Spatial distribution of bumblebees in four different field crops

By: **T.M. Bossinga**

March 2007- September 2007

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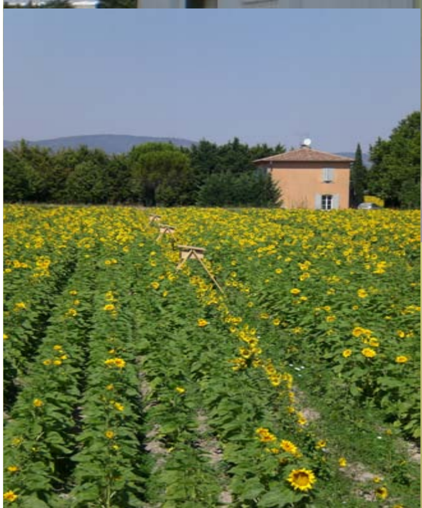
“Time is honey” (Heinrich 1996)



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Introduction

An increasing number of research projects investigating bumblebee behavior and ecology (e.g. Martin *et al.*, 2006; Goulson, 2003) is carried out. These projects are mostly concerning bumblebee colonies under natural conditions. With the increasing implementation of bumblebee species in agricultural crops, not only within greenhouses but also in open field production, more foraging data is needed to specify the optimal conditions for bumblebees to pollinate the crop. The idea that bumblebees possess morphological and ecological features which allow them to fill pollination niches which cannot efficiently be replaced by honeybees is well established (Dramstad, 1995). Buzz pollination by bumblebees can be a more effective way of pollination compared to honeybee pollination. Also the fact that communication between foraging bumblebees is poor and hence no mass movement of bumblebees to better foraging patches takes place. Therefore they form a welcome addition to and sometimes even substitution of the more traditional method of honeybee pollination.

In order to get better insight in bumblebee distribution in open field crops a field trial was carried out during the spring and summer of 2007. Data on bumblebee distribution in four important outdoor crops; cherry, rapeseed, strawberry and sunflower was obtained. Hives containing the indigenous species *Bombus terrestris* were introduced to the test plots.

Using transect techniques scoring (un)marked bumblebees, activity counters and pollen trapping and identification a more detailed set of bumblebee distribution data was created.

After an orientation of several available tracing-and-tracking methods and techniques the method of color marking and (re)observing bumblebees on transects was chosen. Earlier studies show that marked bumblebee observations are rather low (Dramstad, 1996; Kwak *et al.*, 1991) and therefore transect walking intensity was increased as well as re-marking newly emerged bumblebees. An additional benefit of the marked bumblebees was that bumblebees switching between/in hive clusters also could be observed and recorded.

A special pollen trap was designed to prevent restrictions involved using an observer (e.g. loss of concentration, misinterpretations of color, etc.). Although bumblebee workers differ in size (Goulson *et al.*, 2002) and the rigid mesh design of the trap allows smaller workers to pass without any obstruction still a relevant indication of collected pollen over a period of days/weeks was acquired.

Data collected during this experiment hopefully leads to improved insight in bumblebee deployment on a commercial basis as well as better insight in bumblebee foraging behavior in general.

Materials and Methods

Bumblebees

For this project Koppert colonies of the large earth bumblebee (*Bombus terrestris,* Linneaus, 1758) (Pic.1) were used. These so-called Natupols consist of, at start, one queen and approximately 120 workers. Colonies can consist of approximately 600 workers after a few weeks in thee field. Bumblebee colonies reared at Koppert contain pollen and sugar water, Bee Happy (1.2 l) for transportation and the first days in the field. Depending on the amount of pollen and nectar produced by the crop the access to the Bee Happy and/or pollen can be closed. Active bumblebees produce heat and to prevent the hive from overheating ventilation slots are present in the outside cardboard box. On very warm days bumblebees will actively ventilate the hive by waving their wings at the hive entrance very fast. To prevent bumblebees from cold or even frost bumblebees build from cotton sheets, together with wax, a protective insulating “blanket” over the cell.

Pic.1. Worker (above) and queen (under) of *Bombus terrestris.*

Experimental field set-up

Three sets containing three bumblebee colonies are placed in a straight line in the field (15-30 meters between each set, depending on the field size). Preferably, depending on the place of the sets in the field, the orientation of the flight exits/entrances of the colonies is orientated southwards. All sets are placed in the field from the moment that approximately 10% of the flowers is blooming.

Two days prior to the start of the experiment the colonies are introduced in the field to give the bumblebees the opportunity to orientate. The next day the entrances to the stock of pollen and the sugar water solution in the hives are closed, which forces the bumblebees to search for natural pollen and nectar. To protect the colonies and the electronic equipment against weather conditions the sets are placed in a house-like platform (Pic.2). Special observations and remarks during the experiment are collected in a journal.

Pic.2. Bumblebee colony support as weather protection; sunflower field Meyrargues, France.

Coloring of bumblebees

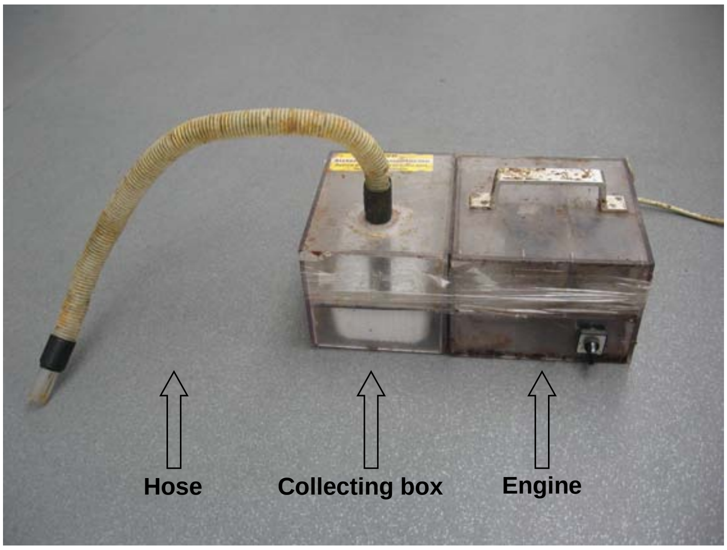
In order to distinguish “Koppert” bumblebees from “Wild” bumblebees all introduced bumblebees are color marked. Each colony in the second set is given a different color (Red, Blue and Green). The other sets are considered as one big colony is completely color marked with only 1 color (White or Yellow).

All bumblebees, except from the queen, are removed from the hive by a specially designed exhauster (Pic.3). The bumblebees are collected and stored in a freezer for a short period. Under cold conditions bumblebees are temporarily immobilized and easier to handle.

All bumblebees are colored with special markers and returned to their original colony. The paint is applied on the centre of the thorax, a little in front of the wings.

During the experiment new bumblebees emerge, so the procedure has to be repeated after 5-7 days after start of the experiment.

At the end of the trial all the hives are collected, bumblebees frozen, counted and their (absence of) color is noted. Different colors within one hive can give a better insight in the ratio of bumblebees that switch to other colonies. Not only data on bumblebees from other sets is obtained, but also data of switching bumblebees within 1 set can de scored for the second, multicolored set.



Pic.3. Bumblebee exhauster used for extracting bumblebees from a hive.

Transects

A total of 3 transects per field, each with a length of at least 250 meter subdivided in sections of 10 meter, is monitored (Fig.1). The subsections are indicated by sticks with a distance label. Maintaining a moderate walking speed all (un)marked bumblebees in a 10 meter sector (with 1 meter on the left-hand side of the observer) are counted and their color scored. Other insects found on flowers in the transect are also counted ("queens", "honeybee" and "other bumblebees", "other pollinators").

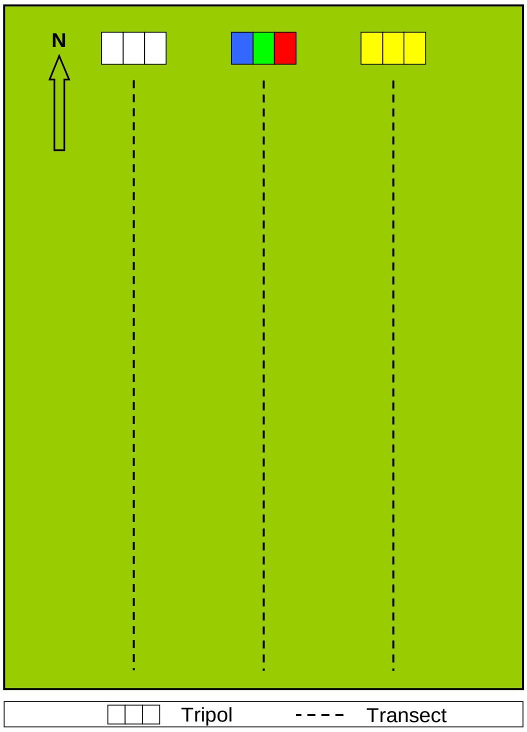


Fig.1. Schematic field with transects and placement of color marked Natupols.

Data loggers

Bumblebee counters

To avoid bumblebee preference for non-obstructed in-flight entrances all entrances in this experiment are obstructed. On the second set of Natupols bumblebee counters are installed (Pic.4). These devices record all outgoing flights (by means of a motion sensor). Data of an event, a passing bumblebee, is stored, together with time of day, on a data logger (Pic.5). During logging or after 42.000 events (maximum capacity of data logger) data can easily be copied to a computer. To prevent extra event counts of bumblebee returning to the nest one way traffic is ensured by the fact that two sets of small flaps, as a one-way door, are installed in the transparent tube. Also returning bumblebees can not easily orientate on transparent spatial objects, so it is assumed that only outgoing flights take place from the transparent tube. On the last Natupols (Yellow Natupol group in Fig.1) dummy bumblebee counters are attached to avoid bumblebee preference for non-obstructed entrances.

Pic.4. Bumblebee counter with electronic eye (under black tape) and data logger (in white can).

Temperature and Relative Humidity logger

In order to obtain data on abiotical conditions as temperature and relative humidity, a data logger, especially designed for outdoor use, is used (Pic.5). To communicate with the software it uses two infrared LED's in the base station. This data logger records both weather conditions every 10 minutes throughout the trial. The collected data gives detailed information on these circumstances and might be combined with data on bumblebee activity (event logger).

Pic.5. Temperature/RV-logger (above right) with optical base station (above left) and event logger (under).

Pollen collectors and identification

Collectors

On one cluster of Natupols (White Natupol in Fig.1) specially designed pollen collectors are attached (Pic.6). Bumblebees enter the collector and are forced to squeeze themselves through three metal meshes (6x6 mm.). All or a part of the collected pollen falls from the bumblebee and through/on a perforated floor in a collecting jar (Pic.7). The content of the jar is emptied in smaller tubes every other day to prevent pollen to rot or mould. Labels (with type of crop, time and date) are added to the collecting tubes. In the field an extra piece of Natupol cardboard box and lid are placed on front of the pollen trap to give the bumblebees a place to land on and also serves as an orientation point. The collectors, without the meshes, are placed in the field two days prior to the start of the experiment. At the start of the experiment the meshes are inserted.

Pic.6. Pollen collector attached to a Natupol colony.

Identification

After solving in water pollen samples are stained. Microscope slides are prepared and analyzed under a microscope. The identification of the collected pollen is carried out by a specialist. The form and size, together with the time of year the pollen is collected, are features to identify the pollen species. For detailed information on staining pollen samples, see appendix I. The original flower/plant and the relative amount of a pollen species is noted.

Samples of crop flowers and from flowers surrounding the crop field are collected and used as reference samples.

Pic.7. Different types of pollen in pollen collector (Cherry trial, Deest).

Results

Cherry

- Marked bumblebees have been observed at a maximum distance of 110 meters.
- Most observations (89%) within 70 meters.
- No significant difference in number of bumblebees between transects => assume homogenous distribution in field.
- Bumblebee activity between 9am and 9pm.
- Switching bumblebees between clusters from 2-5%.
- Switching bumblebees within cluster from 7.1-14.3%.
- Considerable amount of cherry pollen next to a large amount of willow pollen.

The crop

The first part of the project was carried out in an orchard in the vicinity of a small village called Deest, the Netherlands (Pic.8). The cherry orchard consisted of two different cherry varieties, Kordia (main) and Regina (for cross pollination). In total there are 13 rows of cherry trees. Both varieties bloom relatively late in the cherry season. To protect the plants from rain, which causes fruit damage, a permanent transparent plastic roof was placed over the trees. This also benefits cherry growth; (air) temperature under the roof is higher compared to “outdoor” conditions. By placing nets over the roof birds can not enter the orchard.

Specific details and observations

Prior to the main experiment a pilot study was carried out to check the bumblebee counters, data loggers and the efficiency of the pollen collectors. Three Natupols were placed in the centre of the orchard. Cherry flowers produce enough nectar so the Bee Happy was closed. The collectors seemed to work as pollen could be collected every other day. The size of bumblebee workers varies and smaller workers could pass the collector easily whereas larger workers had more difficulty entering the hive. The size of the mesh was correct because no large workers got stuck and died, which could have a negative effect on the total amount of pollen collected and consequently population growth.

The efficiency of the sets of one-way doors was lower than expected. So called sentry bumblebees guarded the hive between the flaps and their activity was registered as an event while not actually leaving the hive.

Therefore the first set of flaps was removed to see if any improvement was noticeable. As this did not solve the problem it was decided to remove the flaps completely halfway the experiment.

For the main experiment 3x3 Natupols were placed, as described earlier, in transects of 250 meters long. One week after placement the colonies were re-marked.

This caused a minor disturbance in bumblebee activity, but once reinstalled bumblebees proceeded collecting nectar and pollen.

To monitor the amount of flowers visited in a minute individual bumblebees were tracked. Two bumblebees could be followed during two minutes. A “white” bumblebee visited 32 flowers (mainly Kordia) and a bumblebee queen visited in respectively 41 and 22 flowers (in apple). Bumblebees do not fly in straight patterns and it was very hard to keep track of the individual bumblebees.

