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Effect of intensity of bee visitation and the foraging behaviour of honeybees on the fruit set and yield of apple (*Malus domestica* Borkh.)

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Summary: Based on the results of our experiments, both the relative and the effective intensity of bee visitation were rather different depending on the cultivars as well as the time of the day. While it varied between relatively extreme values (40–80%) in the morning for the varieties examined, there were much smaller differences between the intensity of bee visitation at the afternoon, because the relative bee visitation attained 70–90% at each cultivar. These results showed that the differences arising from intensity of bee visitation of different cultivars should be taken into consideration more carefully in the morning in orchard planning and in estimating the number of honeybee colonies required.

The results showed that the greatest percentage of fruit set and the highest number of viable seeds per fruit were measured on branches of those cultivars that were most frequently visited by pure pollen gatherer bees as well as by bees collecting both nectar and pollen (mixed behaviour). The effect of pure pollen gatherers and of bees with mixed behaviour was highly significant from the statistical point of view on the fruit set and the number of viable seeds per fruit.

Those bees that were sucking nectar only from apple flowers did not proved to be effective pollinators at all. Relationship between their number and the fruit set as well as the number of viable seed per fruit were not significant because the coefficient of correlation was close to nil.

The ratio of side worker nectar gatherers was negatively correlated with the fruit set and the seed content of fruits of apple cultivars examined at both of our experimental sites, at Mosonmagyaróvár and Feketeerdő as well. The presence of side worker nectar gatherers resulted in higher decrease of fruit set and seed content of fruits at Feketeerdő than at Mosonmagyaróvár, especially in the morning.

The effect of flower visiting intensity by other pollinating insects was found to be fairly variable according to the time of the day. In the morning they had no effect on the fruit set as well as on the seed content of fruits either at Mosonmagyaróvár or at Feketeerdő. However, at the afternoon, when their intensity was greater, the correlation was a bit stronger.

Key words: apple, foraging behaviour of bees, fruit set and yield, honeybees, intensity of bee visitation, seed content of apples

Introduction

The role of insect pollinators, especially honeybees, in pollinating fruit trees has been recognized for a long time (*Free*, 1960).

It is proved experimentally the longer the effective time of bee pollination the higher the fruit set and the seed content of fruits as well (*Benedek* et al., 1974; *Free*, 1993; *Benedek*, 1996; *Benedek* & *Nyéki*, 1996a, 1996c; *Benedek* et al., 2000). The results clearly showed that the bee visitation of apple cultivars and the ratio of behaviour classes of honeybees could be largely different at different cultivars being at the same phase of their flowering (*Benedek* & *Nyéki*, 1996b).

Bee behaviour is known to be influenced by numerous interacting factors but the nectar and pollen production of flowers are the features that influence the attractiveness of fruit trees to bees over all (*Benedek* & *Nyéki*, 1996b). Apple pollen and nectar are eagerly collected by honeybees and play an important role in spring build-up of their colonies. It is to be considered that the apple trees flower in the early part of the spring when the honeybee colonies are low on stores and relatively weak, therefore the pollen stored in brood comb cells is the main supply of protein and vitamins for the larvae. Accordingly, the proportion of pollen gatherers is higher when the colonies need much pollen to increase brood (*Hellmich* and *Rothenbuhler*, 1986).

Benedek and *Nyéki* (1996b) found that the ratio of pure pollen-gatherers ranged between 40–60%, and the amount of pure nectar gatherers and of the bees with mixed behaviour (collecting both nectar and pollen) are rather changeable concerning different apple cultivars. The behaviour of bees and their flower constancy as well as the flower characters of apple cultivars determine their efficiency as pollinators (*Benedek* et al., 1989; *Free*, 1963, 1993).

Those honeybees that collect pollen deliberately on apple flowers (pure nectar gatherers and bees with mixed

behaviour) necessarily contact the anthers and the stigmas and work faster than nectar-gatherers. For this reason they are known to be more valuable and efficient pollinators (*Free*, 1993; *Benedek*, 1997).

A bee can collect nectar in the following ways: 1. Standing on the anthers and pushing its tongue as well as the front part of its body toward the nectaries and touching the stigmas and stamens and so can pollinate the flowers. 2. Landing on the petals and inserting its tongue to the nectaries through the „basal gaps" between the staminal filaments from the side of the flower without touching the flower organs and so cannot pollinate them. This type of behaviour is called to be side working (*Free*, 1993; *Benedek*, 1996).

Several authors (e.g. *Roberts*, 1945; *Free* and *Spencer-Booth*, 1964; *Robinson & Fell*, 1981; *Kuhn & Ambrose*, 1982; *DeGrandi-Hoffman* et al., 1985; *Benedek & Nyéki*, 1994) found that the ratio of side worker nectar gatherers depends on the structure of stamens of the apple varieties. At cultivars characterized by flowers with relatively upright and rigid stamens leaving a large space between petals and stamens, consequently the percentage of side worker bees increases, consequently the efficiency of pollination decreases.

In this study the aim of our experiments is to evaluate the effect of intensity of insect visitation as well as the foraging behaviour of honeybees on the fruit set and seed content of fruits at different apple cultivars both in the morning and at the afternoon. Our results can help to estimate the number of honeybee colonies necessary to pollinate a given apple orchard.

Material and method

Experiments were made at two sites in Hungary between 2001 and 2003, in a small experimental orchard with 7–12 year old trees of 18 cultivars in Mosonmagyaróvár and in a commercial plantation where small blocks were available with 10–12 year old trees of 6 cultivars at Feketeerdő. Apiaries were moved to both orchards just before the flowering had begun (3 strong honeybee colonies per ha).

