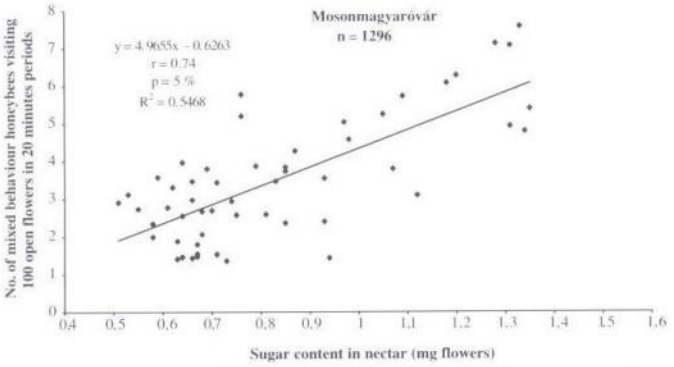

Figure 15. The effect of sugar content in apple nectar to the intensity of visitation by mixed behaviour honeybees at flowering apple trees

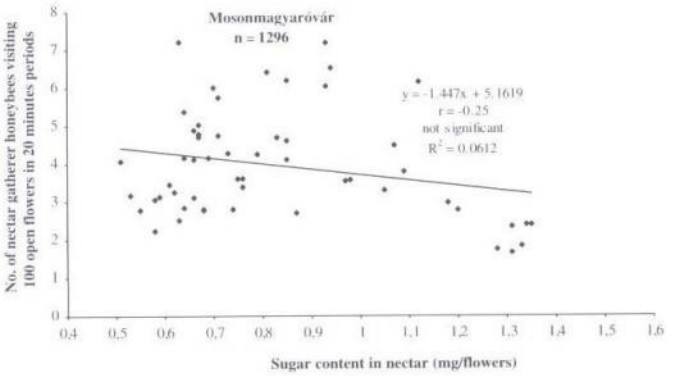

Figure 16. The effect of sugar content in apple nectar to the intensity of visitation by nectar gatherer honeybees at flowering apple trees

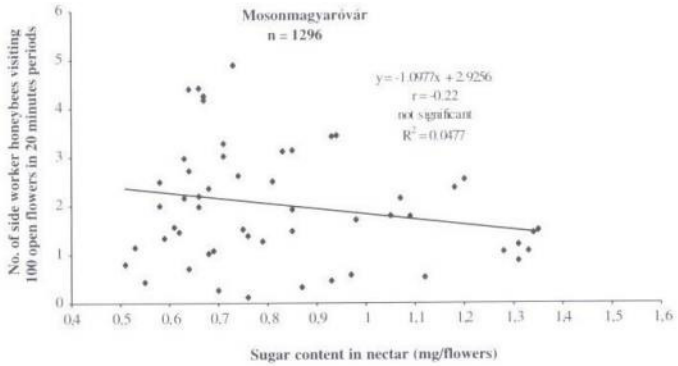

Figure 17. The effect of sugar content in apple nectar to the intensity of visitation by side worker honeybees at flowering apple trees

coefficients of correlations were not significant statistically (*Table* 6). Finally the activity of wild bees was positively affected by the sugar content (*Fig.* 18), the correlation was significant only for the whole day but not for the morning and the afternoon hours separately (*Table* 6).

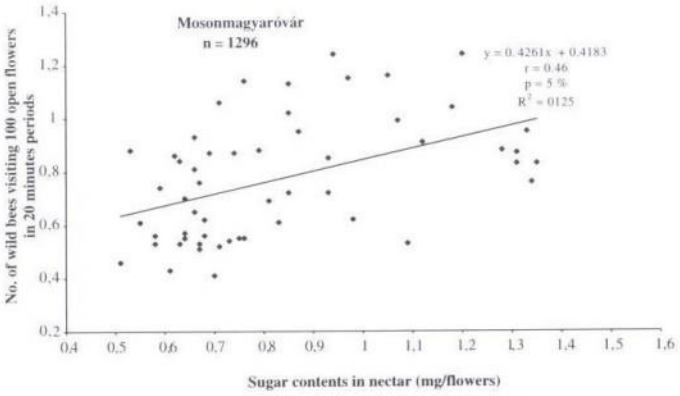

Figure 18. The effect of sugar content in apple nectar to the intensity of visitation by wild bees at flowering apple trees

