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ORIGINAL RESEARCH ARTICLE

Do sunflowers influence the development of honey bee, *Apis mellifera,* colonies in areas with diversified crop farming?

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Summary

In Switzerland, the cultivation of sunflowers has expanded since the 1990s, and today nearly 5000 ha are cultivated. Sunflower seed is not treated with systemic insecticides (neonicotinoids, fipronil) but nevertheless, Swiss beekeepers claim to have observed a weakening of bee colonies after foraging on sunflowers. The purpose of this test was to evaluate whether the sunflower itself causes the weakening and if so, to quantify it. The results show that bee foraging on flowering sunflowers had neither a noxious effect on bee populations during the blooming period nor in the following months. Likewise, winter losses did not increase. The bees visited the sunflowers intensively but harvests of sunflower nectar were non-existent or low. Sunflower pollen was collected in the first few days after moving to the sunflower fields but, in a poly-culture environment like Switzerland, the bees then turned to alternative pollen sources such as corn (*Zea mays*) or clover (*Trifolium* spp.).

¿Influyen los girasoles en el desarrollo de colonias de la abeja melífera *Apis mellifera* en áreas agrícolas con cultivos diversificados?

Resumen

En Suiza, el cultivo de girasol se ha extendido a partir de 1990, y actualmente cerca de 5000 hectáreas son cultivadas. Las semillas de girasol no se tratan con insecticidas sistémicos (neonicotinoides, fipronil), pero sin embargo, los apicultores suizos afirman haber observado el debilitamiento de las colonias de abejas después de pecorear en los girasoles. La finalidad de este estudio fue evaluar si la causa del debilitamiento es ocasionada por el girasol y en caso afirmativo cuantificarla. Los resultados demostraron que el pecoreo de las abejas en los girasoles durante el periodo de floración no tenía un efecto nocivo sobre las poblaciones de abejas, ni en los meses siguientes. Asimismo, no se incrementaron las pérdidas durante el invierno. Las abejas visitaron intensamente los girasoles, pero la cosecha de néctar de girasol fue nula o baja. El polen de girasol fue recolectado durante los primeros días posteriores al traslado de las colonias de abejas hacia los campos de girasol, pero en un área con diversos cultivos como Suiza, las abejas prefirieron otras fuentes alternas como el polen de maíz (*Zea mays*) o el trébol (*Trifolium spp.*).

Keywords: honey bee, *Apis mellifera*, sunflower, *Helianthus annuus*, bee pasture, foraging

Introduction

The cultivation of sunflowers (*Helianthus annuus*), which did not exist in Switzerland in the 1990s, has increased in importance over the last decade. According to the 2008 Agricultural Report of the Federal Office for Agriculture, close to 5000 ha of sunflowers are currently being cultivated. The presence of pollinators during the flowering of this oleaginous plant is essential for the yield and quality of the harvest (Burgstaller, 1990; Calmasur and Ozbek, 1999; DeGrandi-Hoffman and Watkins, 2000; Freund and Furgala, 1982; Oz *et al.*, 2009), shortens the flowering period and increases the homogeneity of seed maturity (Hedtke, 1998).

The sunflower, with nearly 10 million florets per hectare and a long flowering period would seem to be a plant of interest for the pollinator. Honey bees (*Apis mellifera*) and especially bumble bees (*Bombus* sp.) are attracted in great numbers. The simultaneous presence of both honey bees and non-*Apis* bees enhances pollination efficiencies (Greenleaf and Kremen, 2006). Production of pollen and nectar, according to the literature, is average to good (Maurizio and Schaper, 1994). The nutritional value of sunflower pollen is, however, low (Odoux *et al.*, 2004; Tasei and Aupinel, 2008; Wille *et al.*, 1985) which can have a negative impact on the development of the hypopharyngeal glands and ovaries of newly emerged bees fed only on

sunflower pollen (Pernal and Currie, 2000). Nectar secretion differs greatly between sunflower varieties and also depends on the nature of the soil and climate (Hedtke, 1998; Ion *et al.*, 2008; Zajacz *et al.*, 2006).

In various European countries, beekeepers have reported weakening of bee colonies when they are near fields of sunflowers in bloom, and systemic insecticide seed treatment (neonicotinoids, fipronil) has been blamed (Anon., 1999; Laurent and Rathahao, 2003). In Switzerland, where none of these substances are authorized for use on sunflowers, weakening of colonies also seems to occur. The trial presented here was carried out to determine whether the sunflower itself is harmful to the development of bee populations and if necessary, to quantify this damage. We also wanted to test whether the detrimental effects of sunflower pollen observed in laboratory tests (Pernal and Currie, 2000) may also have a detrimental impact on colony development in areas with diversified crop farming.

Materials and methods

We compared two groups of colonies which were placed at different locations during flowering of the sunflowers. The "test" group was moved to the edge of a field of sunflowers, and the colonies of the "control" group were placed at least 3 km from a sunflower field. Outside this period, both groups were located in the same apiary and the colonies were managed in the same way. The test was repeated in two successive years and repeated twice each time. In 2003, the test sites were located in Müntschemier and Wabern, and in 2004 in Bellechasse and Changins. The control site in both years was at Liebefeld (Table 1).