Intensity of bee visitation and the foraging behaviour of honeybees on apple flowers

We made parallel observations at each cultivar examined whose intensity of flowering was approximately similar and their anthesis (anther dehiscence) had begun.

Two trees were selected per cultivar and bee visitation was observed on days with sunny weather being favourable for honeybee flight. Branches bearing 50 flowers were chosen per tree towards the northerly and southerly direction of the compass. Each branch was observed for 20 minute periods in the morning (8–12 a.m.) and at the afternoon (12–16 p.m.) and the number of bees visiting as well as the number of flowers visited by bees was counted.

Foraging behaviour of honeybees was also observed at each cultivar. Four kinds of behaviour classes were used related to food gathering behaviour of honeybees: pollen gatherers, nectar gatherers, bees with mixed behaviour (collecting both nectar and pollen) and side worker nectar gatherers. The fifth group was recruited from flower-visiting insects, other than honeybees, their numbers were also registered regardless of their food gathering behaviour.

The number of flowers visited by the whole pollinating insect population was counted as the relative bee visitation (percent). The effective bee visitation was calculated excluding the number of flowers visited by the ineffective pollinators (side worker honeybees and the pollinating insects of allotrophic, hemitrophic and the harmful distrophic groups).

Relationship between the intensity of bee visitation as well as the flower visiting behaviour of honeybees and the fruit set, and the seed content of fruits

Two trees were chosen per cultivar and the fruit set, yield and seed content of fruits were measured on the same branches where the intensity of bee visitation and the foraging behaviour of honeybees were observed. Treatments were as follows:

1. Pollination in the morning: we left uncovered the previously marked branches and caged them with parchment bags from 12 to 18 o'clock.
2. Pollination at the afternoon: we caged the branches from 6 to 12 o'clock and removed them afterwards from 12 o'clock.

Later fruit set and the seed content of fruits were measured on the branches.

The effect of bee visitation and foraging behaviour of honeybees on the fruit set and on the seed content of fruits was evaluated statistically (at P=5% level).

Results

Foraging behaviour of pollinating insects on apple flowers

We found that the half of the flower visiting insect populations were made of pure pollen gatherer honeybees, in the morning and at the afternoon but the proportion of pollen gatherers was greater (from 5 to 10%) at the afternoon than in the morning. The ratio of pure nectar gatherers and of bees with mixed behaviour and of side workers was fairly changeable depending on the cultivars examined and on the time of the day. The ratio of bees with mixed behaviour and of pure nectar gatherers ranged from 20 to 30% and of nectar gatherers approaching nectaries from the side was from 0 to 20%, respectively. The proportion of side worker bees was higher at the afternoon than in the morning, especially in days with favourable weather.

The ratio of other pollinating insects ranged from 1 to 5% on flowers of each cultivar, however, their proportion was

also higher at the afternoon. The wild *Apoidea* formed the highest percentage (from 90 to 95%) of this class. Notable amongst these were bumblebees, (*Bombus*) sweat bees (*Halictidae*), digger bees (*Andrenidae*) and mason bees (*Osmia – Megachilidae*) and they collected mainly pollen from the apple flowers. Various *Diptera* (*Syrphidae*, *Bombylidae*, *Bibionidae*, and *Muscidae*) had also been found on apple trees, but their population was not considerable at all. The rest of the other pollinating insects was recruited from the distrophic group but their population was also not abundant (*Table 1–2*).

Table 1. Foraging behaviour of honeybees and the ratio of pollinating insects other than honeybees insects in an experimental orchard (Mosonmagyaróvár, 2001–2003)

No. of cultivars	Number of flower visiting insects	Pollen gatherers (Mean and ratio, %)		Mixed behaviour (Mean and ratio, %)		Nectar gatherers (Mean and ratio, %)		Side workers (Mean and ratio, %) (Mean and ratio, %)		Other pollinators (wild bees)	
	per 100 flowers in 20 minute periods (8 a.m. – 16 p.m.)										
1.	14,26	7,45	52,22	2,65	18,59	2,80	19,63	0,72	5,07	0,64	4,49
2.	13,86	6,64	47,93	1,98	14,27	2,52	18,22	2,17	15,68	0,54	3,90
3.	22,33	12,00	53,75	3,11	13,93	6,08	27,20	0,42	1,88	0,72	3,24
4.	16,82	8,73	51,49	2,75	16,21	3,71	21,88	1,29	7,60	0,48	2,82
5.	18,27	9,34	51,13	2,75	15,04	3,00	16,40	2,44	13,33	0,75	4,10
6.	19,80	11,10	56,21	3,34	16,85	3,19	16,11	1,32	6,66	0,83	4,18
7.	21,52	8,73	40,56	2,45	11,41	6,61	30,70	3,02	14,04	0,71	3,29
8.	23,51	11,20	47,81	5,87	24,95	3,03	12,87	2,23	9,50	1,14	4,86
9.	20,20	8,91	44,16	1,60	7,93	4,84	23,99	4,23	20,94	0,60	2,98
10.	20,43	9,67	47,35	1,42	6,94	4,19	20,51	4,57	22,37	0,58	2,83
11.	18,74	6,57	35,04	3,63	19,35	4,94	26,38	3,04	16,22	0,57	3,02
12.	22,59	11,20	49,66	3,67	16,24	4,67	20,67	2,02	8,92	1,02	4,51
13.	22,67	13,10	57,61	5,04	22,25	2,38	10,50	1,38	6,08	0,81	3,55
14.	23,75	12,80	54,05	7,26	30,58	1,75	7,36	1,00	4,22	0,90	3,79
15.	23,19	13,50	58,33	5,03	21,67	3,21	13,86	0,34	1,47	1,08	4,67
16.	22,78	12,40	54,88	3,84	16,95	4,18	18,46	1,27	5,62	0,92	4,08
17.	21,16	10,10	47,91	5,17	24,42	3,66	17,31	1,62	7,67	0,57	2,68
18.	22,05	9,90	44,90	1,46	6,61	6,50	29,46	3,15	14,27	1,05	4,76
Mean (2001–2003)	20,44	10,20	49,72	3,50	16,90	3,96	19,53	2,01	10,09	0,77	3,76