Pic.8. Aerial picture of the cherry orchard, Deest (Google Earth).

Weather conditions

Unfortunately the Temperature/RV-logger was not available during this trial. Temperatures were relatively high for the time of year (Fig.2) which resulted in higher evaporation. To compensate this water loss the orchard was irrigated several times so RV values might have been higher under plastic, especially shortly after irrigating the orchard.

Date	11-4-2007	General	15-4-2007	General	19-4-2007	General	23-4-2007	General
Temp. ave. (ºC)	13.0	8.0	18.6	8.0	10.6	8.0	16.0	9.7
Temp. max. (ºC)	17.2	12.7	28.8	12.7	17.4	12.7	22.8	14.6
Temp. min. (ºC)	8.2	3.2	8.6	3.2	1.4	3.2	6.4	4.6
RV ave. (%)	68	77	60	77	72	77	59	75

Fig.2. Temperature and RV data during cherry trial (location: De Bilt, The Netherlands. From www.knmi.nl).

Distance

Although transect length was from -20 m to 230 m the farthest observation was at 110 m (Fig.3). Only marked bumblebees were counted; a total of 16 on the white transect, 19 on the colored transect and 10 on the yellow transect. Most bumblebees were observed in a range of 0 – 70 meters from the hives (40 of total of 45 observations, 89%) (Fig.4).

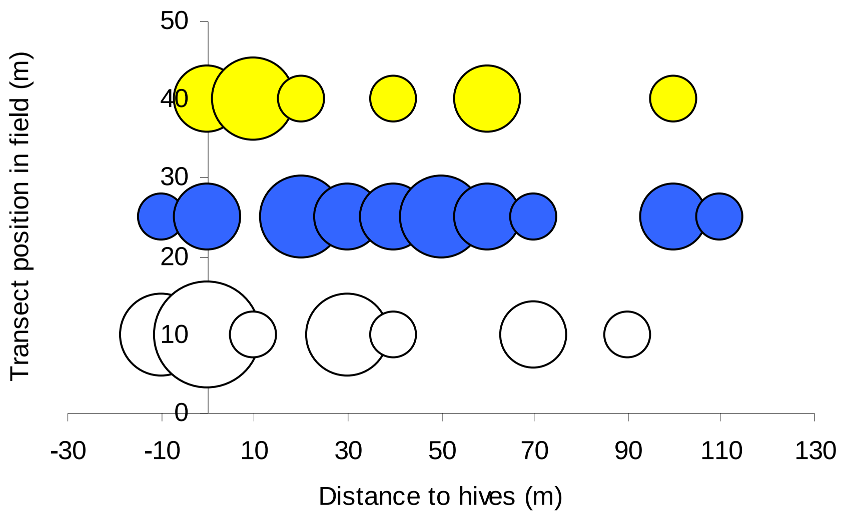


Fig.3. Marked bumblebee observations on yellow, coloured (blue) and white transect. Small dot: 1 bumblebee observed, largest dot: 5 bumblebees observed.

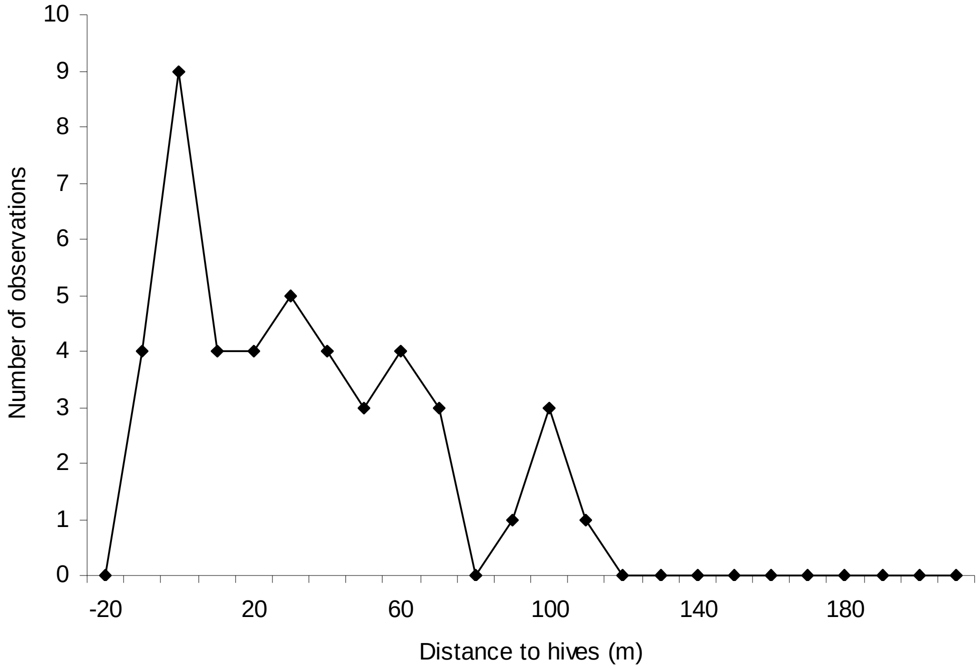


Fig.4. Distribution of total of observed marked bumblebees on three transects.

Bumblebee activity

At the start of the trial the middle (green) colony showed a lower activity rate compared to the outside colonies. During the trial bumblebee activity started around 9am and stopped at 9pm. The decrease in activity on 18 April is due to re-marking. A total of 18157 events in 12 days is recorded for the blue colony, 15945 events for the green colony and 27097 for the red colony. In the beginning of the trial the one-way doors were present and may have caused the relative high number of events in the first week. During the first 10 days the red colony showed highest activity.

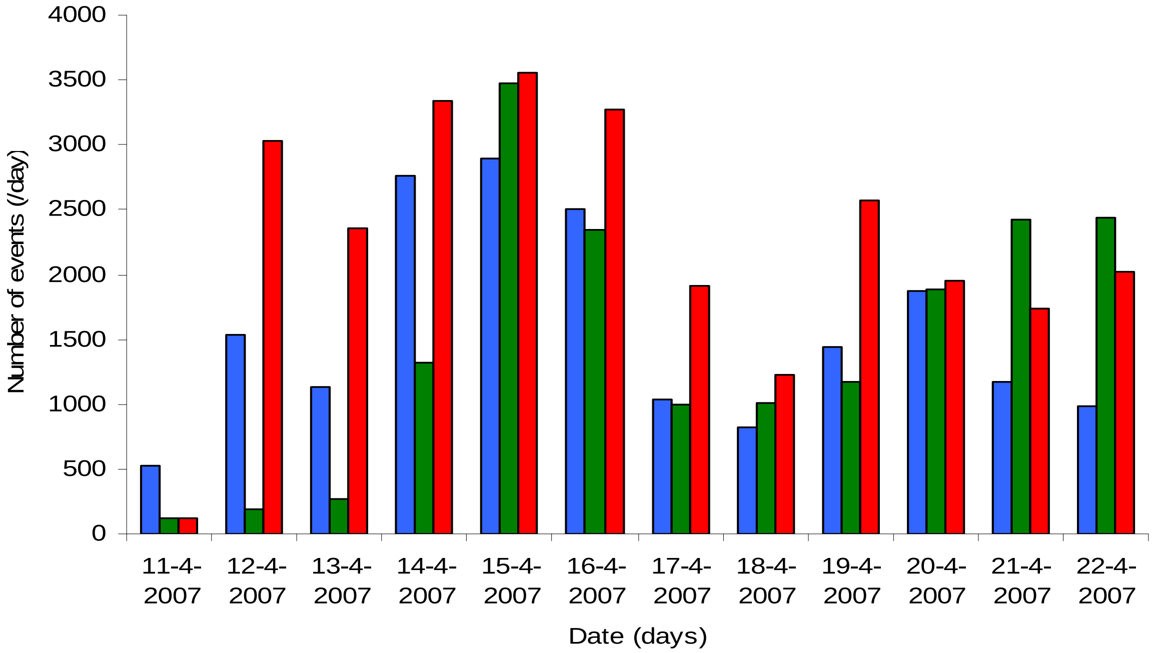
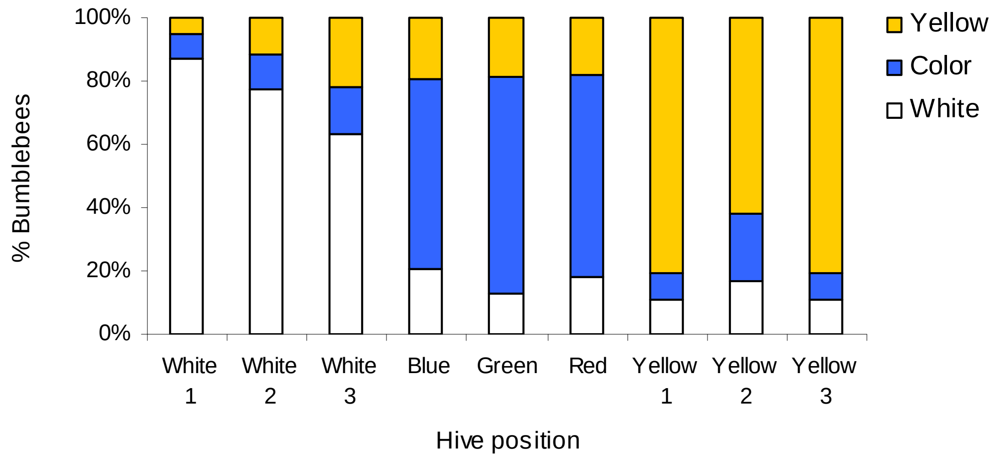


Fig.5. Bumblebee activity per colony per day.

Switching between hive clusters

In all clusters there is remarkably no significant difference in the ratio of switching bumblebees from the two other marked clusters (Fig.6). This might have been expected for the middle cluster (bumblebees from the side clusters have to travel the same distance to enter the “colored” cluster), but the same observations are made for the side clusters. For instance, in a white hive the same amount of yellow bumblebees is observed as bumblebees from the colored hive. The total amount of retrieved marked bumblebees per cluster did not differ very much (Total white: 330, total colored: 274, total yellow: 301).

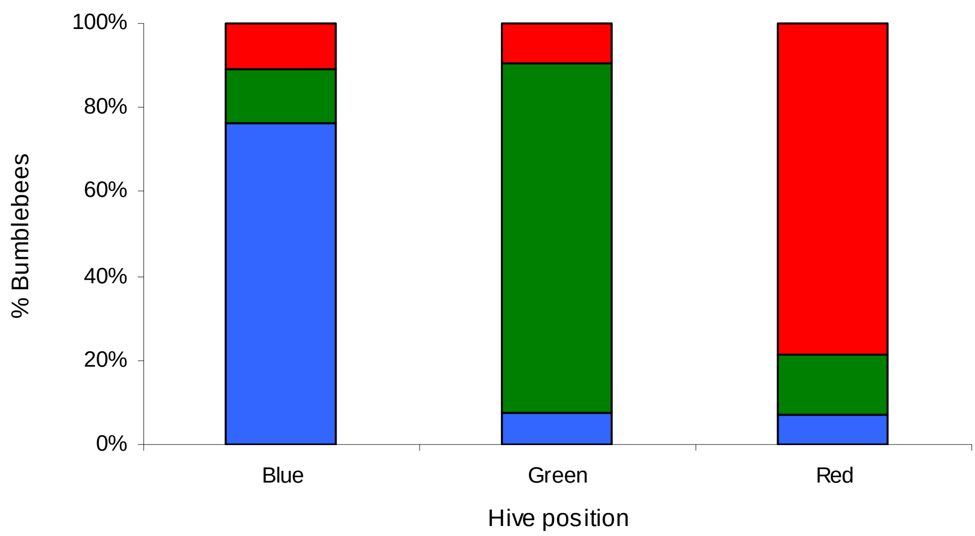


Marked	94	76	160	77	153	44	84	119	98

Fig.6. Switching ratio of marked bumblebees between hive clusters.

Switching within cluster

Within the colored cluster no significant preference for a specific hive position was visible and most bumblebees were retrieved in the hive they originated from (Fig.7).



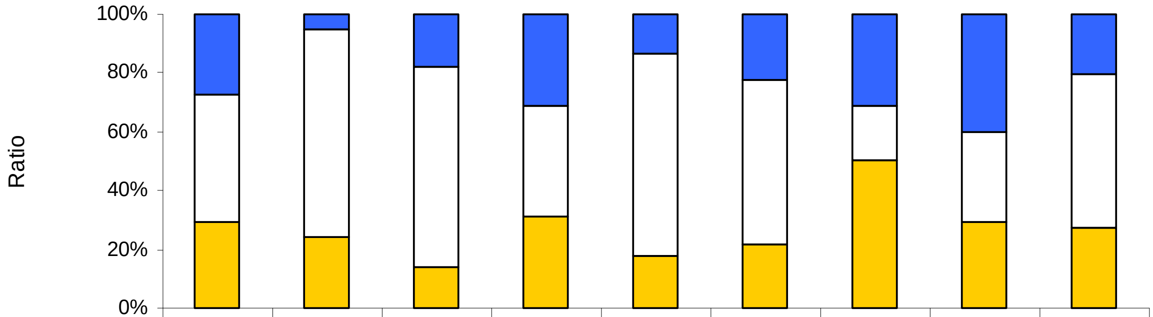
		Hive		
		Blue	Green	Red
	Blue	35	8	2
Color	Green	6	86	4
	Red	5	10	22
	Total	46	104	28

		Blue	Green	Red
	Blue	76,1	7,7	7,1
Color	Green	13,0	82,7	14,3
	Red	10,9	9,6	78,6

Fig.7. Switching ratio of marked bumblebees within colored cluster.