In order to record the possible effect of foraging on sunflowers on the populations of bees, we measured populations at three week intervals from the end of June to the end of October according to the standard "Liebefeld" method (Imdorf *et al.*, 1987). This method allows the accurate estimation of the number of worker bees and the area of open and sealed brood cells by observation of each comb side, and is reliable when used by a trained and calibrated person. A measurement was also carried out in March of the following year to determine winter losses. Since these measurements took place during the hours of bee foraging, the results are all relative, but permit comparison between the groups. The trial colonies were distributed between the test and control groups based on a preliminary measurement of bee populations in order to have homogeneous groups of comparable size (Figs 1 to 3). The healthy colonies of *A. mellifera* were housed in twelve frame Dadant Blatt hives.

Both the control and test hives were weighed before and after sunflower flowering time in order to record any possible weight gain or loss. Three hives per group were equipped with entrance pollen traps (Fig. 4), and the pollen was collected for three days per week. This pollen was sorted according to its botanical origin based on its colour but in cases of doubt a pollen analysis was undertaken. The weight of the various pollens was measured after drying at 40°C for 12 h. In order to record any possible immediate noxious effect of sunflowers on the adult bees or mortality of pupae, we placed "under-basket" dead bee traps (Accorti *et al.*, 1991) in front of five colonies per apiary. The flight intensity was measured at 09.00, 11.00, 14.00 and 16.00 h three days per week during the flowering period. The number of bees present on a group of ten flower heads at several locations in the sunflower field was observed. The time the bees remained on the flower heads was also measured.

In Changins, we conducted a test of sunflower varieties, where flight intensity was measured on nine separate areas. Each 160 m^2 block contained a different sunflower variety.

For statistical comparison of populations as well as weight gain of the test and control groups, we carried out variance analysis (ANOVA; $p < 0.05$) followed by a Tukey test ($p < 0.05$, Systat 11-software).

Table 1. Description of the experimental conditions for the two trial years repeated twice (in 2004, the same control colonies were used for both repetitions). * Additional variety trial of 0.3 ha at Changins

Year	"Control" Apiary		"Test" Apiary		Sunflower Field		Migratory period
	Location	No. Colonies	Location	No. Colonies	Variety	Surface (ha)	
2003	Liebefeld	2 x 10	Müntschemier	10	Cadasol	14,3	2 – 21 July
			Wabern	10	Elansol	2,0	3 – 22 July
2004	Liebefeld	10	Bellechasse	10	Aurasol	12,1	6 – 28 July
			Changins	10	San Luca*	3,7	8 – 27 July