Cultivars: 1. Akane; 2. Arlet; 3. Braeburn; 4. Early Gold; 5. Florina; 6. Freedom; 7. Gala Must; 8. Gloster; 9. Golden B; 10. Golden Spur; 11. Granny Smith; 12. Idared; 13. Jonagold; 14. Jonagold Wilmuta; 15. Jonathan M 41; 16. Naményi Jonathan; 17. Ozark Gold; 18. Red Elstar

Table 2. Foraging behaviour of honeybees and the ratio of pollinating insects other than honeybees in a commercial apple orchard (Feketeerdő, 2001–2003)

No. of cultivars	Number of flower visiting insects	Pollen gatherers (Mean and ratio, %)		Mixed behaviour (Mean and ratio, %)		Nectar gatherers (Mean and ratio, %)		Side workers (Mean and ratio, %)		Other pollinators (wild bees) (Mean and ratio, %)	
1.	20,82	9,86	47,33	4,20	20,18	5,90	28,31	0,33	1,57	0,54	2,60
2.	21,71	9,82	45,22	4,87	22,42	2,70	12,43	3,59	16,56	0,87	4,01
3.	20,17	8,90	44,15	1,53	7,56	5,45	27,03	3,75	18,61	0,54	2,65
4.	20,73	10,80	52,03	3,38	16,29	4,93	23,77	1,92	9,27	0,82	3,94
5.	23,97	13,80	57,36	4,63	19,30	3,20	13,34	1,31	5,45	1,09	4,55
6.	23,49	10,30	43,89	1,26	5,35	7,03	29,91	4,15	17,69	0,74	3,16
Mean (2001–2003)	21,82	10,57	48,33	3,31	15,18	4,87	22,47	2,51	11,53	0,77	3,49

Cultivars: 1. Braeburn; 2. Gloster; 3. Golden B; 4. Idared; 5. Jonagold Wilmuta; 6. Red Elstar

The side worker nectar gatherers appeared at each cultivar, but this behaviour was rather frequent at the following varieties: Arlet, Gala Must, Gloster, Golden B, Golden Spur and Red Elstar. (Their ratio ranged from 15 to 22% of the pollinating insect population). This type of foraging behaviour greatly influences the effectiveness of bee pollination at apple (as it has been proved for Delicious, especially Red Delicious for a long time). We found that the percentage of apple flowers visited by honeybees foraging for pollen only, for nectar and pollen, for nectar only, was 50–68, 9–27 and 8–17%, respectively. The percentage of apple flowers visited by side workers ranged from 1 to 13% depending on cultivars. The proportion of flowers visited by other pollinating insects was relatively low; it was only 2 or 3%.

Intensity of honeybee visitation according to the number of flowers visited by bees

The relative bee visitation of examined cultivars was also found to be more variable in the morning than at the afternoon. In the morning we measured greater differences between the relative bee visitation of inspected cultivars (from 40 to 80%), than at the afternoon (from 70 to 90 %).

The effective bee visitation of cultivars was more changeable than the relative bee visitation. The effectiveness of bee visitation was diminished due to number of ineffective pollinators, mainly of side worker nectar gatherers, that are known not to touch the stigmas and anthers and thus not contribute to the effective pollination of apple flowers.

The comparison relating to the examined cultivars showed that the ratio of side worker bees as well as the number of flowers visited by them could be largely different at cultivars inspected. We found that the efficacy of pollination could be decreased by 2–10%. The intensity of visitation of side worker nectar gatherers was definitely high on the following cultivars: Arlet, Gala Must, Gloster, Golden B, Golden Spur, Granny Smith and Red Elstar. 9–12% of flower visits were made by side workers at these cultivars.

It is to be noted that the decrease of effectiveness of pollination proved to be greater in the morning, when the relative bee visitation was lower, than at the afternoon.

The average bee visitation of cultivars, that was examined at both experimental sites simultaneously, was some percent lower at Feketeerdő than that at the same cultivars at Mosonmagyaróvár (*Table 3*).

Table 3. Intensity of honeybee visitation at apple flowers.
(Mosonmagyaróvár – with no asterisk and Feketeerdő – with an asterisk, 2001–2003)