Final composition

The total amount of bumblebees within a cluster over after 12 days was 1038 (white cluster), 1377 (colored cluster) and 1208 (yellow cluster). In the end approximately a quarter of the total amount of marked bumblebees was retrieved and consisted the rest of the hive of new workers and queens (except from yellow 1, with a ratio of 50% original marked bumblebees) (Fig.8). The ratio of queens in the middle hive of the white and colored clusters was considerably lower (resp. 5% and 13%) compared to yellow cluster (40%). The ratio of queens differed not more than ±10% between the both side hives of all clusters.



	White 1	White 2	White 3	Blue	Green	Red	Yellow 1	Yellow 2	Yellow 3
Queen	0,27	0,05	0,18	0,31	0,13	0,22	0,31	0,40	0,20
Unmarked	0,44	0,70	0,68	0,37	0,69	0,56	0,19	0,31	0,53
Marked	0,29	0,25	0,14	0,31	0,18	0,22	0,50	0,29	0,27

Hive position

	White 1	White 2	White 3	Blue	Green	Red	Yellow 1	Yellow 2	Yellow 3
Queen	58	104	120	72	33	57	83	87	99
Unmarked	35	80	311	115	438	219	100	456	251
Marked	94	76	160	77	153	44	84	119	98
Total	**187**	**280**	**591**	**264**	**624**	**320**	**267**	**662**	**448**

Fig.8. Final composition (relative (above) and absolute (under)) of marked bumblebee hives.

Pollen

On eight days pollen was collected. After analysis no significant differences were present in pollen consistency between the different hives. Samples consisted mainly of willow pollen as this tree produces huge amounts of pollen and is very attractive to insects. The amount of cherry pollen found in the samples is according to the time of bloom of the cherry trees (Fig.9). In Fig.9 the main species found are shown. Next to these species also pollen of *Lonicera*, Maple and some other Rosaceae (pear, apple) were identified (Appendix II-III).

Species		6 April	8 April	11 April	13 April	16 April	18 April	20 April	23 April
Willow		95%	80-90%	80%	70%	-	-	-	-
Cherry		**3-5%**	**3-10%**	**5%**	**10%**	**25%**	**10-20%**	**10-15%**	**0%**
Comfrey		±	+	+	+	+	+	+	+
Ground Ivy		±	±	-	±	-	-	±	±
Chestnut		-	-	-	-	±	±	±	+

Fig.9. Pollen species identified in cherry. - = few, ± = sometimes, + = frequently.

Rapeseed

- Bumblebees observed from 30-160m.
- No significant difference in number of bumblebees between transects => assume homogenous distribution in field.
- No “fresh” colonies in field so hard to compare with other fields and no insight in colony development.
- Bumblebee activity started around 8-8.30am until 8-9pm.
- Considerable ratio of collected pollen consisted of rapeseed pollen (5-30%).

The crop

Rapeseed (*Brassica napus*) is a crop which is cultivated more and more last decades. It is grown for its seeds from which oil is pressed. Rapeseed is a heavy nectar producer and therefore very attractive to bumble- and honeybees. Normally rapeseed growers contract with beekeepers for the pollination of the crop.

The rapeseed field (60m x 400m) for this trial was located next to a small village called Erichem (Pic.9). The main crops surrounding the rapeseed field were different sorts of fruit orchards.

Specific details and observations

Due to overlap in time of bloom with cherry, and therefore lack of time to mark new colonies, the clusters used in cherry were placed in the rapeseed field. As rapeseed is a fast growing crop in a high density it was impossible to walk a transect through the field. Two transects (400m) alongside the field were monitored.

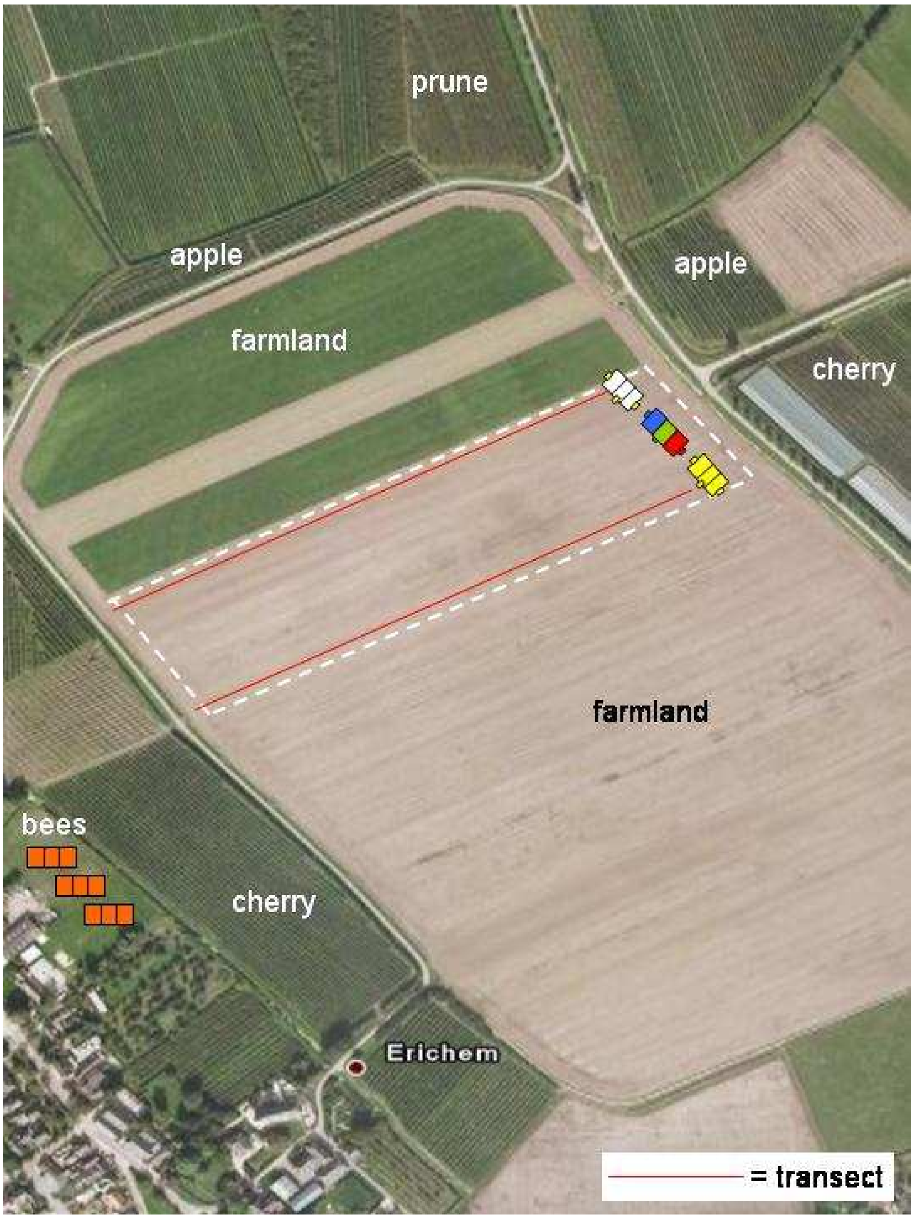
A large number of bee hives was present in a field adjacent to the rapeseed field and large numbers of honeybees were counted (homogenous distributed in the field). Insect activity in the rapeseed was considerably lower compared to earlier findings (personal remark of grower and beekeeper).

Weather conditions

The Temperature/RV-logger was available during this trial, but only a few bumblebee observations are made. Therefore only weather data of three days is given (Fig.10). Temperatures were extremely high for the time of year which resulted in decrease of nectar production. No irrigation was applied during the trial and there was no shade in the field.

Date	25-4-2007	General	28-4-2007	General	1-5-2007	General
Temp. ave. (ºC)	19.6*	9.7	17.8*	9.7	15.7*	11.4
Temp. max. (ºC)	29.2*	14.6	25.6*	14.6	22.3*	16.3
Temp. min. (ºC)	11.2*	4.6	11.8	4.6	7.3*	6.3
RV ave. (%)	44*	75	62*	75	43*	75

Fig.10. Temperature and RV data during rapeseed trial, *: data logger data (General data location: De Bilt, The Netherlands. From www.knmi.nl).



Pic.9. Aerial picture of the rapeseed field, Erichem (Google Earth).

Distance

In total 5 observations of marked bumblebees were made on the white transect and 8 on the yellow transect over a period of 9 days (Fig.11). The farthest observation of a worker bumblebee was made at 160m. from the hive. Because the colonies were already well-developed also mating queens were observed on the hive supports.

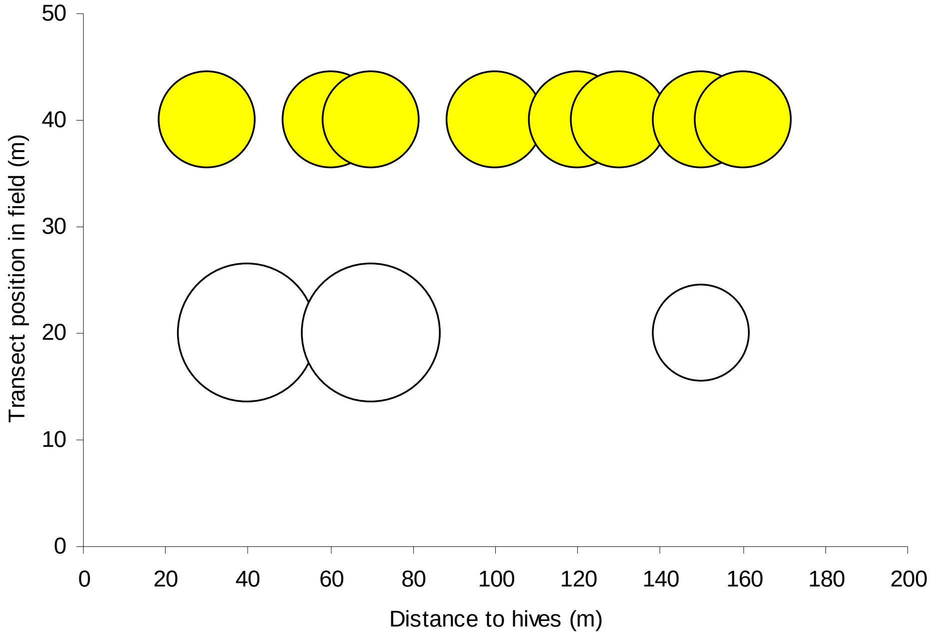


Fig.11. Marked bumblebee observations on yellow and white transect. Small dot: 1bumblebee observed, larger dot: 2 bumblebees observed.

Bumblebee activity

During the length of the rapeseed trial showed the green colony highest activity (Fig.12). Regarding the extreme warm conditions ventilating sentry bumblebees might have caused the extremely high number of activity on April 25th. Compared to the blue colony activity in the red hive showed higher values along the trial. Total bumblebee activity decreased compared to the activity of the same colonies in the cherry trial.

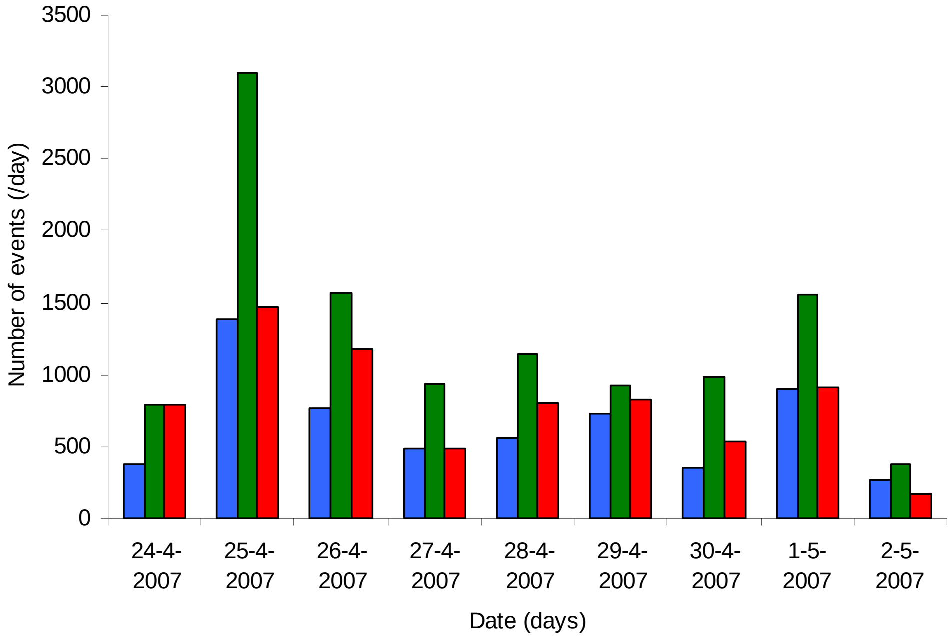


Fig.12. Bumblebee activity per colony per day.

Pollen

On two days pollen was collected (Fig.13). After analysis no significant differences were present in pollen consistency between the different hives. Next to these species also pollen of *Lonicera* and Rosaceae (*Prunus*) were identified (Appendix IV).

Species		26 April	1 May
Rapeseed		**10-30%**	**5-10%**
Willow		+	+
Chestnut		+	+
Comfrey		±	+
Maple		+	+
Pinus		±	±

Fig.13. Pollen species identified in rapeseed. - = few, ± = sometimes, + = frequently.

Strawberry

- Two bumblebees have been observed at a maximum distance of 150 meters.
- Most observations (78%) within 70 meters.
- Considerable amount of bumblebees (32%) close (<20m) to the hives.
- Weather conditions not optimal.
- Honeybees caused nectar deficiency in bumblebee colonies.