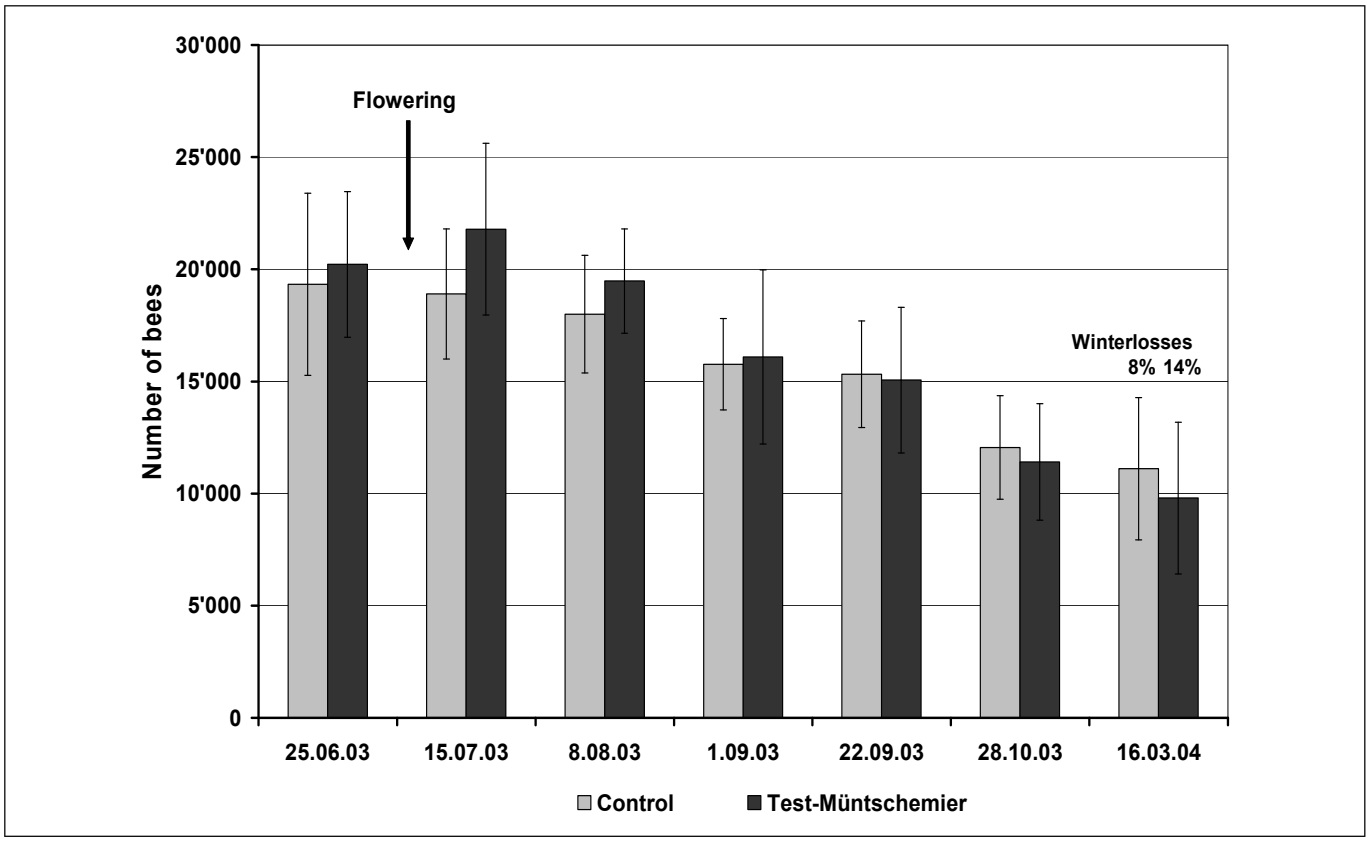

Fig. 1. 2003 trial. Mean number of bees per colony in the control and test groups at Müntschemier measured before and after the flowering of the sunflowers (average and standard deviation; 10 colonies per group). The average bee losses during the winter are indicated.

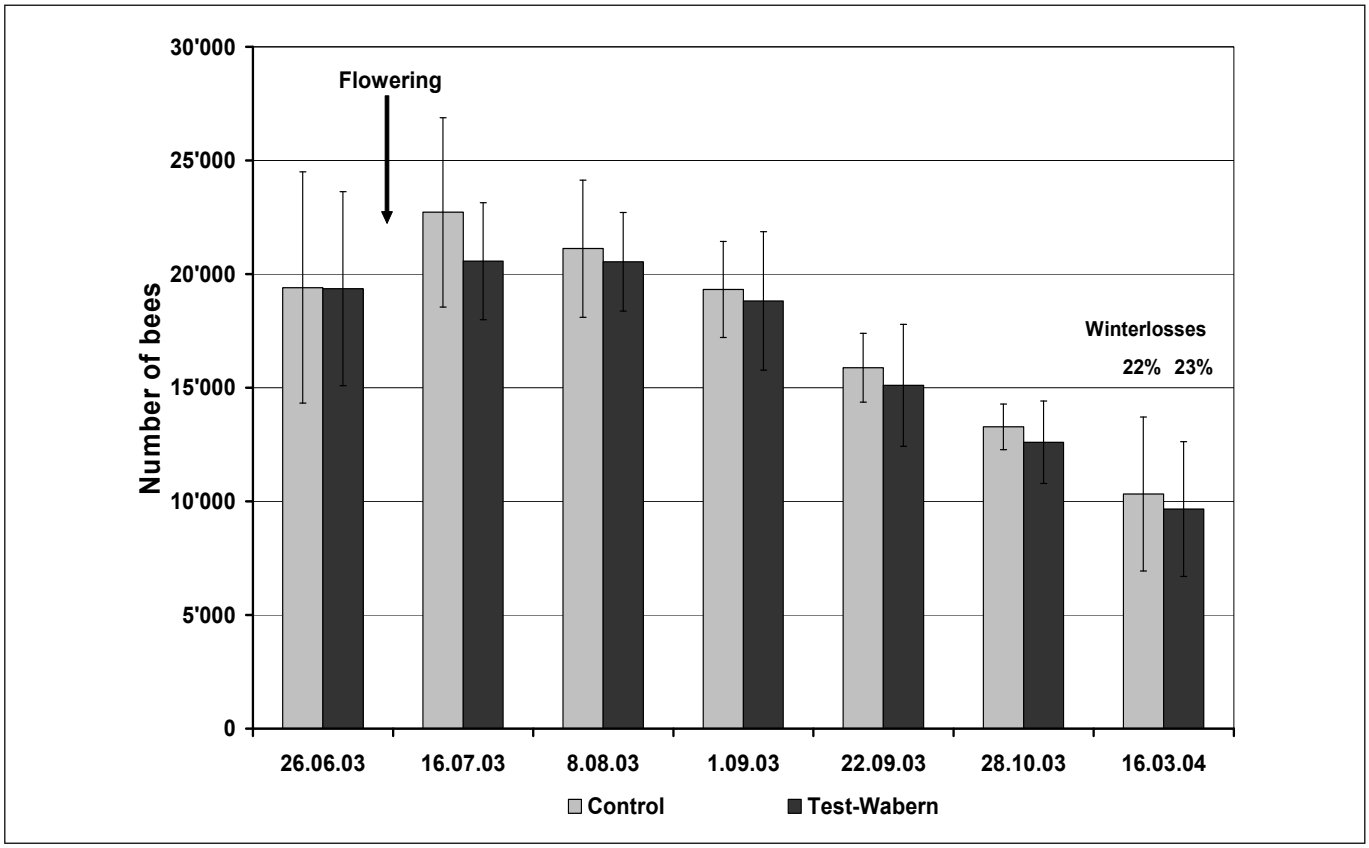

Fig. 2. 2003 trial. Mean number of bees per colony in the control and test groups at Wabern measured before and after the flowering of the sunflowers (average and standard deviation; 10 colonies per group). The average bee losses during the winter are indicated.