	Cultivar	Relative	Effec-tive	Relative	Effec-tive	Relative	Effec-tive
		Bee visitation (per 100 flowers in 20 minute periods)					
		8–12 a.m.		8–12 a.m.		Mean	
1.	Akane	46,32	45,79	72,13	68,78	59,22	57,28
2.	Arlet	42,82	39,31	70,92	63,23	56,87	51,27
3.	Braeburn	79,54	78,80	106,96	105,56	93,25	92,19
	Braeburn*	70,75	70,62	100,15	98,71	85,45	84,65
4.	Early Gold	55,22	53,46	83,59	79,12	69,40	66,28
5.	Florina	56,73	51,95	94,32	85,75	75,52	68,84
6.	Freedom	72,35	70,82	98,02	93,32	85,18	82,07
7.	Gala Must	67,33	61,73	93,99	84,78	80,66	73,26
8.	Gloster	81,92	77,88	112,40	104,71	97,16	91,29
	Gloster*	69,19	62,53	103,31	92,07	86,25	77,35
9.	Golden B	62,05	54,55	88,06	75,94	75,05	65,23
	Golden B*	55,36	48,74	94,20	83,06	74,78	65,90
10.	Golden Spur	59,14	51,64	96,74	84,00	77,94	67,81
11.	Granny Smith	51,81	47,24	83,83	73,96	67,82	60,61
12.	Idared	75,22	71,97	107,08	100,14	91,15	86,05
	Idared*	64,94	62,47	109,46	102,73	87,20	82,60
13.	Jonagold	77,08	76,32	116,07	111,23	96,58	94,77
14.	Jonagold Wilmuta	81,35	80,89	122,15	118,53	101,75	99,70
	Jonagold Wilmuta*	82,24	79,53	119,72	114,87	100,98	97,18
15.	Jonathan M 41	77,59	76,95	122,15	121,05	99,87	99,00
16.	Naményi Jonathan	76,84	75,46	114,44	109,18	95,64	92,33
17.	Ozark Gold	62,32	60,41	109,48	102,74	85,90	81,57
18.	Red Elstar	57,74	52,69	101,37	91,94	79,55	72,32
	Red Elstar*	61,84	54,79	106,81	94,13	84,33	74,46

Relationship between the intensity of honeybee visitation as well as the flower visiting behaviour of honeybees and the fruit set and seed content of fruits

We measured the highest percentage of fruit set and the highest number of seed content of fruits at those cultivars that were the most favourable for bees. At the afternoon the free pollination resulted in greater fruit set, furthermore, the average mass of apples was higher and the fruits had more developed seeds (morning – fruit set: 4–10%, viable seeds: 6–9 per fruit; afternoon – fruit set: 8–17%, viable seeds: 7–10 per fruit) (*Table 4*).

The relationship between the number of pollinating insects visiting apple flowers and the fruit set as well as the seed content of fruits proved to be fairly strong (fruit set: r=0,64–0,85, viable seeds per fruit: r=0,41–0,88). It is stressed that the correlation was even stronger without taking the ratio of side worker nectar gatherers and of the harmful pollinating insects, the distrophic pollinator beetles into account (Fruit set: r=0,93–0,96, viable seeds per fruit: r=0,91–0,97).

Those cultivars that were the most intensively visited by bees set approximately 12 or 13 apples per 100 flowers and the number of developed seeds was even 8–9 per fruit. Cultivars with less intense bee visitation gave a 2–5% decrease in the fruit set and the number of viable seeds ranged from 7 to 8 per apple. The fruit set of those cultivars that were least preferred by bees had been diminished by as much as half compared with the set of cultivars visited most intensively. Their fruits had only 6–7 viable seeds, however, about six or seven seeds are enough to obtain a good fruit set (*Hartman & Howlett*, 1954).

The results showed that the greatest percentage of fruit set and the highest number of viable seeds per fruit were measured on branches of those cultivars that were visited the most frequently by pure pollen gatherer bees as well as bees collecting both nectar and pollen (Braeburn, Gloster, Idared, Jonagold, Jonagold Wilmuta, Jonathan M 41, Naményi Jonathan, Ozark Gold and Red Elstar). The fruit set of cultivars mentioned above was more than 5–10%, that level was found to be a turning point for the economic yield for apples (*Free*, 1966, 1993; *Benedek & Nyéki*, 1996a). The effect of pure pollen gatherers and of bees with mixed behaviour on the fruit set and the number of viable seeds per fruit was highly significant from the statistical point of view (pure pollen gatherers – fruit set: r=0,75–0,9, viable seeds: r=0,64–0,89; bees with mixed behaviour – fruit set: r=0,61–0,69, viable seeds: r=0,63–0,7) (*Figures* 1 to 4).

Table 4. Effect of the bee pollination on the yield of apple cultivars in the morning and at the afternoon (Mosonmagyaróvár – with no asterisk and Feketeerdő – with an asterisk, 2001–2003)

Cultivars		Free pollination (8–12 a.m.)			Free pollination (12–16 p.m.)		
		Fruit set (%)	Average mass of fruits (g)	Viable seeds per fruit	Fruit set (%)	Average mass of fruits (g)	Viable seeds per fruit
1.	Akane	5,02	138,60	6,75	8,23	138,18	7,13
2.	Arlet	5,27	138,95	6,42	7,93	147,23	7,33
3.	Braeburn	11,04	152,82	9,23	15,76	155,82	9,68
	Braeburn*	10,25	152,78	9,17	14,49	157,02	9,54
4.	Early Gold	5,96	164,99	6,35	10,97	173,59	8,05
5.	Florina	4,93	170,82	6,15	9,69	176,26	7,69
6.	Freedom	7,60	205,69	7,17	12,00	219,79	8,78
7.	Gala Must	5,81	153,07	6,72	12,55	160,10	9,14
8.	Gloster	8,08	199,11	8,00	14,28	208,57	9,24
	Gloster*	6,60	197,67	8,20	16,32	201,67	8,85
9.	Golden B	4,73	186,31	6,34	10,33	190,05	8,00
	Golden B*	4,18	186,65	6,31	11,05	190,66	8,39
10.	Golden Spur	4,81	161,47	6,23	12,11	171,28	8,50
11.	Granny Smith	4,69	156,80	6,36	9,85	162,62	7,84
12.	Idared	8,65	189,67	8,88	15,71	194,18	9,33
	Idared*	7,77	188,94	7,86	15,68	191,54	9,22
13.	Jonagold	9,56	263,31	9,42	15,96	265,70	9,64
14.	Jonagold Wilmuta	9,60	249,53	9,32	16,23	253,44	9,79
	Jonagold Wilmuta*	10,46	251,76	9,23	16,68	254,80	9,50
15.	Jonathan M 41	10,10	133,35	9,03	16,92	144,03	9,85
16.	Naményi Jonathan	9,57	142,50	9,11	16,22	148,27	9,68
17.	Ozark Gold	7,01	149,67	7,64	15,70	157,28	9,63
18.	Red Elstar	6,24	168,44	7,13	14,87	179,06	9,29
	Red Elstar*	6,64	167,32	7,32	15,49	172,75	9,05