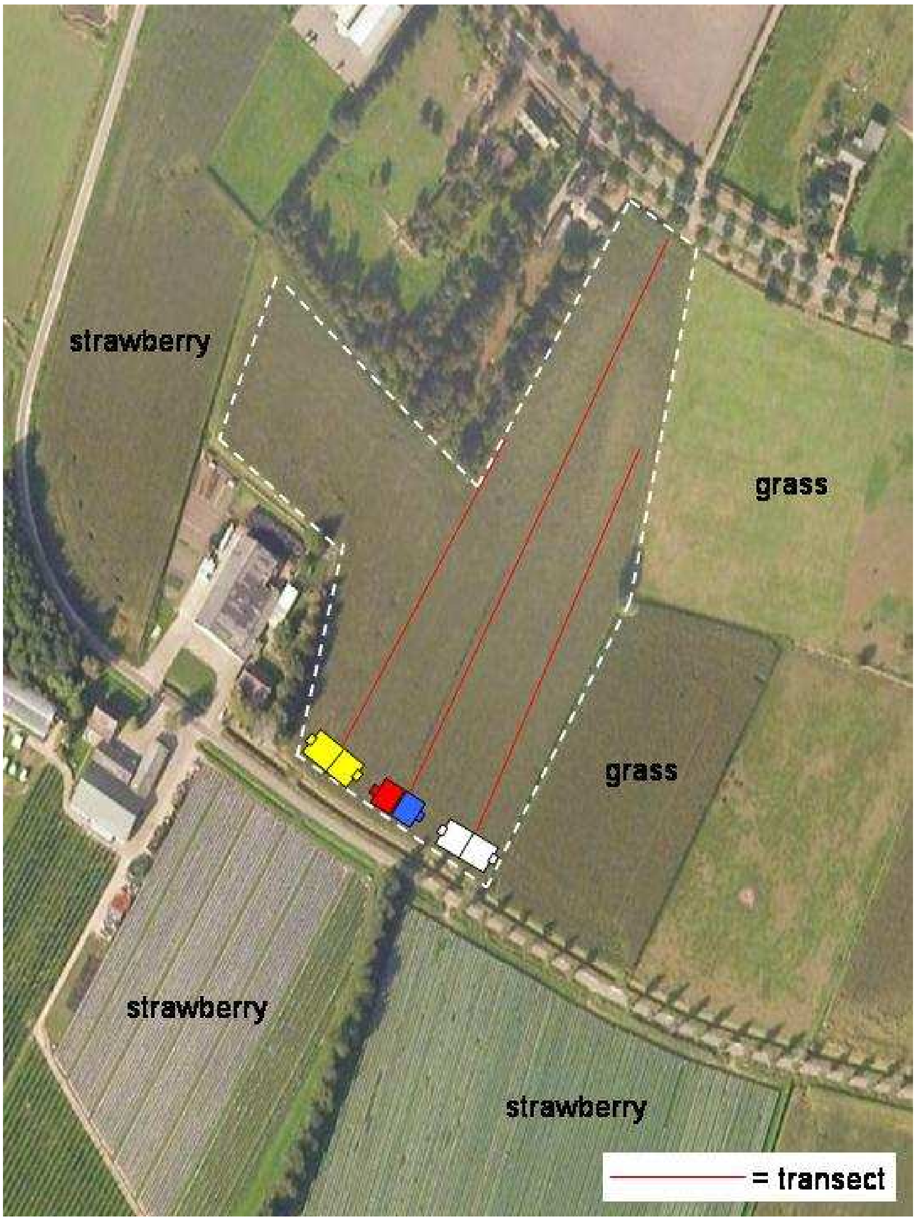
The crop

The strawberry field location was situated in the agricultural area of Heeswijk-Dinther (Pic.10). The used variety “Elsanta” was grown on normal farmland. Several other fields with Elsanta surrounded our test field. On these fields strawberries were grown on racks and semi-full farmland. All fields were irrigated regularly.
The strawberry plant can fertilize itself, so no cross pollination is needed but to obtain nice and large fruit insects are used for pollination, especially honey and bumblebees. No extra honeybee colonies from a beekeeper were present during the trial.

Specific details and observations

Due to the shape of the field it was not possible to make three identical transects. The white transect was 100m; colored transect 280m and yellow transect 160m. As this field was also used for another trial, with more bumblebee density sensitive data, only two colonies per cluster were used. The trial started on June 6th. After 12 days all colonies were re-marked.
As strawberry produces not enough nectar to sustain the bumblebee colonies the Bee Happy was available for the bumblebees during the trial. Unfortunately also bees, ants and sometimes even wasps were attracted to the sugar water, resulting into an energy deficiency in bumblebee colonies. This problem was recognized too late. In the end of the trial all Bee Happy reserves were empty and bumblebee colonies started to deteriorate. Due to this problem activity decreased and no analysis of switching bumblebees could be carried out. Strawberry flowers in the test field were not in bloom anymore by that time.

More detailed information on fruit size related to bumblebee density and weather circumstances can be found in report of Project 3447 (Monique van Kessel, Natupol, Koppert).



Pic.10. Aerial picture of the strawberry field, Heeswijk-Dinther (Google Earth).

Weather conditions

At the start of the trial weather conditions were above average values. A small general decrease over two weeks is visible after which weather conditions slightly improved (Fig.15).

Date	10-6-2007	General	19-6-2007	General	28-6-2007	General	7-7-2007	General
Temp. ave. (ºC)	20.6*	14.8	20.4*	14.9	15.8*	15.9	16.0	17.3
Temp. max. (ºC)	22.7*	19.6	27.9*	19.5	20.4*	20.4	22.8	22.1
Temp. min. (ºC)	17.6*	9.8	11.1*	9.9	12.0*	11.0	6.4	12.3
RV ave. (%)	81*	77	72*	76	69*	78	59	77

Fig.14.Temperature and RV data during strawberry trial, *: data logger data (General data location: De Bilt, The Netherlands. From www.knmi.nl).

Relative humidity reached, in general, every day a maximum value of 90-95% (Fig.16). This is due to the long periods of rain in the first weeks of the experiment (personal observation); normally conditions are drier (Fig.14). Average relative humidity showed values between 72-88%. Flowering conditions were less optimal compared to other years (personal remark of grower).

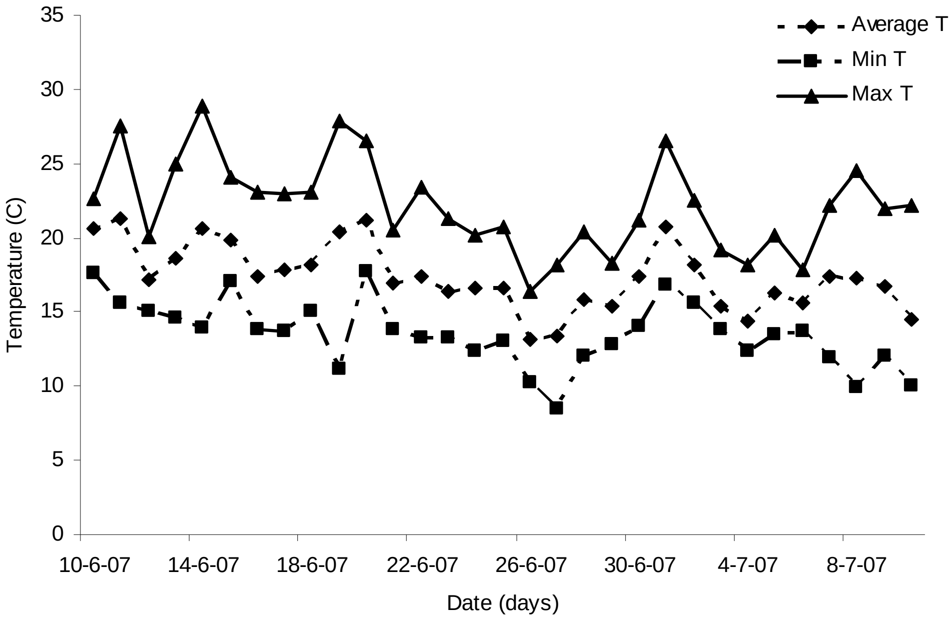


Fig.15. Maximum, average and minimum field temperatures during strawberry trial.

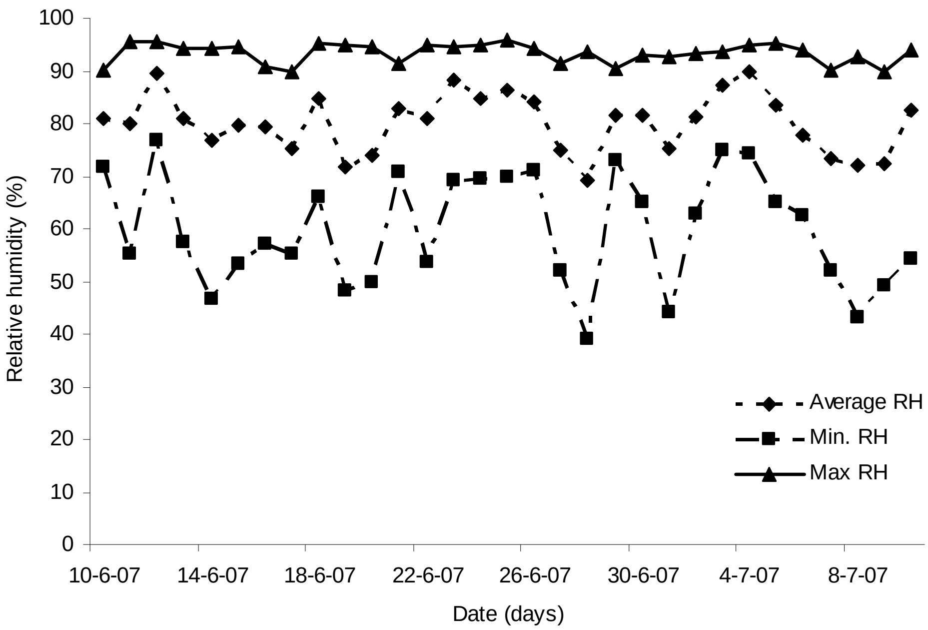


Fig.16. Maximum, average and minimum relative humidity during strawberry trial.

Distance

On all transects marked bumblebees were observed at a maximum length of 140-150 meters (3 observations) (Fig.17). A total of 20 on the white transect, 14 on the colored transect and 25 on the yellow transect. Most bumblebees were observed in a range of 0 – 70 meters from the hives (46 of total of 59 observations, 78%) (Fig.18). A substantial number of marked bumblebees was observed on strawberry flowers close to the hive (32% within 20 meters). Even one bumblebee was observed leaving the hive, visiting the first flower in the field (personal observation). Along the sides of the field more marked bumblebees were observed compared to the middle transect.

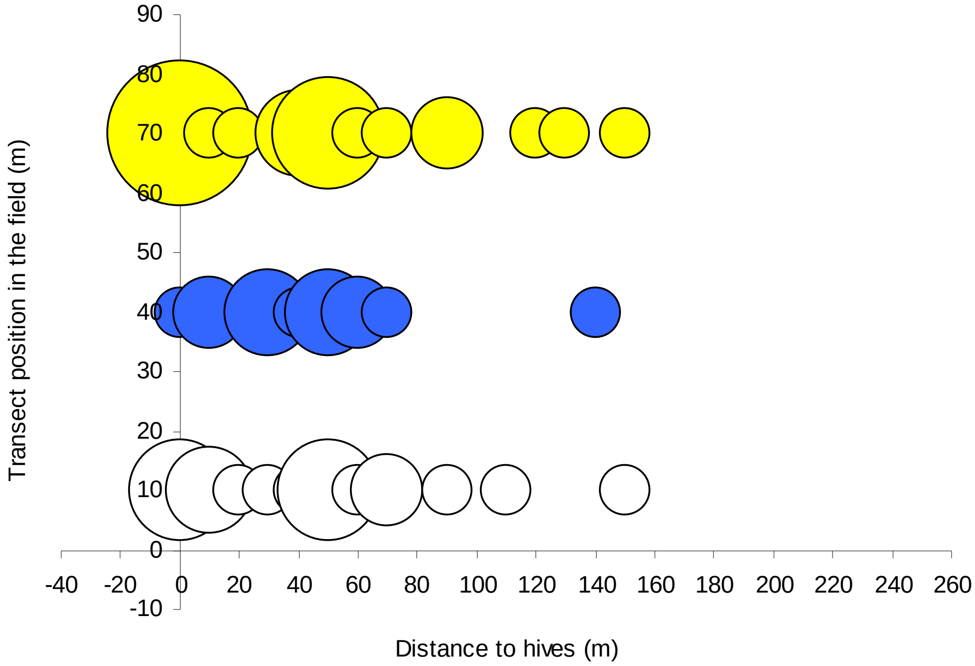


Fig.17. Marked bumblebee observations on yellow, coloured (blue) and white transect. Small dot: 1 bumblebee observed, largest dot: 8 bumblebees observed.

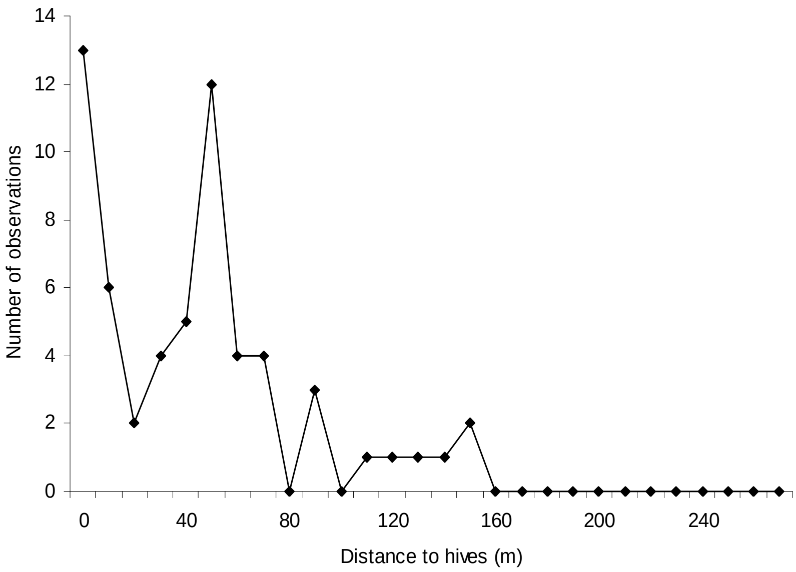


Fig.18. Distribution of total of observed marked bumblebees on three transects.