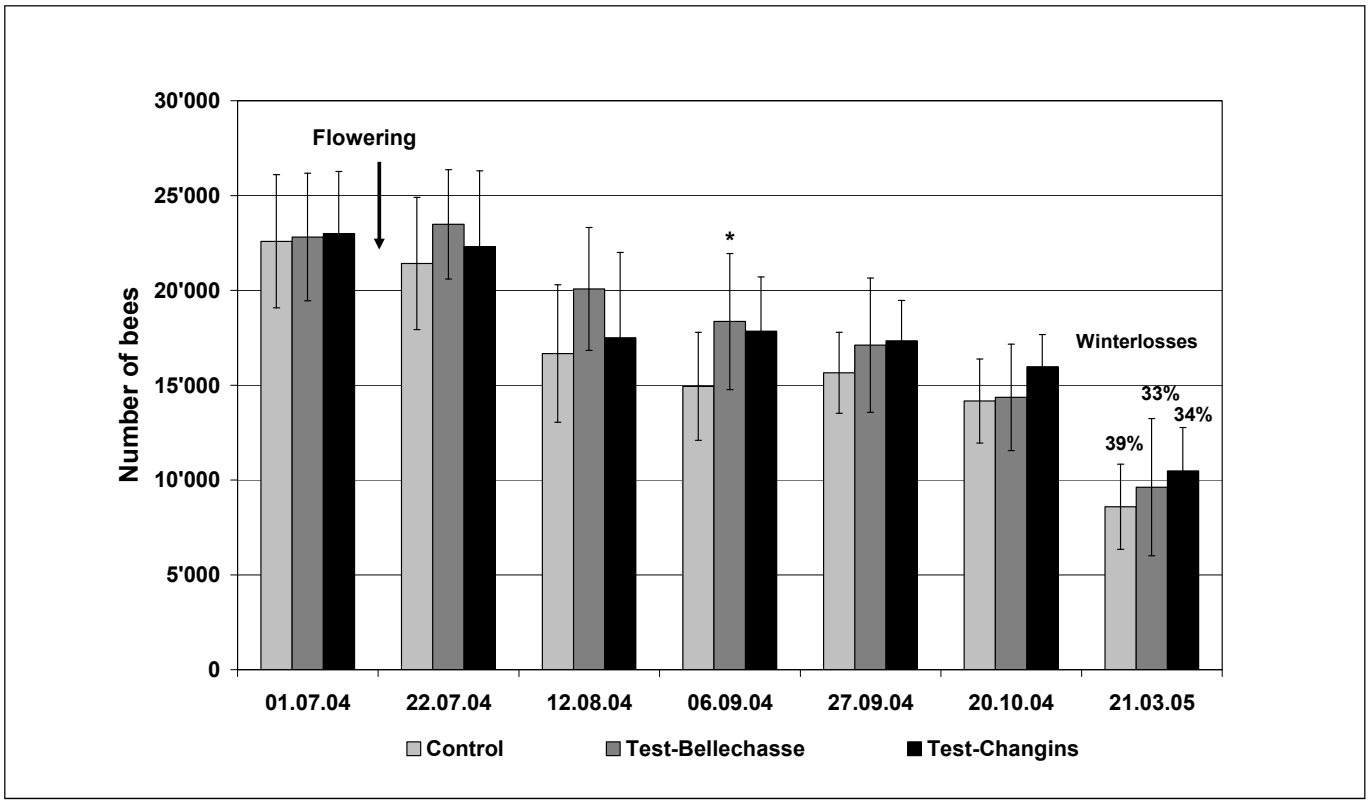

Fig. 3. 2004 trial. Mean number of bees per colony in the control and test groups measured before and after the flowering of the sunflowers (average and standard deviation; 10 colonies per group). The average bee losses during the winter are indicated. *Average significantly different from the control group (Tukey-test, $p < 0.05$).

Fig. 4. Pollen trap at the entrance of the hive on the left.

Results

Population development

In 2003, no significant difference between the test and control groups was observed with regard to the adult bee population (Figs. 1 and 2). At the Müntschemier site, after sunflower flowering, the strength of the test colonies as well as the quantities of brood raised tended to be slightly greater than in the control group. In contrast, at the Wabern site, the colonies of the control group were slightly stronger and raised a little more brood. These differences between apiaries show that there are local factors other than the sunflowers which strongly influence the development of the colonies.

Winter losses of bees in the control and test groups were not significantly different (ANOVA, F = 0.495, p = 0.61). Colonies with 8000 to 10000 bees at the end of winter are normal. On each date of population measurement, the quantities of brood raised by the control and test colonies were not significantly different for the two repetitions during this first year of the test.