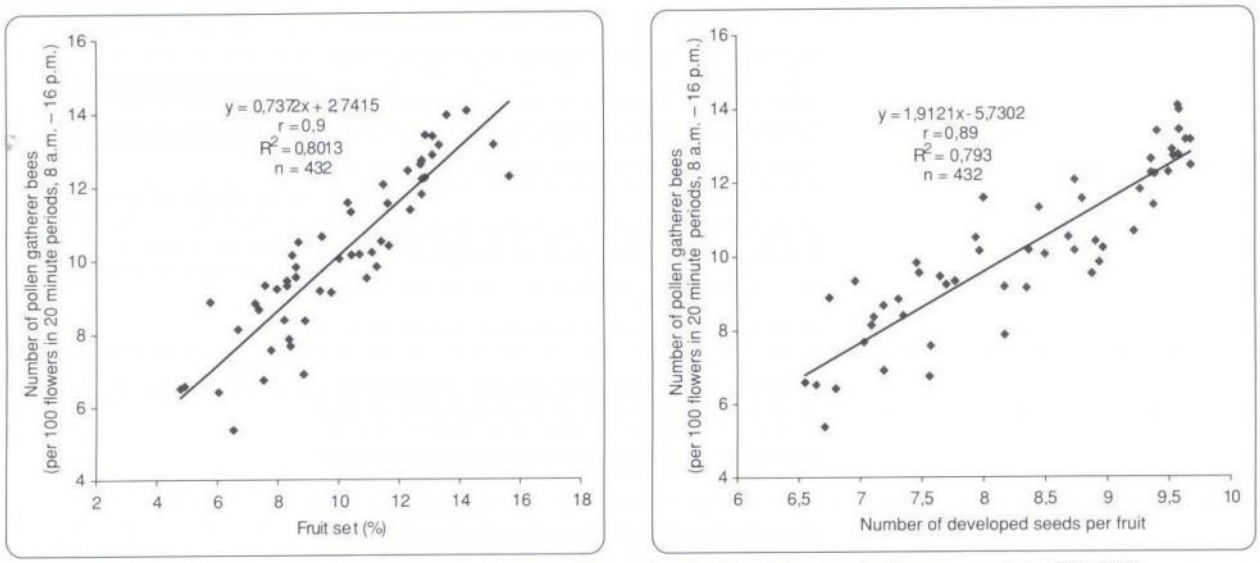

Figure 1–2. The effect of pollen gatherer honeybees on the fruit set and the number of viable seeds per apple (Mosonmagyaróvár, 2001–2003)

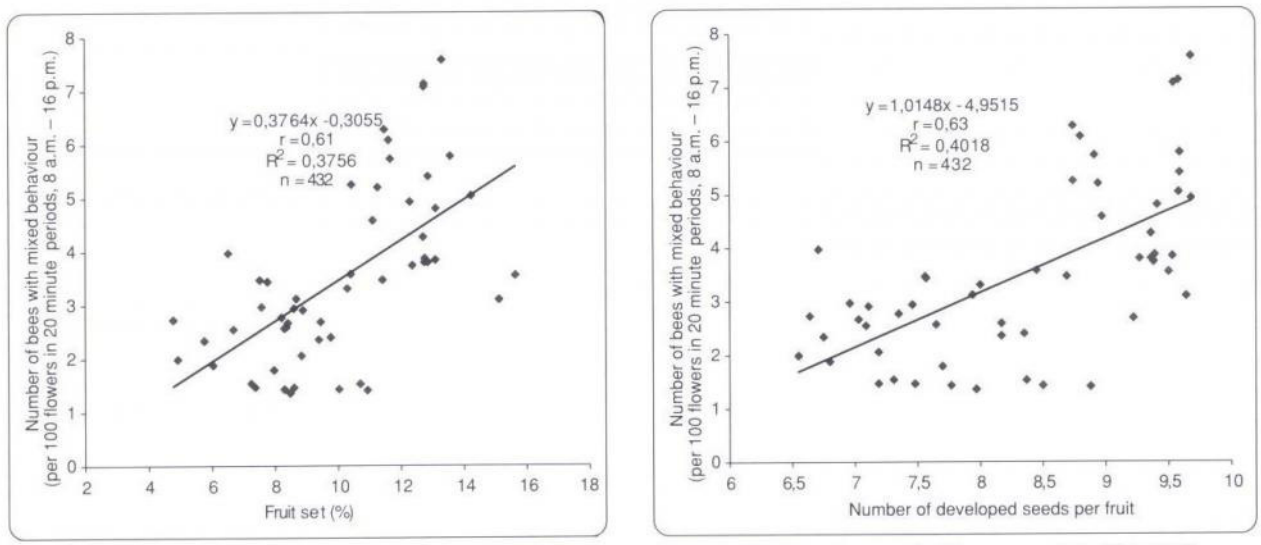

Figure 3–4. The effect of honeybees with mixed behaviour on the fruit set and the number of viable seeds per apple (Mosonmagyaróvár, 2001–2003)