Bumblebee activity

Both colonies showed no development of activity as might have been expected. Except from two days with high activity rate all other days showed a very low rate of activity (Fig.19). In the beginning there was enough Bee Happy. Once discovered by honeybees and other insects it formed a limiting resource for the bumblebees.

From June 23rd bumblebee activity of both colonies is similar. A slow increase of activity from June 27th until July 5th is corresponding to an increase in field temperature.

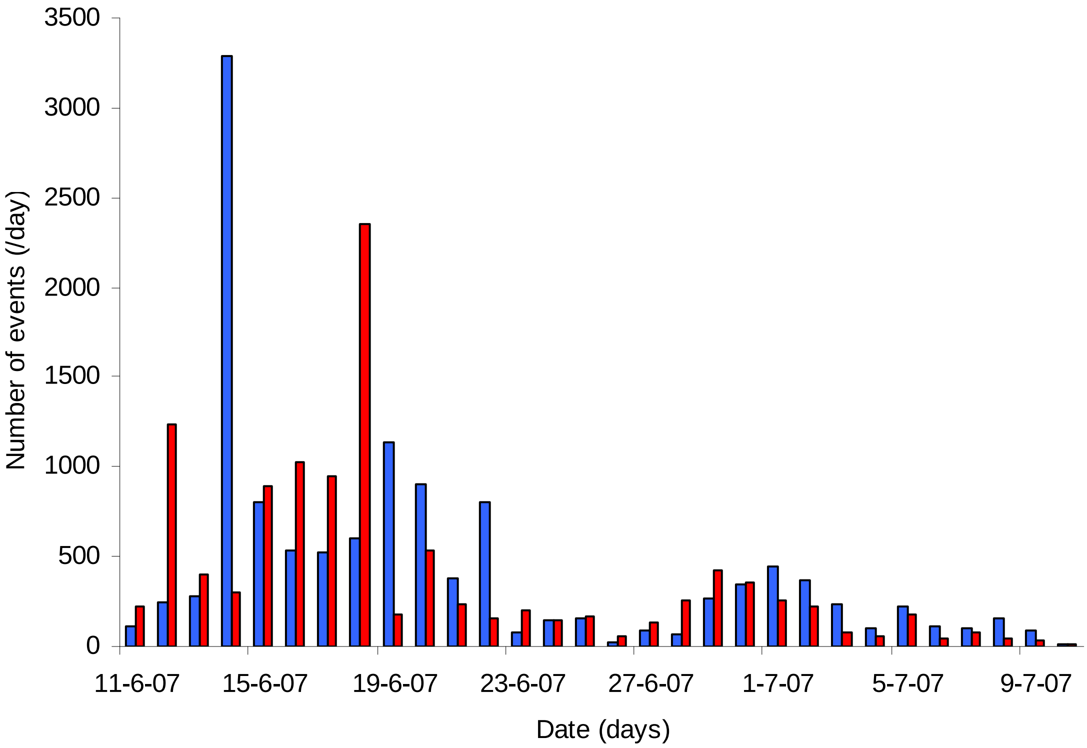


Fig.19. Bumblebee activity per colony per day.

Pollen

Not yet available.

Species		13 June	20 June	27 June
Strawberry				

Fig.20. Pollen species identified in strawberry. - = few, ± = sometimes, + = frequently.

Sunflower

- Marked bumblebees have been observed at a maximum distance of 190 meters.
- Most observations (67%) within 30-100 meters.
- No significant difference in number of bumblebees between transects => assume homogenous distribution in field.
- Bumblebee activity between 8am and 9.30pm.
- Switching bumblebees between clusters from 1-8%.
- Switching bumblebees within cluster from 2,3-24%.
- Bumblebees visited sunflower very well. On 11-7-2007 even 90% of the collected pollen consisted of sunflower pollen. On other days pollen samples consisted of 40-80% of sunflower pollen.

The crop

Because sunflower is not a commercial important crop in the Netherlands data of bumblebee distribution in sunflower was collected in Meyrargues, next to Aix-en-Provence, Provence, France (Pic.12). The sunflowers in the trial were of a semi low-growing variety, grown for their seeds. Eight rows of female plants were interchanged by two rows of male plants (smaller and with more flowers per plant) for pollination.

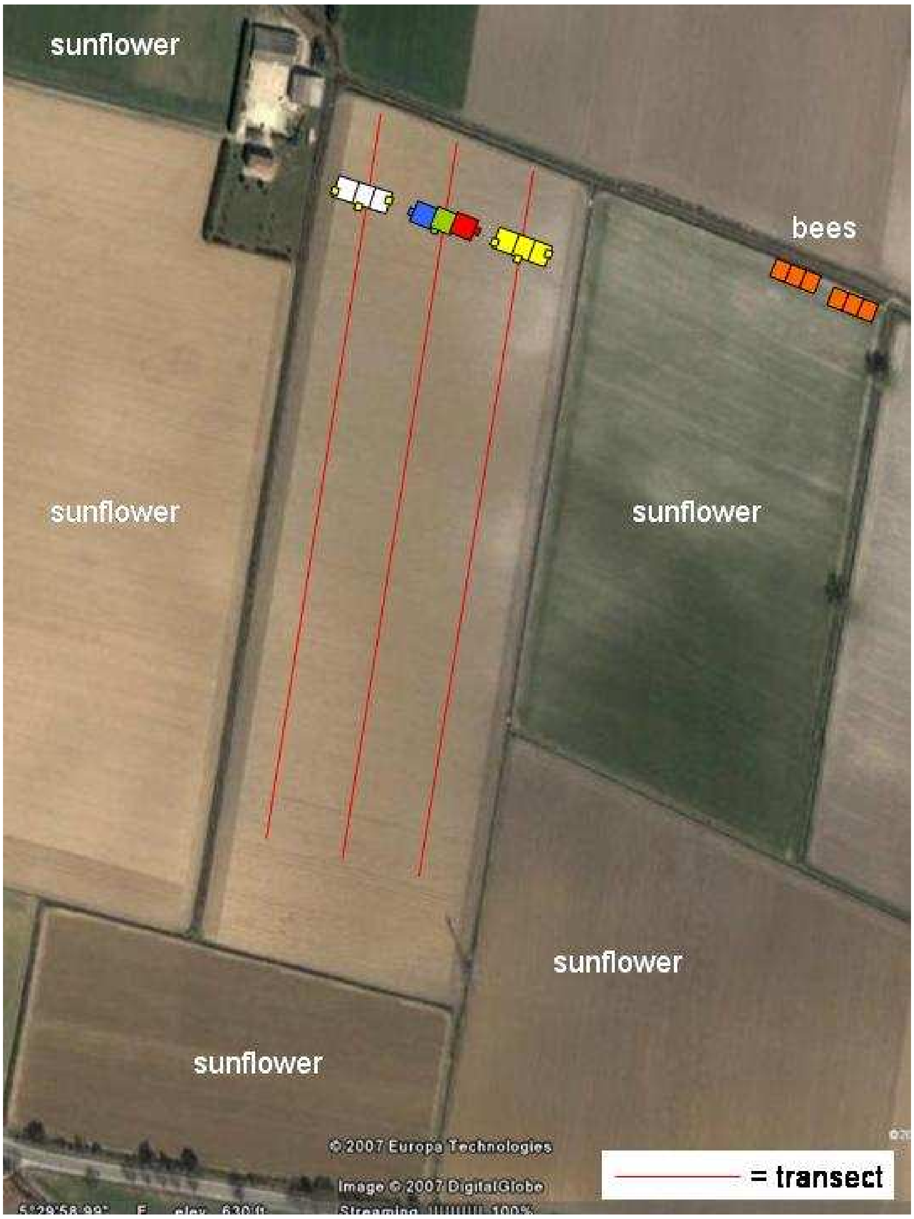
Female flowers appeared 1 ½ week after appearance of the first male flowers. Overall bloom of sunflower was late as a cold spring had slowed down the development of the sunflowers.

The large field (430m x 100m) was irrigated several times by running water through furrows during a certain time span (Pic.11).

Pic.11. Main irrigation canal with furrows (left).

During and shortly after irrigation the field was not accessible. The test field was surrounded by other sunflower fields (other varieties) in this agricultural area.

The ground consisted mainly of clay and in parts of the field more gravel was embedded, causing a higher ground temperature. As sunflower is very susceptible to ground temperature and forms in case of a warm ground bigger plants and flowers, specific parts in the field showed a higher flower quality.



Pic.12. Aerial picture of the sunflower field, Meyrargues, France (Google Earth).

Specific details and observations

Clusters were placed 60 meters into the field, 30 meters apart from each other. Three transects, ranging from -60 until 340 meters were prepared. Sunflower produces not enough nectar to sustain bumblebee colonies, so access to Bee Happy was provided. Natupol colonies were equipped with an extra large version of Bee Happy (1.7liters). After two weeks other insects were attracted to the sugar water. By placing mesh over the slots (Bee Gone) or a polystyrene cap over the Bee Happy wick further loss of sugar water was prevented (Pic.13).

One week after start of the experiment bees were introduced by the grower in the field adjacent to the trial field.

Pic.13. Bee Gone-mesh nets.

Weather conditions

Although weather was relatively mild for the time of year (personal remark of grower) maximum temperature reached almost 35 ^{0}C in the shadow (Fig.21). A critical temperature for bumblebee colonies and ventilating bumblebees were spotted. The strong wind, le Mistral, might have formed some relief to the colonies on a warm day. During night time temperatures dropped to a minimum of 11 ^{0}C (Fig.21).

In the afternoon lowest RH-values (e.g. 22,89% on 16-7-2007) were recorded (Fig.22). Values increased during night fall and decreased by the time the sun was setting. On several days clouds were present. During the trial there was no rain recorded.

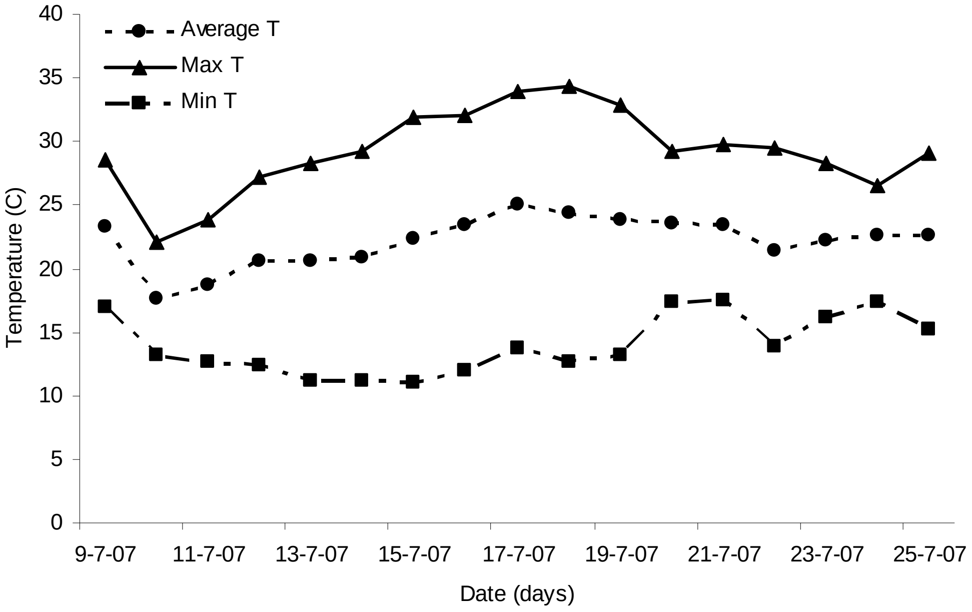


Fig.21. Maximum, average and minimum field temperatures during sunflower trial.

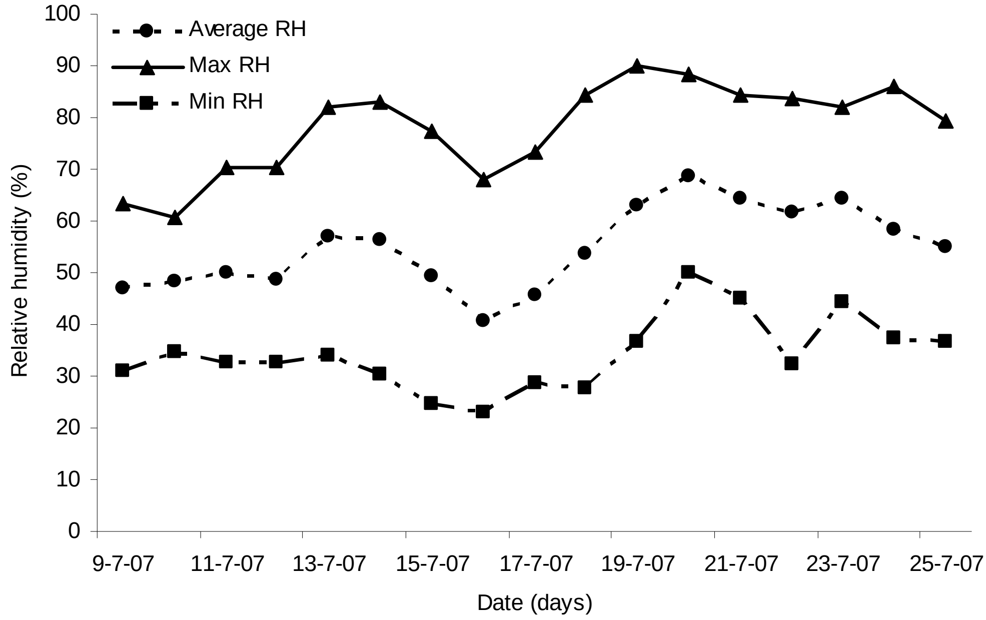


Fig.22. Maximum, average and minimum relative humidity during sunflower trial.