Discussion and conclusions

Present results contribute to previous findings that nectar production (nectar content) of apple flowers is fairly different according to the cultivars and that nectar production (nectar content) of flowers is negatively correlated with the sugar concentration in nectar (*Free,* 1970; *Benedek* et al., 1974; *McGregor,* 1976; *Benedek & Nyéki,* 1996; *Benedek,* 1996; *Benedek,* 2003). Some investigated cultivars produced much less nectar than average (*Golden Spur, Golden B, Red Elstar, Arlet, Early Gold*) while others produced much more (*Jonagold, Jonagold Wilmuta, Gloster*). As clearly shown triploid cultivars (*Gloster, Jonagold, Jonagold Wilmuta*) that produced the greatest amount of nectar attracted fairly great number of bees (*Fig.* 1). Interestingly, at the majority of the inspected 18 cultivars the nectar production has shown minor or no changes in the morning and at the afternoon, however, some authors report on greater nectar production in the morning or at the afternoon (reviewed in *Free,* 1993; *Benedek,* 1996).

The nectar production (nectar content) of flowers clearly encouraged the total bee activity at apple trees at the 18 inspected cultivars during the three consecutive years of our investigations (r = 0.54, *Fig.* 1) but the effect was clearly different to bees with different gathering behaviour. This finding is in accordance with the earlier statements that bee activity in general is not clearly correlated to nectar production of flowers at fruit tree species in general; but in contrast, in the case of apple this relationship is clearly positive (*Benedek & Nyéki,* 1996). Accordingly, bees less frequented apple cultivars with smaller than with greater

nectar production in this study, too. We found that the more was the nectar content (nectar production) of flowers in this study the more was the sugar content in nectar (r = 0.95) in general, with the exception of some few cultivars. This was the explanation of the finding that sugar content of flowers also was in a strong positive correlation with the total bee activity (r = 0.88, *Fig.* 3) in spite of the fact that bees were unable to perceive the sugar content itself. However, it was well known that bees were able to perceive the nectar content of flowers (nectar production) and the sugar concentration of nectar and so they were visiting abundant nectar with greater sugar concentration most intensely in this study than less abundant nectars with smaller sugar concentration. When the amount of nectar was similar but the sugar concentration was different among apple cultivars bees visited the cultivar with more concentrated nectar. Comparing the bee visitation of apple flowers at different sections of the day we found that the activity was increasing only when abundant nectar production was combined with increasing sugar concentrations.

Nectar parameters, however, affected the bees with different types of gathering behaviour in different way. Intensive activity by pollen gatherer honeybees was observed at triploid cultivars that produced abundant nectar (*Gloster, Jonagold* and *Jonagold Wilmuta*). It is important to notice that these cultivars also produce abundant pollen and this character also affects bee behaviour definitely. Unfortunately, triploid pollen is not suitable to pollinate apple flowers successfully because its viability is very low. Therefore, triploid apples being highly attractive to honeybees can decrease the cross-pollination success in apple plantations when their ratio is high among the trees in an orchard. This fact should be taken into account when planning how to associate cultivars within an orchard (*Soltész* 1997). Some diploid cultivars with high nectar production were also highly frequented by pollen gathering honeybees (*Jonathan M 41, Naményi Jonathan*). Contrarily, diploids with high sugar concentrations in their nectar (*Gala Must, Golden B, Golden Spur, Red Elstar*) were most intensely visited by nectar gatherer and side worker nectar gatherer honeybees. The activity of pollen gatherer honeybees and of mixed behaviour bees (nectar gatherers with pollen loads) was, on the other hand, negatively correlated to the sugar concentration in the nectar (pollen gatherers: r = -0.51, *Fig.* 9; mixed behaviour bees: r = -0.73, *Fig.* 10). This finding probably can be explained by the fact that their behaviour was much more affected by the amount of pollen than by any nectar parameters. Accordingly, "mixed behaviour honeybees" should probably rather be called as "pollen gatherers with nectar load" instead of "nectar gatherers with pollen load", as widely used in literature (c.f. Free 1970, 1993).