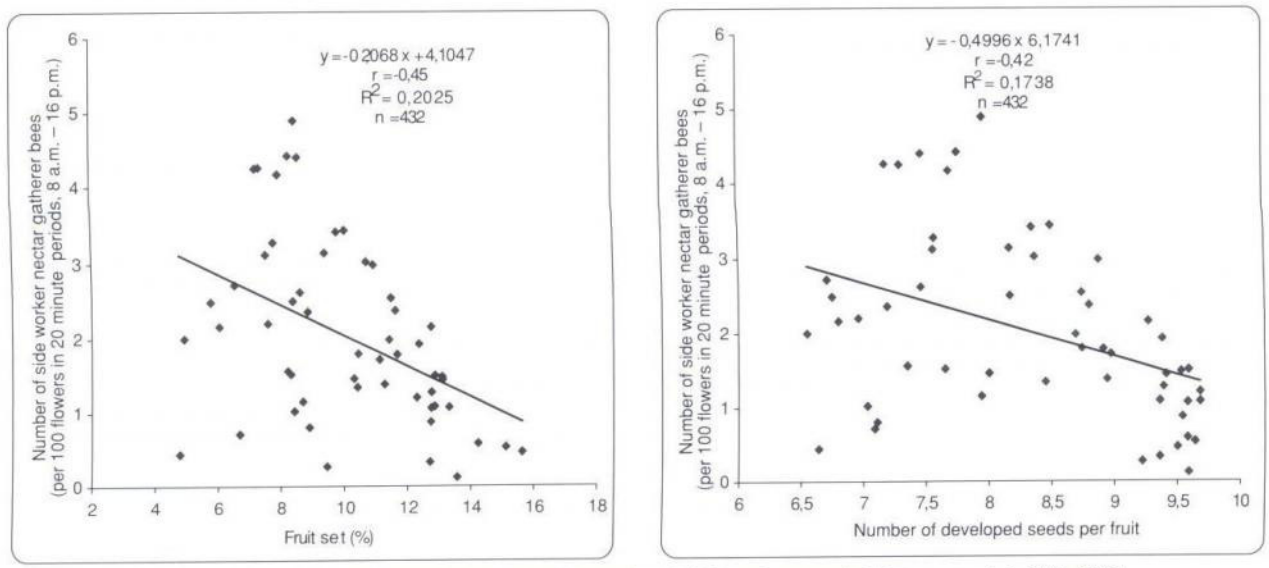

Figure 5–6. The effect of side worker honeybees on the fruit set and the number of viable seeds per apple (Mosonmagyaróvár, 2001–2003)

Based on our data, the pure pollen gatherer bees proved to be much more effective pollinators than bees with mixed behaviour at Mosonmagyaróvár. However, at the apple orchard at Feketeerdő the effectiveness of bees collecting both nectar and pollen was as much as that of bees foraging pollen only, furthermore, sometimes it was higher than that of pure pollen gatherers.

Those bees that were sucking nectar only on apple flowers did not proved to be effective pollinators at all. Relationship between their number and fruit set as well as the number of developed seeds per fruit were not significant, because the coefficient of correlation was close to nil, however, all figures were negative (fruit set: r=0,01– -0,33, viable seeds: r=0,03– -0,24).

The ratio of side worker nectar gatherers was in a negative correlation with the fruit set and the number of viable seeds of apple cultivars examined both at Mosonmagyaróvár and Feketeerdő. The presence of side worker nectar gatherers resulted in higher decrease of fruit set and seed content of fruits at Feketeerdő than at Mosonmagyaróvár, especially in the morning (Mosonmagyaróvár, in the morning – fruit set: r=-0,49, viable seeds: r=-0,53, at the afternoon – fruit set: r=-0,35, viable seeds: r=-0,31; Feketeerdő, in the morning – fruit set: r=–0,79, viable seeds: r=–0,7, at the afternoon – fruit set: r=–0,23, viable seeds: r=–0,74) (*Figures* 5 to 6).

The effect of activity of other pollinating insects was found to be fairly variable according to the time of the day. In the morning they had no effect on the fruit set as well as on the number of viable seeds of fruits either at Mosonmagyaróvár or at Feketeerdő (fruit set: r=0,11–0,41, viable seeds: r=0,22–0,37), but at the afternoon, when their activity was more intense, the correlation was a bit stronger (fruit set: r=0,47–0,65, viable seeds: r=0,31–0,44) (*Figures* 7 to 8).

Discussion and conclusions

Our results showed that the pure pollen gatherer honeybees formed the highest percentage of the pollinating insect population visiting apple flowers of cultivars examined. Both in the morning and at the afternoon more than a half of the flower-visiting honeybees collected pollen only, but their proportion was 5–10% higher at the afternoon. The ratio of bees with mixed behaviour and of pure nectar gatherers both appeared to be less than one third of the pollinating insect population (from 20 to 30%).

According to our data, we found that each cultivar examined more or less encouraged bees to land on petals and to reach the nectaries through the basal gaps between petals and stamens without touching them. The proportion of those nectar gatherers that approached the nectaries from the side was found to be changeable depending on cultivars, their percentage ranged from 0 to 20%. This type of behaviour can appear especially at apple cultivars, because in contrast to spreading stamens of the flowers of other fruit species (e.g. pear, cherry, plum, peach and apricot), those of apple are relatively erect and rigid that can enable bees to obtain nectar from the side (*Robert*, 1945; *Free*, 1960, 1963).