Distance

A total of 88 bumblebees over a period of 2 weeks were recorded. Except from 2 observations on 180 and 190 meters, all observations on all transects were made between -40 and 140 meters (Fig.23). Bumblebees were evenly distributed in the field. Most bumblebees (67%) were observed between 30 and 100 meters on all transects (Fig.24).

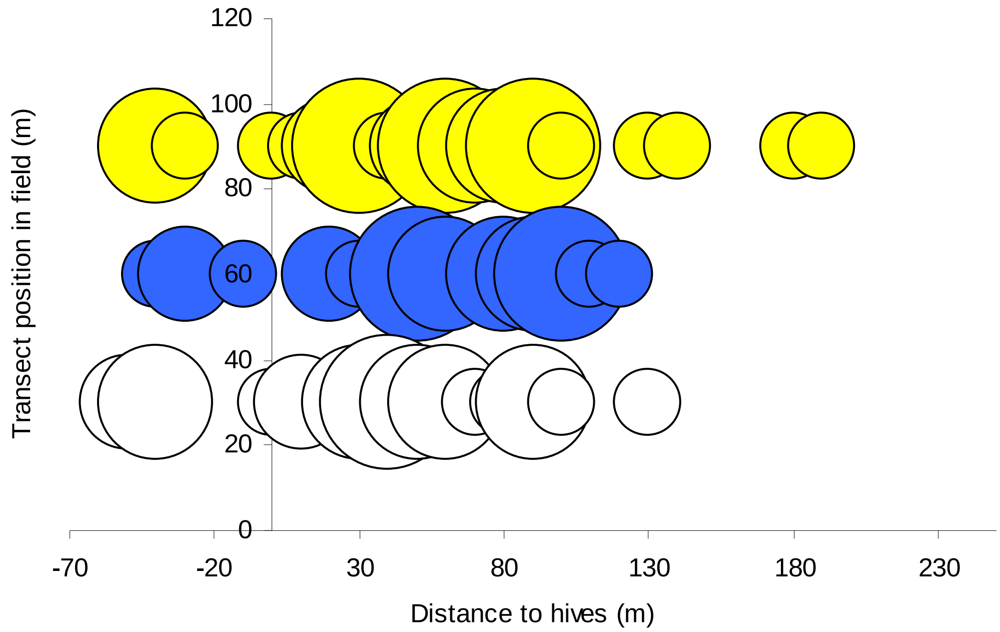


Fig.23. Marked bumblebee observations on yellow, coloured (blue) and white transect. Small dot: 1 bumblebee observed, largest dot: 4 bumblebees observed.

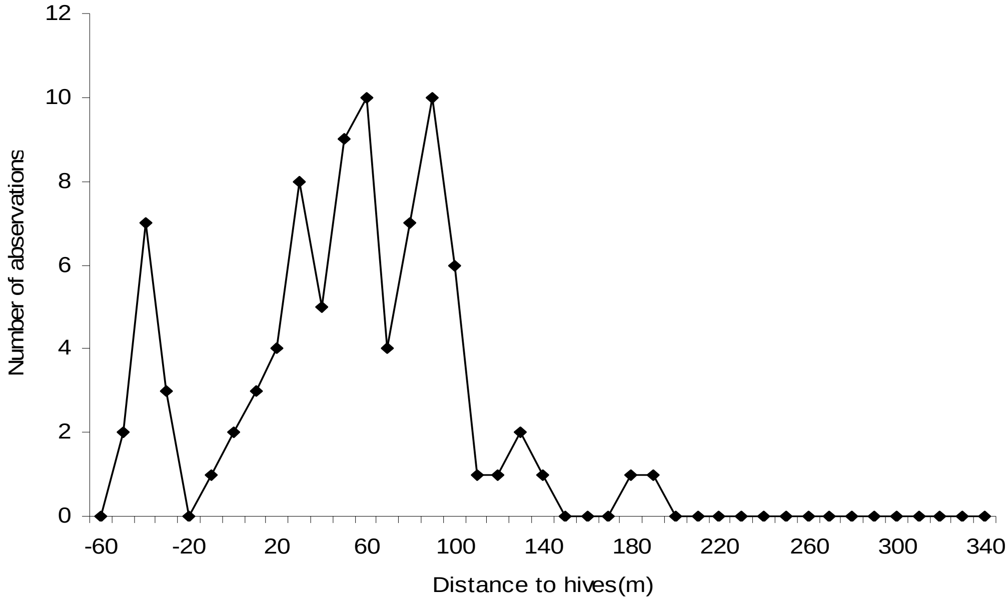


Fig.24. Distribution of total of observed marked bumblebees on three transects.

Bumblebee activity

In the first week all colonies show an increase in activity. After a slight incline activity in the green hive decreases (Fig.25). Blue shows a fast incline in activity. The (relative) high activity of this colony might be due to sentry bumblebees, whereas e.g. 4 events occur within only 11 seconds. Bumblebee activity of blue and red colony decrease after re-marking from 1500-2000 to ± 1000 events per day. Activity in the green hive remains low.

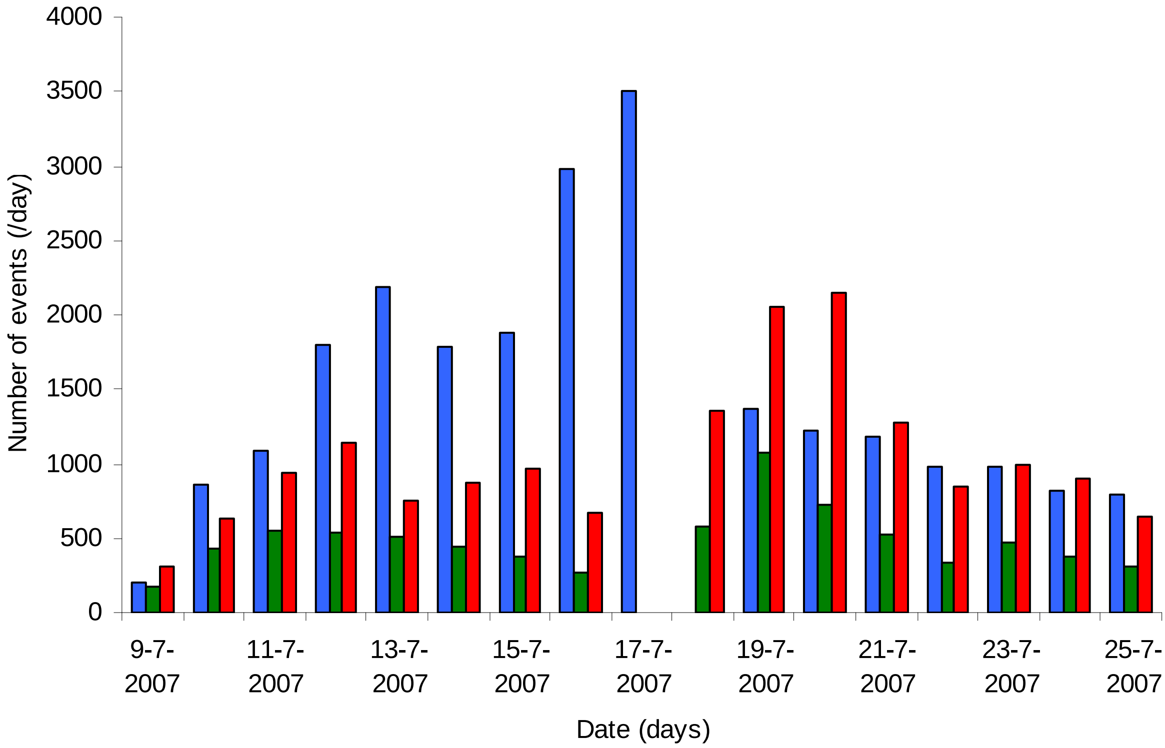
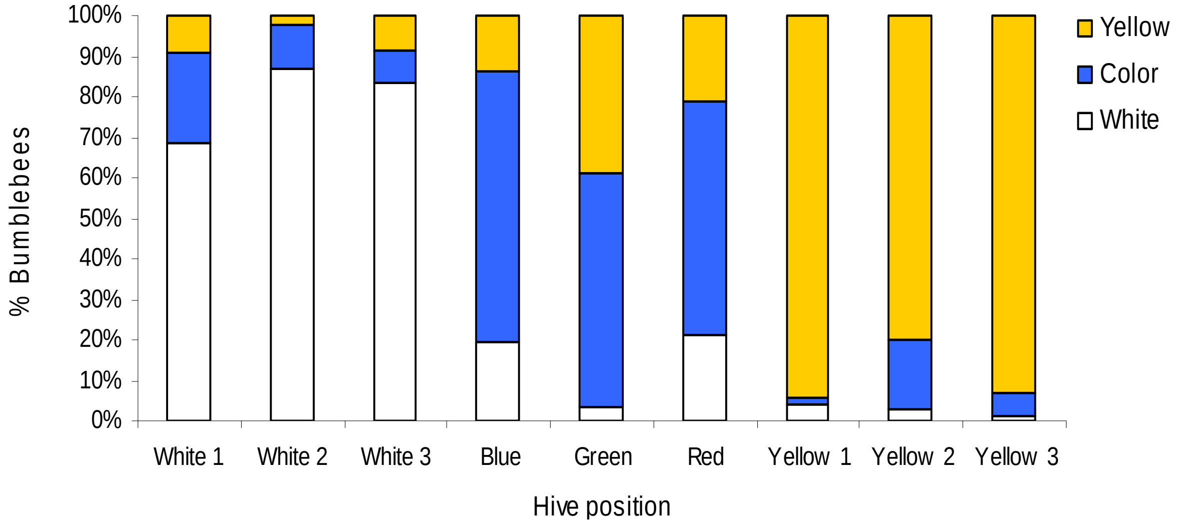


Fig.25. Bumblebee activity per colony per day (original value 17-7 blue is twice value above; missing values on 17-7 due to re-marking).

Switching between hive clusters

In all clusters there is remarkably no significant difference in the ratio of switching bumblebees from the two other marked clusters (Fig.6). This might have been expected for the middle cluster (bumblebees from the side clusters have to travel the same distance to enter the “colored” cluster), but the same observations are made for the side clusters. For instance, in a white hive the same amount of yellow bumblebees is observed as bumblebees from the colored hive. The total amount of retrieved marked bumblebees per cluster differed (Total white: 169, total colored: 140, total yellow: 212).

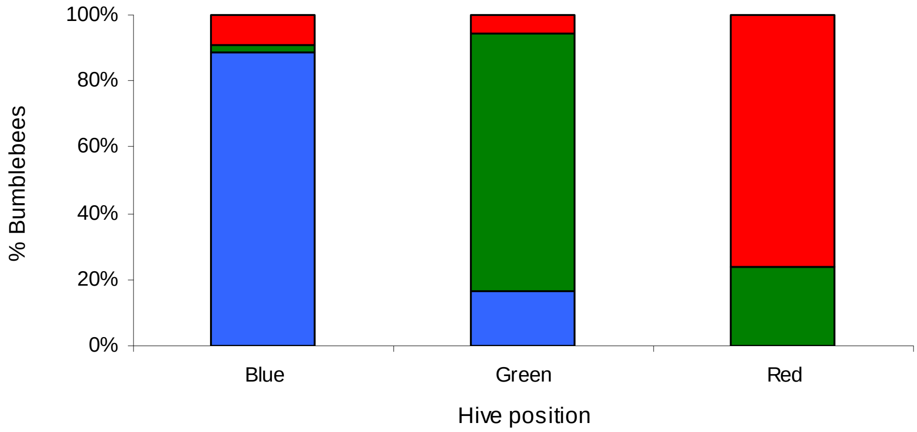


Marked	54	91	24	66	31	43	53	70	89

Fig.26. Switching ratio of marked bumblebees between hive clusters.

Switching within cluster

Within the colored cluster no significant pattern of preference for a specific hive position was present. Most marked bumblebees were observed in the hive they originated from (Fig.27).



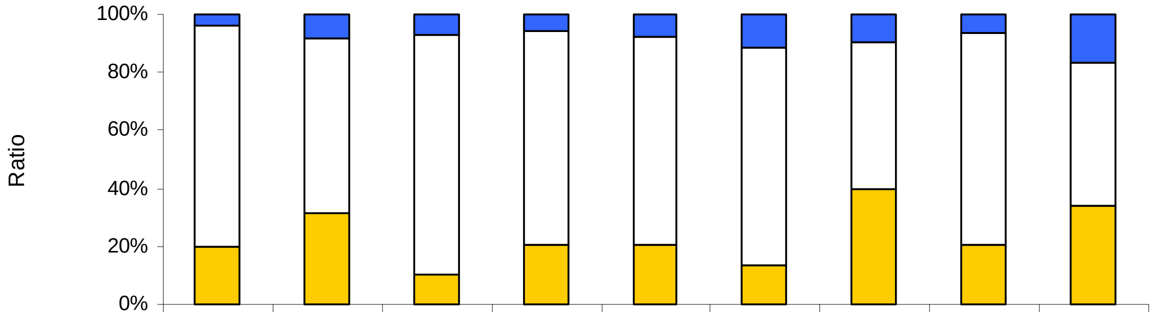
		Hive		
		Blue	Green	Red
	Blue	39	3	0
Color	Green	1	14	6
	Red	4	1	9
	Total	44	18	15

		Blue	Green	Red
	Blue	88,6	16,7	0
Color	Green	2,3	77,8	14,0
	Red	9,1	5,6	76,0

Fig.27. Switching ratio of marked bumblebees within colored cluster.

Final composition

The relative amount of queens was more or less the same for all colonies (except Yellow 3, Fig.28). Colonies were on the same level of development although absolute numbers differ. The rate of unmarked bumblebees ranged fro 49-83%. A total of 799 bumblebees was found in the white cluster, 792 in the colored and 736 bumblebees in the yellow cluster. The composition within the colored hive was similar for the three hives involved (Fig.28).