The activity of ineffective side worker nectar gatherers was greatly encouraged by the sugar concentration in nectar (p = 0.63, *Fig.* 12), similarly to the pure nectar gatherer honeybees (r = 0.72, *Fig.* 11) landing on the top of the flowers and so pollinate the stigmas effectively. For the strong effect of sugar concentration there was a negative relationship between the nectar production (nectar content of flower) and the activity of these behaviour classes (nectar gatherers: r = -0.47, *Fig.* 6; side workers: r = -0.36, n.s., *Fig.* 7). This finding corroborates to our earlier statement that nectar gatherers are more affected by sugar concentration than by the amount of nectar in apple flowers (*Benedek* and *Nyéki*, 1997).

Wild bee visitation was very low as generally experienced in earlier observations published in the literature (reviewed in *Free*, 1970, 1993; *Benedek* et al., 1974). The wild bee species observed (*Osmia cornuta, Andrena flavipes, Anthophora acervorum, Bombus terrestris, Bombus lapidarius and Halictus simplex*) comprised some 3.44 per cent of the total bee visitation at apple flowers only. One flower received only some 0.11 wild bee visits per day while honeybee visitation was calculated to be some 3.07 bee visit at a single apple flower a day. Wild bee visitation was in a positive correlation to the nectar production (nectar amount) of flowers (r = 0,4, n.s., *Fig.* 8) and to the sugar content of nectar (r = 0.46, *Fig.* 18) but it was negatively correlated to the sugar concentration in nectar (r = -0,27, n.s., *Fig.* 13). The correlation, however, was not significant (except in case of nectar production) because their very low flower visiting activity was extremely variable. It should also be noted that wild bees (even *Bombus* queens) mainly collect pollen for feeding their offspring and/or founding the colony (bumblebees) in the early spring period when fruit trees are in flower and so the pollen production of flowers probably affects their activity much stronger than the nectar parameters.

Concluding the findings above we can state that the activity of pollen gatherers and mixed behaviour honeybees being the most effective pollinating agents among honeybees at fruit flowers is strongly encouraged by greater nectar production (greater nectar content) of apple flowers and so cultivars with higher nectar production are more intensely visited by them than cultivars with low nectar production. In spite of this fact their activity is probably dependent firstly on the amount of pollen in apple flowers. This is the reason why the sugar concentration that positively correlates to the activity of nectar gatherers is in a negative relationship to the activity of pure pollen gatherers and mixed behaviour bees. This clearly shows that the sugar concentration of nectar is of secondary importance for pollen collecting bees.

Pure nectar gatherers that are less effective pollinating agents than the pollen collecting ones and also side worker nectar gatherers being ineffective in flower pollination are greatly encouraged by the sugar concentration of apple nectar; but the amount of nectar is not a definite influence on their activity. In fact it is negatively correlated to their flower visiting activity. This is an important finding because side worker honeybees occurred at each cultivar inspected, however, their ratio varied widely among cultivars. It was very high at the Golden-type cultivars as discovered earlier by a number of authors (reviewed by *Free*, 1970, 1993) and it was high at some other cultivars too, as stated by *Benedek &*

Nyéki (1966) but it also occurred at least at a low rate at each of the inspected 18 cultivars. So we can draw the conclusion that, in contradiction with earlier believes, side worker nectar gathering is a general phenomenon in apple flowers. The activity of side workers depends first of all on the relative position of stamens and petals, it is most frequent at cultivars with rigidly standing stamens that leave a large space between them and the petal. However, low sugar concentration of nectars can probably moderate the activity of side workers and probably do not affect pollen gatherers and mixed behaviour bees.

Our result calls the attention to the importance of nectar parameters in the effective honeybee pollination of apple plantations. Most effective pollinating activity of honeybees can be expected in plantations with cultivars of high nectar production because this feature seems to encourage the activity of those behaviour classes (pure pollen gatherers and mixed behaviour bees) that are most effective pollinating agents among honeybees.

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