The ratio of side worker nectar gatherers was fairly high (15–20%) at the following varieties: Arlet, Gala Must, Gloster, Golden B, Golden Spur, Granny Smith and Red Elstar. These cultivars belong to the Delicious group (except Granny Smith) that is known to has flowers with relative upright and rigid stamens leaving a large space between stamens and petals and enabling bees to approach nectaries from the side (*Free* and *Spencer-Booth*, 1964; *Robinson*, 1979; *Benedek* and *Nyéki*, 1994). Contrarily, their proportion was very small at the two triploid cultivars inspected; however, these originated from Jonathan and Delicious (*Soltész & Szabó*, 1998).

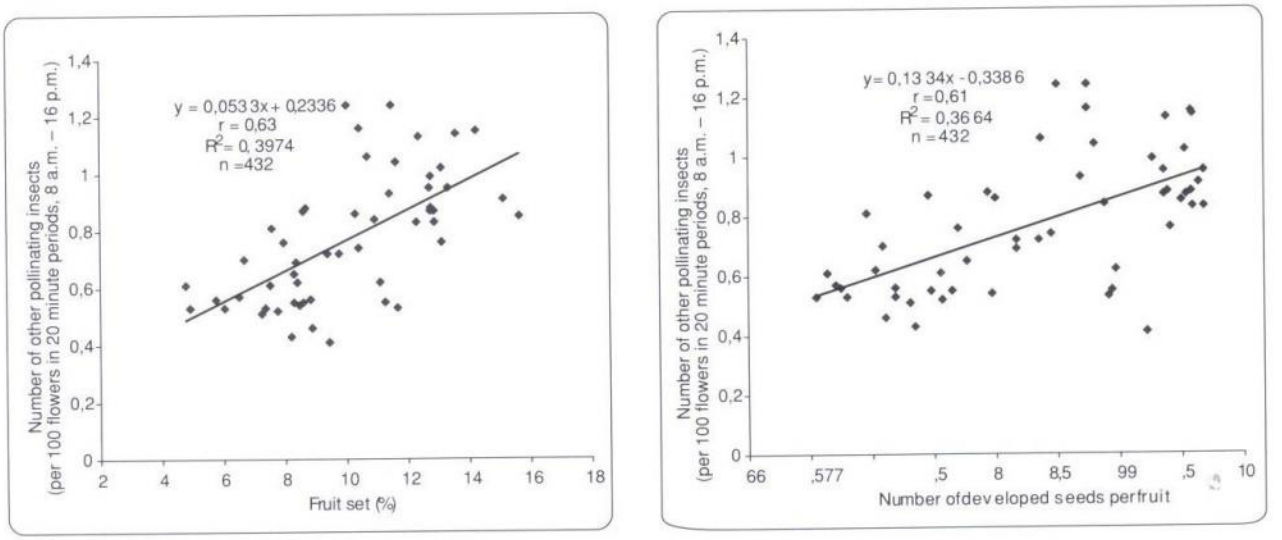

Figure 7–8. The effect of pollinating insects other than honeybees (wild bees and flies, excluding distrophic beetles) on the fruit set and the number of viable seeds per apple (Mosonmagyaróvár, 2001–2003)

Only very small proportion of the pollinating insects was recruited from other pollinators (from 2 to 5%) and it mainly was comprised of wild *Apoidea*: bumblebees (*Bombus terrestris*, *Bombus lapidarius*), as well as another wild bees (including the genera *Andrena*, *Halictus* and *Osmia*) and the rest was given by syrphid flies (*Syrphidae*) and some harmful beetle species (*Cetonia aurata*, *Epicometis hirta*, *Meligethes aeneus*).

We found differences between the relative and effective intensity of bee visitation of apple cultivars examined, accordingly, the pollinating efficiency of bees visiting them was different. In the morning there were larger differences in the intensity of bee visitation at different cultivars than at the afternoon. The weather conditions usually tend to be more favourable for bee flight at the afternoon, and the peak period of pollen presentation of apple is approximately between 12 and 16 o'clock, therefore, the attractiveness of flowers to bees is greater at the afternoon than in the morning. (*Percival*, 1955).

This is very important, because the most favourable pollination can only be expected when the relative attractiveness of flowers as well as the relative bee visitation of the main and the pollinizer cultivars is fairly similar (*Benedek & Nyéki*, 1996a). To take this statement into account, cultivars with similar attractiveness both in the morning and at the afternoon should be chosen and coupled.

The proportion of side worker nectar gatherers more or less resulted in the decrease of the efficiency of pollination (from 2 to 10% depend on cultivars).

Comparing the behaviour of bees visiting apple flowers, we found that pure pollen gatherers and the bees with mixed behaviour were the most effective pollinators. We have measured the highest fruit set and viable seed content of fruits at those cultivars that were visited by the greatest number of pure pollen gatherers as well as of bees collecting both nectar and pollen. Correlation was rather strong to all of data available (pure pollen gatherers – fruit set: r=0,75–0,93, viable seeds: r=0,66–0,91; bees with mixed behaviour – fruit set: r=0,64–0,72, viable seeds: r=0,66–0,74).

The effect of pure nectar gatherers on the fruit set and the viable seed content of fruits was not significant at all, coefficient of correlation was close to nil and all figures went to minus (fruit set: r=0,01– -0,34, viable seeds: r=0,03– -0,27). Accordingly, this behaviour type of bees proved to have a negligible role in pollination, although those nectar gatherer bees that are approaching the flowers from the top and sucking nectar by inserting their tongues between the stamens and stigmas and so touching them may contribute to pollinate the stigmas more or less.