	White 1	White 2	White 3	Blue	Green	Red	Yellow 1	Yellow 2	Yellow 3
Queen	0,04	0,09	0,07	0,06	0,08	0,11	0,10	0,06	0,17
Unmarked	0,77	0,60	0,83	0,74	0,72	0,75	0,51	0,73	0,49
Marked	0,20	0,31	0,10	0,20	0,20	0,14	0,40	0,21	0,34

Hive position

	White 1	White 2	White 3	Blue	Green	Red	Yellow 1	Yellow 2	Yellow 3
Queen	10	25	16	18	12	36	13	21	44
Unmarked	211	175	193	242	109	235	68	250	128
Marked	54	91	24	66	31	43	53	70	89
Total	**275**	**291**	**233**	**326**	**152**	**314**	**134**	**341**	**261**

Fig.28. Final composition (relative (above) and absolute (under)) of marked bumblebee hives.

Pollen

Pollen analysis showed very nice results on bumblebees flying in sunflower. Up to 90% of the collected pollen consisted of sunflower (Fig.29). Bumblebees observed on the flowers itself were often very busy collecting; presence of honeybees did not interrupt the bumblebees. Pollen of sainfoin (fabaceae) and common privet were also found but in smaller amounts. The pollen data indicates that sunflower is a very good pollen provider for bumblebees. Therefore bumblebees might form a good alternative/supplement for honeybees in this crop.

Species		11 July	16 July	18 July	23 July	25 July
Sunflower		**60-90%**	**50-75%**	**40-80%**	**50-80%**	**50-70%**
Clover		+	+	+	+	+
Common privet		±	±	-	-	-
Sainfoin		+	±	±	-	-
Thistle		±	-	-	-	-

Fig.29. Pollen species identified in sunflower. - = few, ± = sometimes, + = frequently.

Discussion and recommendations

Earlier research has recorded bumblebees flying up to 18 kilometres removed from their nest (Heinrich, 1979), but most of the time bumblebees are found more in the vicinity of the nest. This is mainly based on arguments concerning energetics and bumblebees' lack of organized recruitment (Heinrich 1979; Visscher & Seeley 1982). As bumblebees have a high metabolic rate (Heinrich, 1975) a net energy profit by means of collected nectar and pollen is only reached if foraging patches are in the vicinity of the nest. Flying shorter distances can spend more time collecting nectar and maximize energy returns to the nest (Osborne *et al.*, 1999). This might explain the bumblebee recordings (very) close to the hives (0 metres in the strawberry trial), but in general most bumblebee recordings were made at distances from 40-130 metres removed from the hives. In terms of *Bombus terrestris* foraging ranges these distances still belong to the “short distance”-range. Unfortunately it was not possible to collect distance data of marked bumblebees foraging further than the trial field. This short range foraging might involve other risks as facilitating diseases and luring predators or parasites on the other hand as stated by Dramstad (1996). In our study no parasitoids were found. Only in strawberry moths occurred. A bigger problem was created by high densities of honeybees collecting sugar water solution. Under natural circumstances this problem is less occurring as bumblebee nests are not easy to access and bumblebee nests are situated less conspicuous.

Given the fact that each individual bumblebee visits hundreds, sometimes even thousands, of flowers in one foraging trip, flowers next to the hive are very well visited and most of the times depleted of resources by other members of the bumblebee colony (up to 94% of the crop in a small area (Heinrich, 1976). This intra-competition might force a bumblebee worker to forage in a wider radius, covering a larger area (Creswell *et al.* 2000). Results show that in all fields bumblebee densities were evenly distributed across the field, probably as a result of spreading this intra-competition effect.

- In cherry a maximum of 16 bumblebees was recorded in one hour: 16 on a 3 meter wide transect; total field width: 50 meters, so at least a total of 270 bumblebees might have been expected in one hour.
- In rapeseed a maximum of 6 bumblebees was recorded in one hour: 6 on a 3 meter wide transect; total field width: 110 meters, so at least a total of 330 bumblebees might have been expected in one hour.

- In strawberry a maximum of 9 bumblebees was recorded in one hour: 9 on a 3 meter wide transect; total field width: 80 meters, so at least a total of 240 bumblebees might have been expected in one hour.
- In sunflower a maximum of 6 bumblebees was recorded in one hour: 6 on a 3 meter wide transect; total field width: 150 meters, so at least a total of 300 bumblebees might have been expected in one hour.

Weather conditions were in most cases relatively good; a warm spring and a relatively cool summer provided fine conditions for bumblebees to pollinate. High humidity values, bad for pollen release by flowers, might have caused disadvantages in the strawberry trial. During the trial a lot of rain fell on most days. A light shower does not affect bumblebee activity but heavier showers form an obstruction to normal bumblebee foraging behavior.

Our results show that in none of the trials a significant preference was present for the position of the hive in the field, so placement throughout the field, but taking into account the preferred foraging range, should cause no significant problems.

Collected pollen of the cherry trial consisted of a maximum of 25% of cherry pollen, whereas rapeseed and especially sunflower were much more attractive to bumblebees, reaching percentages ranging from 5%-30% in rapeseed to 40-90% for sunflower. This indicates that, assuming pollen is coming from the crop field the trial was conducted, bumblebees do forage close to their nests as long as the supply of pollen is sufficient and the type of pollen is more attractive then pollen coming from a plant species surrounding the crop fields (e.g. willow).

- If, in future, research focuses on bumblebee activity in combination with foraging range, less disturbing tracking techniques must be used. Disturbance in activity data is caused when hives are taken out the field and bumblebees are slightly affected by the re-marking treatment. Techniques as smaller radars (not like Osborne harmonic radar), small GPS-transponders or RIFD-tagging might contribute to a less labor-intensive and less disturbing way of tracking bumblebees in the open field. Furthermore, with these techniques not only range as well as foraging patterns can be traced. These techniques might become available to this type of research within a couple of years.

- An experiment can be carried out to determine the number of marked bumblebees visiting a crop field related to the total amount of outgoing marked bumblebees thus giving more information on the ratio of the marked bumblebee colony foraging close to the hive and their efficiency.
- The side walls of the supports can be lowered in order to place the colonies like a Tripol. At this moment all exits face the same direction. The observer will be still capable of reading out devices on the back of the support.
- Improvement of the bumblebee counters is recommended. At this moment, especially under warm/hot conditions, a moving or ventilating bumblebee causes various event countings per minute, while not actually flying around and pollinating flowers. Removing this fake data from a data sheet at this moment is too arbitrary.
- More research on efficiency of pollen trap. In case more data is available on ratio of pollen trapped and possible adoption to the trap by bumblebees, then calculations can be made on how much pollen is collected by the colony altogether.

Personal experience

(In Dutch in order to better express and explain my personal experiences)

Het Bedrijf

De komkommerteler Jan Koppert werd, na jarenlang in contact te hebben gestaan met diverse chemische bestrijdingsmiddelen, allergisch voor deze middelen. Het gebruik van natuurlijke vijanden tegen deze schadelijke insecten bleek een mooi alternatief te vormen, maar de natuurlijke vijanden van spint waren niet op commerciële basis en aantallen voorhanden. Na enig vooronderzoek kreeg hij de kweek van een roofmijtsoort tegen spint onder de knie en zette deze roofmijt in tegen spint in het komkommergewas. Na positieve resultaten in de kas en toenemende interesse van omliggende telers voor deze vorm bestrijding verlegde hij zijn inspanningen steeds verder naar het gebied van de biologische bestrijdingsorganismen. De verkoop van roofmijt bleek een dusdanig succes dat de teelt van komkommers kwam te vervallen. Het bedrijf ging over op het verder uitbreiden van het assortiment en het verder optimaliseren van de kweek van mijten. In 1967 werd het bedrijf Koppert opgericht en in de jaren daaropvolgend groeide het bedrijf uit tot een nationale marktleider in biologische bestrijdingsmethoden. Naast mijten werden onder andere het kweekproces van sluipwespen voor de bestrijding van bladluis uitgezocht en opgeschaald naar commerciële proporties; *Chrysoperla carnea* werd ingezet tegen witte kasvlieg en werden nematoden gekweekt om varenrouwmuggen tegen te gaan. Nog steeds worden er nieuwe producten "uitgevonden" die zorgen voor een effectieve bestrijding. Zo heeft het op de markt brengen van de mijt *Amblyseius swirskii*, die breed inzetbaar is, de laatste jaren een enorme vlucht genomen en vormt nu een zwaargewicht in de totale verkoopcijfers. Naast het assortiment (Pic.13) werd ook het aantal markten verbreed en op dit moment zijn er niet alleen in Europa (Engeland, België, Frankrijk, Italië, Slowakije, Polen en Spanje), maar over de hele wereld vestigingen van Koppert te vinden (USA, Canada, Mexico, Kenia, Marokko, Zuid-Korea en Nieuw Zeeland). Niet alleen op het gebied van biologische bestrijding werd er geëxperimenteerd maar ook de inzet van hommels als natuurlijke bestuivers van gewassen werd bekeken. Verschillende soorten werden bestudeerd, maar met name de *Bombus*

Pic. 13. Overzicht van Koppert produkten.

terrestris bleek erg geschikt te zijn om te worden ingezet in bijvoorbeeld de tomatenteelt; een bedrijfstak waar bestuiving van de planten voor het verkrijgen van een mooi gezond produkt eerst nog met de hand werd gedaan. Met de komst van de hommels was dit niet langer nodig en werd nog een doelstelling van het bedrijf, naast het willen leveren van een kwalitatief hoogwaardig product, gehaald, namelijk de telers de zorg uit handen nemen van het controleren en beheersen van de bestuiving van hun gewas.
Door de inzet van verschillende Research & Developmentafdelingen, Marketing, ondersteunende afdelingen (ICT, Technische Automatisering, Expeditie etc.) en de bouw van faciliteiten over de hele wereld groeide het bedrijf uit tot wereldleider en heeft op dit moment ongeveer 600 werknemers in dienst.

Het project

Na een korte kennismakingsronde bij alle afdelingen binnen het bedrijf aan de slag gegaan met het verzamelen van literatuur. De reeds bestaande database doorzocht en aangevuld met nieuwe artikelen. Aangezien prof J. Osborne, in het Engelse Hertfordshire bij Rothamstead Research Centre, ervaring had met het merken van hommels en de inzet van een harmonische radar bij het volgen van hommels in het veld was het handig om bij haar informatie in te winnen over de verdere opzet van het project. Met mijn begeleider naar Engeland gereisd en een middag op het onderzoeksinstituut ons laten informeren en een rondleiding gekregen over haar onderzoeksafdeling. Ik heb de mogelijkheid gehad om veel vragen te kunnen stellen aan haar en haar wetenschappelijke staf. Aan de hand van deze informatie en ervaringen kon ik het projectplan verder uitwerken.

Naast het zoeken van literatuur en het verzamelen van het benodigde materiaal ook een aantal middagen meegedraaid op de afdeling waar de hommelkolonies worden “gemaakt”. Het bevruchten van koninginnen gebeurt in een faciliteit in Slowakije. Daar blijven de koninginnen totdat ze een aantal werksters hebben voortgebracht en worden ze naar Nederland getransporteerd. Daar vind het samenstellen van de uiteindelijke kolonies plaats; de kleine cupjes met koningin en werksters worden overgezet in grotere bakken, voorzien van meer suikerwater en pollen. Dit gebeurt in rood licht aangezien hommels die kleur niet kunnen waarnemen. Door hier mee te helpen ben ik vertrouwd geraakt met het gedrag van de hommels, iets wat later van pas kwam bij het zelf hanteren van de kolonies in verband met het merken ervan. In het begin ben ik een aantal keren gestoken, maar dat is later niet meer voorgekomen. Het gedrag van hommels in het veld bij daglicht werd ook steeds beter herkenbaar naarmate het veldwerk vorderde. Aan de manier van vliegen en rondlopen is redelijk af te lezen of een hommel rustig verder gaat met fourageren of dat hij andere bedoelingen heeft.

Materiaalontwikkeling

Door de afdeling technische automatisering was er al een hommelteller ontwikkeld. Het nadeel van de teller was dat heen en weer lopende hommels elke keer werden geteld als een event. Dit geeft valse data en door middel van het installeren van eenrichtingsverkeerklepjes hoopte ik dit verschijnsel tegen te gaan.

Een eerste pilot test werd uitgevoerd met één rijtje; later werd dat uitgebreid naar 2 rijen; één voor het electronisch oog en één erna. Tijdens de pilot test leek alles naar behoren te werken. Meerdere hommeltellers werden met deze klepjes uitgerust, maar éénmaal in het veld zorgden waarnemingen aan de efficiëntie van deze klepjes ervoor dat er gekozen werd de klepjes weer te verwijderen.

Aangezien er ook stuifmeel verzameld werd was een stuifmeelverzamelaar nodig. Er was al een protoype van een pollenval beschikbaar. Dit protoype is door mij verder ontwikkeld in de technische werkplaats. Het resultaat was een apparaat dat steviger en handiger in gebruik was dan het origineel (zie Materiaal en Methode). Tegelijkertijd heb ik in de werkplaats kunnen zien hoe verschillend ondersteunend technisch materieel werd gemaakt.

Ook het ontwerp voor een “hommelhuis” gemaakt en in alle drie de gevallen heeft het me verbaasd hoe snel het materiaal, meerdere pollenvallen, klepjes en huisjes, werden geproduceerd. Dit was echter nodig omdat de plaatsing van de eerste kolonies eerder was dan gepland vanwege de redelijk warme lente.

Tegen de tijd dat de kersenproef moest worden uitgevoerd had ik de beschikking gekregen over een eigen bestelauto om al het materiaal te kunnen vervoeren (Pic.14) en om de reis naar Berkel en Rodenrijs en Cavaillon te kunnen maken. Gedurende de hele praktische veldperiode heb ik de beschikking gehad over deze auto.

Pic.14. Vervoer van hommelhuisjes in de bestelwagen.