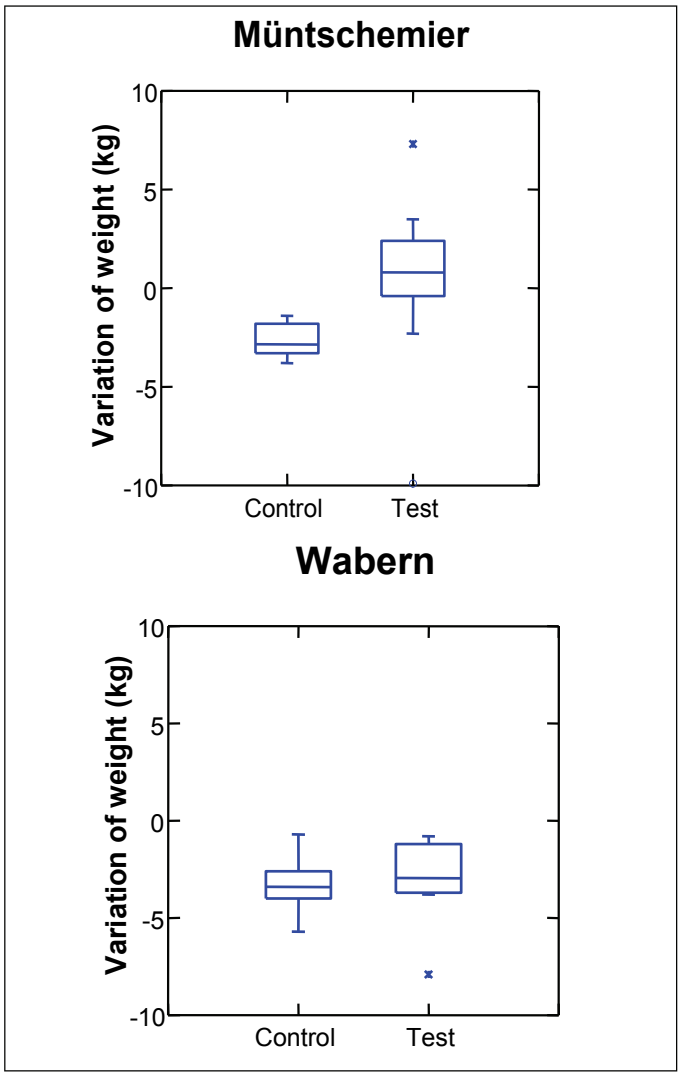

Fig. 5. Variation in the weight of the hives during the sunflower flowering period in 2003 at the test apiaries in Müntschemier (p = 0.06) and Wabern (p = 0.73).

The results obtained in 2004 confirmed those obtained in 2003. The colonies which foraged on sunflower were slightly stronger (Fig. 3). The difference was, however, only significant for the measurement on 6 September at Bellechasse (p = 0.04). In 2004, the quantities of brood raised were not statistically different between the control and test hives and the same was true for winter losses. The reduction in the number of bees from 14000 to 9000 during the winter is again a normal phenomenon.

Colony weight

At the time of sunflower flowering in July, sources of nectar other than the sunflower are rare or only available in small quantities. In certain years the honeydew of coniferous or deciduous trees can be collected by the bees, but in the two test years and chosen sites, no important harvest of honeydew was recorded. All of the control colonies therefore lost weight (Figs 5 and 6). The hives placed at edge of the sunflower fields at Wabern decreased, on average, by 3 kg whereas those at Müntschemier gained 0.3 kg (Fig. 5). The differences in loss or gain of weight between the control and test groups were not statistically significant.

During the 2004 flowering period, the control hives lost on average 2.8 kg (Fig. 6). In Changins the test hives decreased by 0.4 kg (p = 0.12) whereas in Bellechasse the weight of the hives increased significantly by 2.2 kg (p = 0.001). Organoleptic examination and pollen analysis of the honey showed, however, that it had not come from sunflowers.

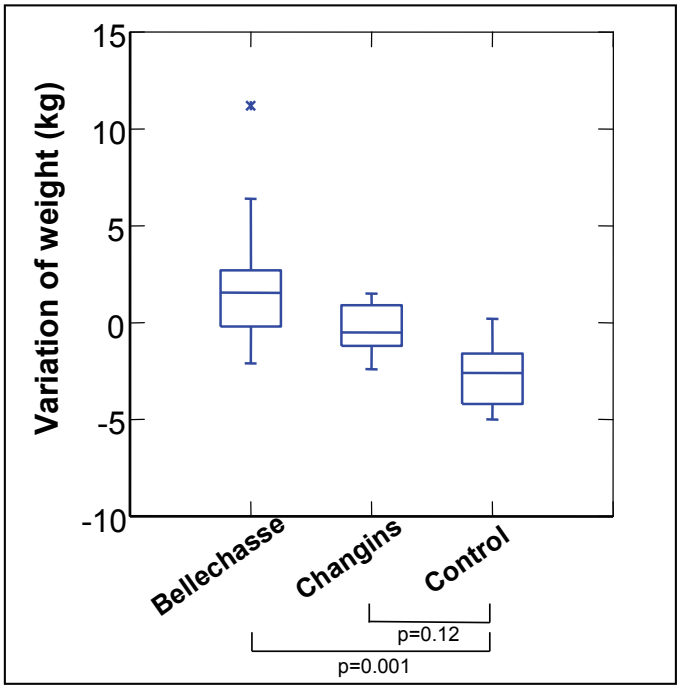

Fig. 6. Variations in the weight of the hives during the flowering of the sunflowers in 2004.