The reason for the pure nectar gatherer bees failed to transfer pollen effectively might be the fact that they collected nectar from flowers with stigmas not receptive yet or already lost receptivity. It can also be a possible reason that the anthers did not begin to dehisce at those flowers that the bees collected for nectar, and the pollen grains on the bodies of nectar gatherer bees might had a decreased viability or the stigmas did not receive adequate amount of pollen from body hair of nectar gatherer bees.

We found that the side worker nectar gatherers had a negative effect on the fruit set and the seed content of fruits at both orchards examined (fruit set: r=-0,52– -0,65, viable seeds: r=-0,45– -0,85), although their negative influence was not significant from the statistical point of view at Mosonmagyaróvár. Their presence led to higher decrease of fruit set and of the amount of viable seeds per fruit at Feketeerdő than at Mosonmagyaróvár, especially in the morning.

It is to be noted that the most effective pollinators, namely the pure pollen gatherers and the bees with mixed behaviour visited the apple flowers much less intensely in the morning than at the afternoon, therefore the negative influence of side worker nectar gatherers was more remarkable in the morning, even if their number or proportion was smaller.

The intensity of other pollinating insects proved to be variable according to the size of their populations and the time of the day as well. Their proportion was relatively small in the morning, so they had no effect on the fruit set and the seed content of fruits either at Mosonmagyaróvár or at Feketeerdő (fruit set: r=0,2–0,44, viable seed content: r=0,33–0,46). However, at the afternoon, when the intensity of other pollinating insects was greater, their effect proved to be highly significant especially on the fruit set (fruit set: r=0,54–0,8, viable seed content: r=0,46–0,49).(Supported by OTKA Grant No. T 46723)

References

Benedek, P. (1996): Insect pollination of fruit crops. In: Nyéki, J. – Soltész, M. (eds.): Floral biology of temperate-zone fruit trees and small fruits. Akad. Kiadó, Budapest, 287–340.

Benedek, P. (1997): Az irányított méhmegporzás technológiája. In: Soltész M. (1997): Integrált gyümölcstermesztés. Mezőgazda Kiadó. 359–362.

Benedek, P., Manninger, S. & Virányi, S. (1974): Megporzás mézelő méhekkel Mezőgazdasági Kiadó, Budapest, 199 pp.

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

Benedek, P. & Nyéki, J. (1996a): Relationship between the duration of insect pollination and the yield of some apple cultivars. Horticultural µ **(1996c):** Fruit set of selected self-sterile and self-fertile fruit cultivars as affected by the duration of insect pollination. Acta Horticulturae, 423: 57–63.

Benedek, P., Nyéki, J. & Lukács, Gy. (1989): A méhmegporzás intenzitásának hatása az alma kötődésére és termésére (Effect of intensity of bee pollination on the fruit set and yield of apple trees). Kertgazdaság, 21, (3): 8–26.

Benedek, P., Nyéki, J., Soltész, M., Erdős, Z., Skola, I., Szabó, T., Amtmann, I., Bakcsa, F., Kocsis-Molnár, G., Vadas, Z. & Szabó, Z. (2000): The effect of the limitation of insect pollination period on the fruit set and yield of temperate-zone fruit tree species. International Journal of Horticultural Science 6 (1): 90–95.

DeGrandi-Hoffman, G., Hoopingarner, R. A. & Baker, K. K. (1985): The influence of honey bee "sideworking" behavior on cross-pollination and fruit set of apples. Hort. Sci. 20(3): 397–399.

Free, J. B. (1960): The pollination of fruit trees. Bee World, 41: 141–151.

Free, J. B. (1963): The flower constancy of honeybees. J. Anim. Ecol. 32: 119–131.

Free, J. B. (1966): The pollinating efficiency of honeybee visits to apple flowers. J. Hort. Sci., 41: 91–94.

Free, J. B. (1993): Insect pollination of crops. Second edition. University of Wales, Cardiff. Academic Press, London.

Free, J. B. & Spencer-Booth, Y. (1964): The foraging behaviour of honeybees in an orchard of dwarf apple trees. J. Hort. Sci. 39: 78–83.

Hartman, F. O. & Howlett, F. S. (1994): Fruit setting of the 'Delicious' apple. Ohio Agr. Expt. Sta. Bul. 745, 64 pp.

Hellmich, R. L. & Rothenbuhler, W. C. (1986): Relationship between different amounts of brood and the collection and use of pollen by the honeybee (*Apis mellifera*). Apidologie, 17: 13.

Kuhn, E. D. & Ambrose, J. T. (1982): Foraging behaviour of honey bees on 'Golden Delicious' and Delicious apple. J. Amer. Soc. Hort. Sci. 107: 391–396.

Percival, M. S. (1955): The presentation of pollen in certain angipsperms and its collection by Apis mellifera. New Phytol. 54: 353–368.

Roberts, R. H. (1945): Blossom structure and setting of 'Delicious' and other apple varieties. Proc. Am. Soc. Hort. Sci. 46: 87–90.

Robinson, W. S. (1979): Influence of 'Delicious' apple blossom morphology on the behaviour of nectar-gathering honey bees. Proceedings 4th International Symposium on Pollination. Maryland Agricultural Experimental Station Special Miscellaneous Publication 1: 393–399.

Robinson, W. S. & Fell, R. D. (1981): Effect of honeybee foraging behaviour on „Delicious" apple set. Hort. Sci. 16: 326–328.

Soltész, M. & Szabó, T. (1998): Alma. In: Soltész M. (editor): Gyümölcsfajta-ismeret és -használat. Mezőgazda Kiadó, Budapest, 119–154.