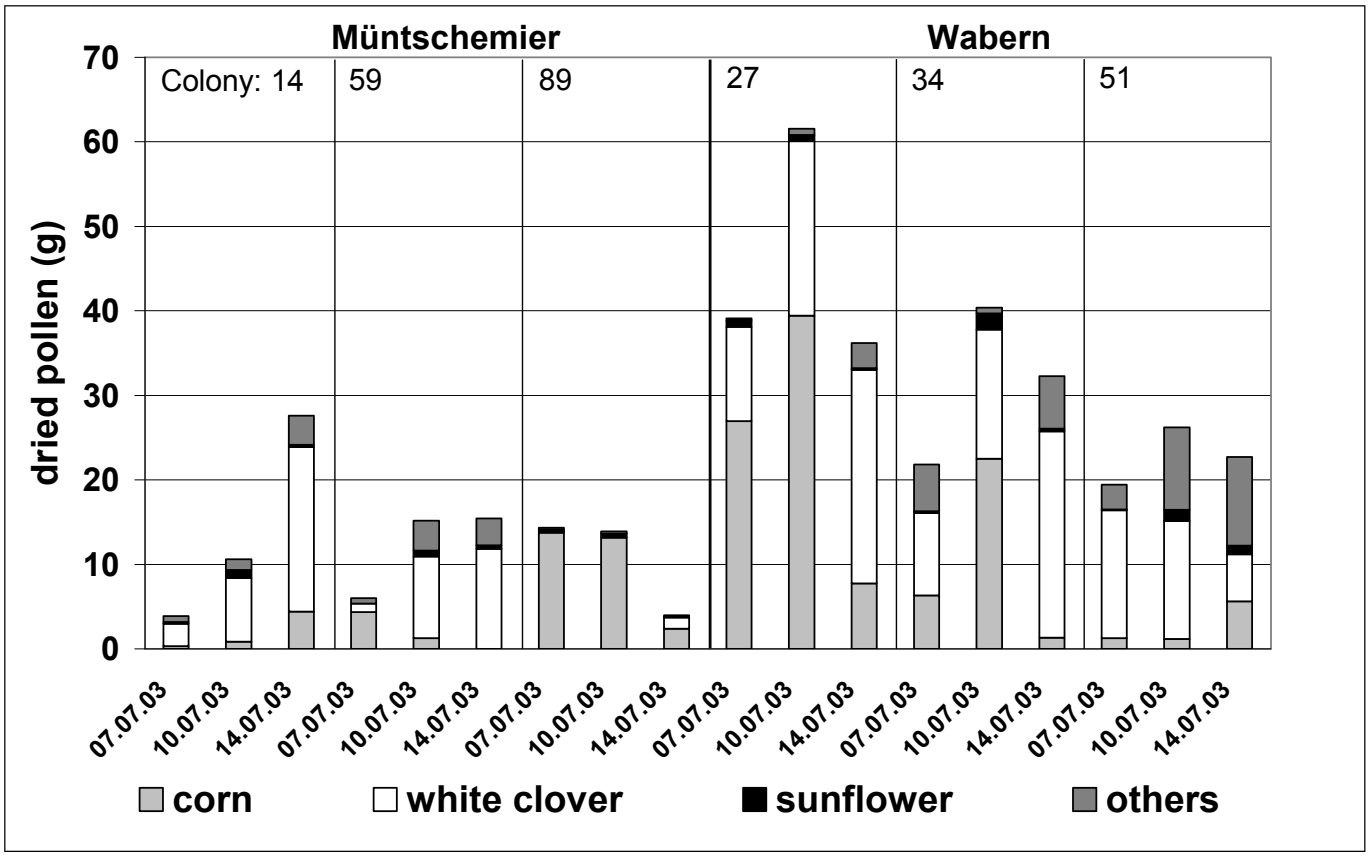

Fig. 7. Quantity and botanical origin of pollen harvested at Müntschemier and Wabern in 2003.

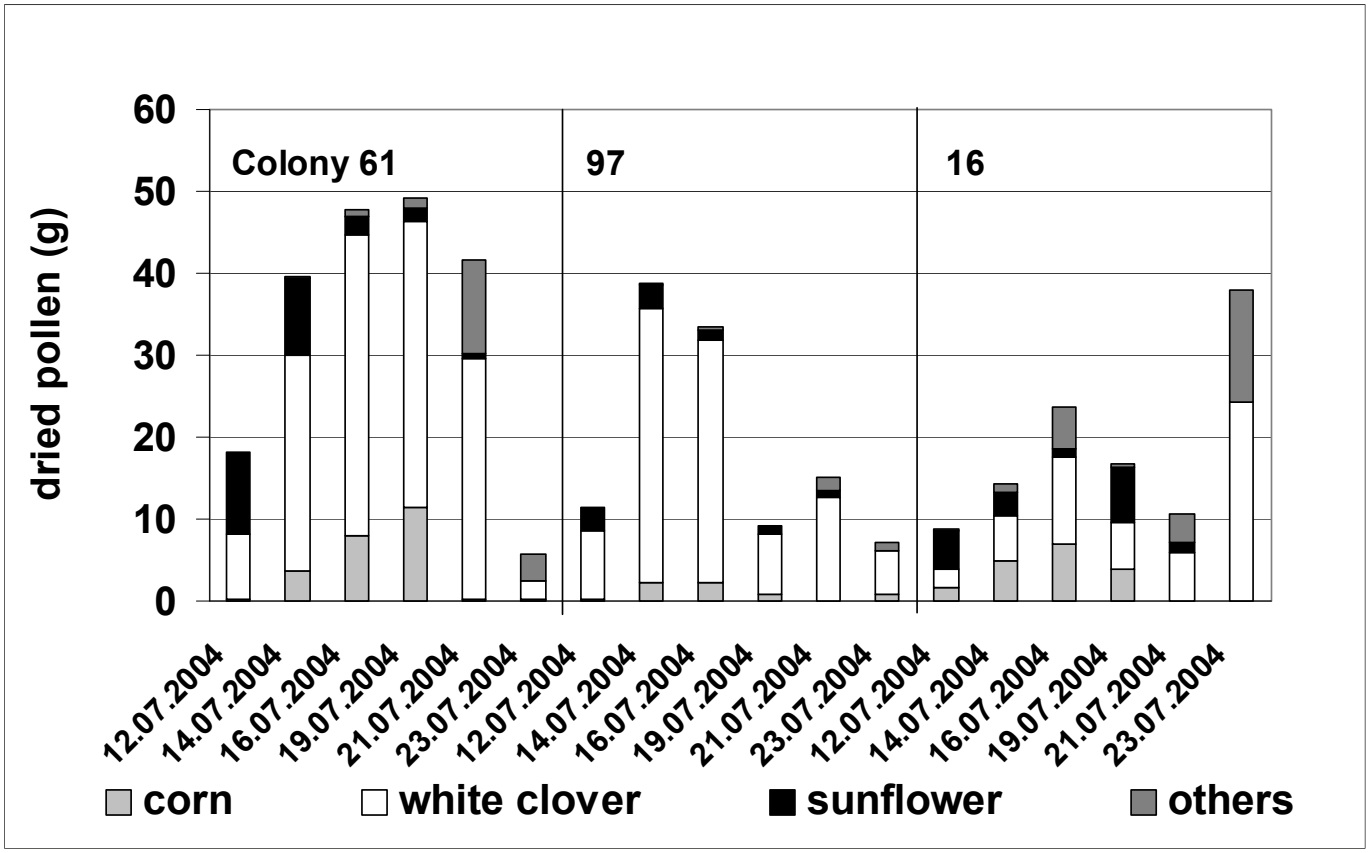

Fig. 8. Quantity and botanical origin of pollen harvested at Bellechasse in 2004.

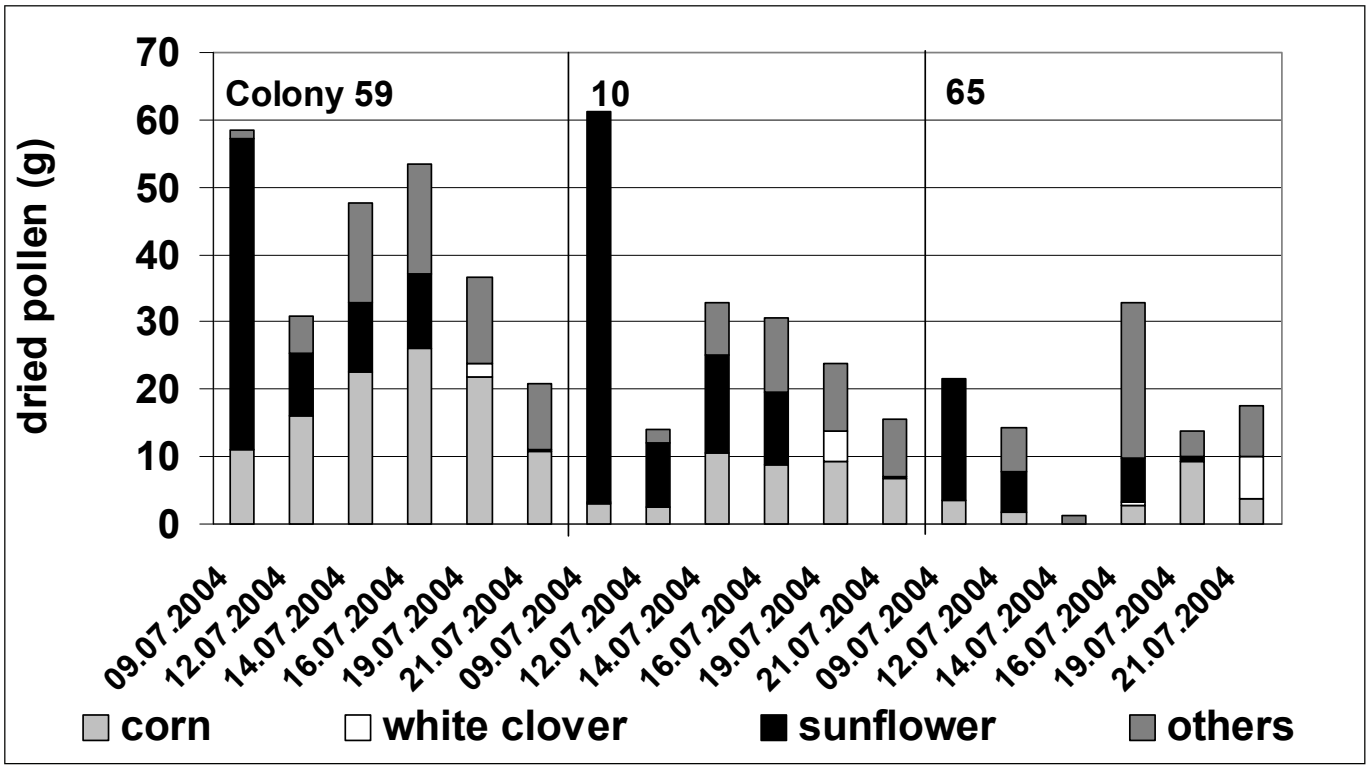

Fig. 9. Quantity and botanical origin of pollen harvested at Changins in 2004.

Pollen collected

In 2003, the pollen collected during sunflower flowering at both test sites came mainly from white clover (*Trifolium repens*) and corn (*Zea mays*) (Fig. 7). The proportion of sunflower pollen was, on average, only 2.2% of the total harvest at Müntschemier and 3% at Wabern. In 2004, the proportion of sunflower pollen collected during the six days of analysis was greater than in 2003, varying between colonies, from 7 to 15% at Bellechasse (Fig. 8) and from 31 to 52% at Changins (Fig. 9). The colonies collected the most sunflower pollen in the days directly following migration to the sunflower fields. At the control apiary, 0.5% was sunflower pollen, probably coming from ornamental sunflowers cultivated nearby; 72% was corn pollen; 20% clover and 8% had other origins.

The pollen collected in 2004 at Bellechasse and Changins was analyzed by the Interregional Research Group of Agropharmaceutic Products (GIRPA) at Angers for the presence of imidacloprid and its

Table 2. Average flight intensity observed during the flowering of the sunflowers.

	Apiary	Variety	Number of bees on 10 flower heads		Time on flower head (seconds)	
			Average	max.	Average	max.
2003	Müntschemier	Cadasol	2.8	10	68	88
	Wabern	Elansol	8.8	24	96	155
2004	Bellechasse	Aurasol	3.7	8	47	70
	Changins	San Luca	2.5	13	52	87
		Prodisol	2.2	8	35	70
		Allstar	1.4	12	52	94
		Pegasol	0.8	6	34	54
		Elansol	3.7	18	40	82
		Aurasol	3.2	9	38	82
		LG5380	2.9	10	39	74
		Dynamic	3.5	13	43	80
		PR64H41	3.0	8	39	66

metabolite (acid 6-chlornicotinic). All of the samples had levels below the quantification limit (LQ = 1 µg/kg).

Acute mortality

Mortality of adult worker bees found in the dead bee traps was within the normal range (< 30 bees/day) and only slightly higher than mortality in the control colonies. One cannot therefore conclude that the sunflower fields were acutely toxic for adult bees, and we detected no larval mortality.

Flight intensity on the sunflowers

Foraging on the sunflowers by the bees was intense, especially during the days which directly followed migration to the sunflower fields. In 2003, we found as many as 24 bees on ten flower heads. At Wabern, we measured more than three times as many bees on the flower heads than at Müntschemier and also a longer foraging time (Table 2). These differences could be due the sunflower variety, the soil, climatic conditions or differences in the number of sunflowers available, which was seven times lower at Wabern. The sunflowers were also well visited in 2004 and important differences in foraging were observed depending on the variety. In our test, for example, the Elansol variety was visited four times more often than Pegasol.

Discussion

The trial colonies placed at the edge of a sunflower field were indeed exposed to the sunflowers, as shown by the number of bees found on the flower heads. In spite of the exposure of these test colonies, their strength as well as the quantity of brood raised was no different from the control group during the flowering period, nor in the following months, nor in the following spring. The quantities of dead bees found in the traps were normal and did not indicate acute mortality. In our trials, possibly because they were conducted in areas with diversified crop farming, we discovered no harmful effects on the bee colonies of foraging on sunflowers.

The massive depopulation of hives, sometimes described by beekeepers, was not observed, and is certainly due to causes other than the cultivation of sunflowers. In our trials, the nectar harvest from sunflowers was very low and, apart from a few rare exceptions, the colonies lost weight during the sunflower flowering period. Hedtke (1998) made the same observation in trials in Germany where the colonies lost, on average, between 73 and 174 g per day. He suggested that the dryness and high temperatures as well as the sandy soil could be responsible for low levels of nectar secretion. The very hot and dry weather in the summer of 2003 could explain the absence of harvest that year when sunflower pollen only represented 3% of the total pollen harvest during the sunflower flowering period. Pollen harvest was, however, greater in 2004, with 11% and 38% for Bellechasse and Changins respectively. In his German trial, Hedtke (1998) only found 1.5% sunflower pollen in all of the pollen collected during the flowering period. He also observed that only 16% of the foraging bees collected sunflower pollen actively, the remainder of the foraging bees collecting nectar. The proportions of sunflower pollen were highest in the days following migration of the bees to the edge of sunflower fields. After a few days, the quantities decreased rapidly in favour of other sources such as white clover or corn, despite the abundant availability of sunflower pollen. Burgstaller (1990) in Austria, and Odoux *et al.* (2004) in France also made similar observations. The results obtained by Andrada *et al.* (2004) in southern Argentina indicate that honey bees foraged on pollen and nectar mainly from the flora surrounding the sunflower fields. The reason for this change could be due to the taste, the colour or texture of sunflower pollen (Schmidt, 1982). It seems not to be the protein quality of pollen (Pernal and Currie, 2001; Pernal and Currie, 2002) but the pollen lipids which influence foraging (Singh *et al.*, 1999). With regard to flight intensity, important differences between the sunflower varieties were observed. Schaper (1998), Hedtke (2000) and Kumar *et al.* (2000) also recorded important variations and associated these variations with the colour of the flower or the quantities of sugar produced in the nectar and availability for the bees.

In conclusion, our trial showed that cultivation of sunflowers in areas offering alternative pollen and nectar sources was not harmful to the development of bee populations, neither during flowering nor in the following months or winter. Siede and Berg (2008) have also made similar observations in Germany. The weakening of colonies observed by certain beekeepers following foraging on sunflowers is therefore probably due to other factors. Our results do not, however, exclude detrimental effects on colonies in regions where sunflowers are cultivated on a large scale and few other pollen resources are available.

Our results also confirm various previous studies describing the poor interest in sunflower nectar (Siede and Berg, 2008). Only specific climatic and soil conditions lead to sufficient nectar production, and Swiss conditions seem to be unfavourable so sunflower honey harvests rare. In the presence of alternative sources of pollen such as nearby corn or clover, the honey bee therefore quickly reduces its harvest of sunflower pollen to concentrate on more attractive sources.

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