Communicatie

In elk van de velden was informatie verstrekt door de eigenaars essentieel. In het geval van de kersenboomgaard was het een teler die al overtuigd was van de gemengde vorm van bestuiven met bijen en hommels. Uit zichzelf vertelde hij veel over de teelt van kersen en welke observaties hij heeft gedaan aan hommels in de boomgaard en wat zijn bevindingen waren met deze beesten onder verschillende weersomstandigheden.

In het geval van het koolzaadveld was het een ander geval; de teler was niet tot nauwelijks geïnteresseerd in het project en stelde zijn veld aanvankelijk beschikbaar onder een hoop beperkende voorwaarden. Het was moeilijker om hier enthousiast te blijven naar deze persoon in tegenstelling tot de eerste teler. Na overleg heb ik toch voor elkaar kunnen krijgen om het veld zo in te richten dat het nog enigszins overeen kwam met het ontwerp.

Voor de zoektocht naar een geschikt aardbeienveld heb ik een vertegenwoordiger van een tussenverkoopbedrijf benaderd die goed op de hoogte was van de stand van de aardbeienvelden. Door met deze vertegenwoordiger te praten kreeg ik een goed beeld van het belang van insecten in de Nederlandse aardbeienteelt. Bij de aardbeienteler van het gekozen proefveld was er wel weer sprake van een goede samenwerking en was het mogelijk om het veld volledig in te richten volgens planning. Persoonlijke opmerkingen en waarnemingen vormden een aanvulling op eigen waarnemingen.

Bij deze proefvelden was het kwestie van goed vooruit denken om ervoor te zorgen dat het materieel voor een volgend proefveld alweer klaar of besteld was. Zeker in het begin bij het verzamelen van het materieel was het pittig om alles op tijd voor elkaar te krijgen. Proef op de som vormde het laatste veld, waarin ik hommels en materieel in Frankrijk ging gebruiken. Om dataloggers in te regelen, foto's op te slaan etcetera kreeg ik de beschikking over een laptop en om in contact te blijven een telefoon. Accomodatie voor de eerste week was geregeld via Anne-Isabelle Lacordaire van de vestiging te Cavaillon. Hommels en vernieuwde huisjes werden met de vrachtwagen nagestuurd; de rest werd meegenomen in de auto. Na kennismaking met Anne-Isabelle, waarin we afspraken om zoveel mogelijk frans te praten om mijn Frans te verbeteren, kennis gemaakt met Michael Duriaux. Een Frans student die een parallel veldproject ging uitvoeren. Met hem heb ik een aantal verschillende velden bekeken. Na mijn project compleet in het frans te hebben toegelicht aan vertegenwoordigers van het zonnebloemzaadbedrijf verschillende velden bezocht en uiteindelijk een leuze gemaakt. Het overleggen en plannen kostte meer tijd en moeite gezien de taalbarrière.

De kennis van het Frans nam wel enorm toe. Het veldwerk heb ik ruim naar behoren kunnen uitvoeren en de samenwerking verliep zonder enig probleem. De Franse mentaliteit om, naar mijn idee, van iets kleins een probleem te maken en zonder enig probleem over grotere issues heen te stappen was af een toe een punt waar ik me aan moest passen. Het standvastig innemen van je eigen gelijk en dat blijven herhalen bleek uiteindelijk te werken. Mijn idee om tijdens de lunch verder data te verzamelen en on site wat te eten was echer te hoog gegrepen. Tijdens het veldwerk en de contacten binnen het bedrijf te Cavaillon een beeld kunnen krijgen van de werkhouding van de Fransen; lang leve de Franse slag....Als leermomenten gelden hier zeker de toename in taalkennis en het leren aanpassen aan een andere werkmentaliteit zonder daarbij teveel je eigen doelen uit het oog te verliezen.

Laboratoriumwerk

Na geregeld alle stuifmeelvallen leeggehaald te hebben moest de herkomst van het stuifmeel worden bepaald. Uit de literatuur protocollen gehaald (Appendix I) en met behulp van medewerkers van het microbiologielab uiteindelijk microscopische preparaten kunnen produceren die geanalyseerd konden worden door een deskundige (Pic.15). De samples met opgelost stuifmeel bleken te zijn kapotgevroren, maar de preparaten bleken goed bruikbaar, zodat de pollenanalyse uiteindelijk niet in gevaar is geweest.

Pic.15. Opgeloste pollen samples en slides.

Schrijven

Naast de toegenomen ervaring in het uitvoeren van veldexperimenenten en de verwerking van de data etcetera kwam als onverwacht leermoment het leren schrijven van een degelijke sollicitatiebrief en het opstellen van een volledig CV naar voren. Door het, via mijn begeleider, informeren naar eventuele vacatures aan het einde van de stageperiode kwam ik op de hoogte van de functie van consultant voor de afdeling Bestrijding. Ik had nog niet eerder de ervaring van het schrijven van een dergelijke brief. Het feit dat ik werd uitgenodigd voor een oriënterend gesprek geeft aan dat de brief in ieder geval voldoende goed was.

De eventueel beschikbare functie werd nader toegelicht tijdens dit gesprek, zodat de inhoud wat duidelijker werd, naast de informatie die ik binnen het bedrijf al had ingewonnen. Een praktische aanvulling op dit gesprek was de entomologiecursus van twee dagen die ik gevolgd heb. Hierin kwam eerst de identificatie van plaaginsecten zelf (in verschillende stadia) en het schadebeeld dat ze in kasgewassen veroorzaken aan bod. Daarna kwam de identificatie van de verschillende biologische bestrijders aan bod (indien van toepassing ook de verschillende ontwikkelingsfases). Ter illustratie en als praktisch onderdeel werden beide middagen afgesloten met een bezoek aan een kas waarin deze verschillende schadelijke insecten en de ingezette bestrijders voorkwamen. De taak van een consultant; juiste identifcatie en aandragen van juiste bestrijdingsmethode, werd op deze manier verduidelijkt. Mijn kennis van met name bladluizen en sluipwespen door eerder uitgevoerd werk kwam hierbij goed van pas en is weer opgefrist.

Koppert bedankt!
Als laatste wil ik graag een aantal mensen bedanken. Allereerst en als voornaamste mijn directe begeleider, Remco Huvermann, voor de bijzonder prettige begeleiding tijdens het afgelopen half jaar. Tijdens het project heb ik altijd in ruime mate begeleiding gekregen en was het geen probleem om op welk moment dan ook vragen te stellen of langs te komen. Zijn jarenlange ervaring met bijen en hommels zorgde voor een bron van informatie en praktische kennis die in het veld goed van toepassing was. Zijn enthousiasme en impulsiviteit zorgden af en toe voor ideeën die binnen de tijd of het projectkader volgens mij minder goed uitvoerbaar waren. De heldere communicatie zorgde ervoor dat het wel of niet uitvoeren van deze ideeën plaatsvond. Tegelijkertijd was er voldoende ruimte om eigen inzichten of plannen uit te werken. Ik ben dan ook zeer tevreden met de mate waarin er van me werd verwacht dat ik zelfstandig kan werken en plannen. Wat dat betreft was het project meer te beschouwen als een afstudeervak dan een stage.

Ook de inzet van mevrouw Rensink Hartman was onontbeerlijk aangezien zij belangeloos alle pollensamples, in veel gevallen zelfs tot op soortsnaam, wist te determineren; een klus die veel kennis vergt en zeker niet mogelijk was om voor mij binnen de beschikbare tijd af te ronden.

Ook Anne-Isabelle Lacordaire ben ik zeer erkentelijk. Een gezellige samenwerking met haar en Michael heeft ervoor gezorgd dat ik met veel plezier terugkijk op de tijd in Cavaillon.
Naast informatie over zonnebloemen en andere zaken aangaande het project hebben haar adviezen over accomodatie, eten, drinken en leven in Frankrijk me prima geholpen een weg te vinden in en me aan te passen aan dat mooie land.

Als laatste, maar zeker niet als onbelangrijkste wil ik ook de mensen van de technische dienst en hommelkast assemblage bedanken voor het feit dat ze, ondanks enorme seizoensdrukte, tijd voor me konden vrijmaken. Zowel om iets uit te leggen als om me op tijd te voorzien van de benodigde, soms ad-hoc uitgevonden/ontworpen of bestelde, materialen.

Het gebruik van universitaire stagiaires, op verschillende afdelingen, zie ik als een teken van het streven naar constante innovatie van het bedrijf. Daarnaast zorgde de informele, maar professionele werksfeer waar ik me bijzonder goed in thuisvoel, ervoor dat ik me vanaf het begin volledig betrokken voelde binnen het project. Deze sfeer heerste er op elke afdeling van het bedrijf zodat vragen stellen, bestellingen plaatsen etc. bijzonder laagdrempelig werd. Dit zorgde al snel voor leuke contacten en goede verhalen.
Ik zal dan ook met veel plezier terugdenken aan deze praktische, veelzijdige en leerzame periode!

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Appendices

Protocol Pollen staining

1. Prepare dilution of 1 part 70% ethanol and 4 parts distilled water.
2. Prepare gelatine solution: 7.0 g of gelatine
   42.0 ml distilled water
   50.0 ml glycerine
   0.5 g fenol (if available)

   Staining by 0.1 g Basic Fuchsin diluted in 10.0 ml alcohol; add a few drops of Fuchsine solution to the gelatine until the gel is brightly purple/pink (Sawyer, 1981). Keep solution liquid on a luke warm plate.
3. Add 2.5 ml of the solution of step 1 per gram pollen.
4. Shake firmly until a homogenous solution is visible.
5. Place 1 drop of pollen solution (0.2 ml) on a microscope slide and spread the pollen solution.
6. Let the water evaporate.
7. Add 0.3 ml of Fuchsine gelatine solution to the microscope slide.
8. Place the cover slip and place the slide on the plate. The gelatine will spread under the glass.
9. When the gelatine is evenly spread, remove slide and remove obsolete gelatine with 70% ethanol.
10. Cover the edges of the cover slip with transparent nail polish to preserve the stained pollen sample.
11. Add label (date, type of crop etc.) to the microscope slide.

Pollen analysis

Cherry

KERS		6-4-2007	
	L	M	R
Voornamelijk	wilg 95%	wilg 95%	wilg 95%
Geregeld			
Enkele	kers 3-5% smeerwortel hondsdraf esdoorn mahonia of berberis speenkruid kruisbes	kers 3-5% smeerwortel hondsdraf esdoorn mahonia of berberis speenkruid kruisbes	kers 3-5% hondsdraf esdoorn mahonia of berberis speenkruid kruisbes
		8-4-2007	
	L	M	R
Voornamelijk	wilg 80%	wilg 80%	wilg 90%
Geregeld		kers 5-10% rosaceae (peer?) mahonia of berberis	kers 5% speenkruid bes
Enkele	kers 3-5% smeerwortel	hondsdraf speenkruid	smeerwortel hondsdraf sering
		11-4-2007	
	L	M	R
Voornamelijk	wilg 80%	wilg 80%	wilg 80%
Geregeld	kers 5% smeerwortel	kers 5% smeerwortel	kers 5% smeerwortel
Enkele	hyacint of narcis	hyacint of narcis	hyacint of narcis

	13-4-2007 L	13-4-2007 M	13-4-2007 R
Voornamelijk	wilg 70%	wilg 70%	wilg 70%
Geregeld	kers 10% smeerwortel	kers 10% smeerwortel	kers 10% smeerwortel
Enkele	hondsdraf speenkruid rosaceae	hondsdraf speenkruid rosaceae	hondsdraf speenkruid rosaceae

	16-4-2007 L	16-4-2007 M	16-4-2007 R
Voornamelijk	wilg rosaceae (kers 25%)	wilg rosaceae (kers 25%)	wilg rosaceae (kers 25%)
Geregeld	smeerwortel speenkruid	smeerwortel speenkruid	smeerwortel speenkruid
Enkele	lonicera paardekastanje	lonicera paardekastanje	lonicera paardekastanje

	18-4-2007 L	18-4-2007 M	18-4-2007 R
Voornamelijk	wilg rosaceae (kers 10-20%)	wilg rosaceae (kers 10-20%)	wilg rosaceae (kers 10-20%)
Geregeld	smeerwortel speenkruid	smeerwortel speenkruid	smeerwortel speenkruid
Enkele	lonicera paardekastanje cypres	lonicera paardekastanje cypres	lonicera paardekastanje cypres

		20-4-2007	
	L	M	R
Voornamelijk	wilg rosaceae (kers 10-15%)	wilg rosaceae (kers 10-15%)	wilg rosaceae (kers 10-15%)
Geregeld	smeerwortel speenkruid lonicera esdoorn	smeerwortel speenkruid lonicera esdoorn	smeerwortel speenkruid lonicera esdoorn
Enkele	narcis paardekastanje hondsdraf paardebloem	narcis paardekastanje hondsdraf paardebloem	narcis paardekastanje hondsdraf paardebloem
		23-4-2007	
	L	**M**	**R**
Voornamelijk	wilg	wilg	wilg
Geregeld	rosaceae (geen kers meer) smeerwortel speenkruid lonicera esdoorn paardekastanje hondsdraf	rosaceae (geen kers meer) smeerwortel speenkruid lonicera esdoorn paardekastanje hondsdraf	rosaceae (geen kers meer) smeerwortel speenkruid lonicera esdoorn paardekastanje hondsdraf
Enkele	paardebloem Scilla	paardebloem Scilla	paardebloem Scilla

Rapeseed

Koolzaad		26-4-2007	
	L	M	R
Voornamelijk	koolzaad 30% paardekastanje wilg	koolzaad 10-20% paardekastanje wilg	koolzaad 10-20% paardekastanje wilg
	rosaceae	rosaceae esdoorn	rosaceae esdoorn
Geregeld	esdoorn		
Enkele	speenkruid smeerwortel onbekende	speenkruid smeerwortel gras pinus onbekende	speenkruid smeerwortel gras pinus onbekende
		1-5-2007	
	L	M	R
Voornamelijk	koolzaad 10% paardekastanje rosaceae (prunus) smeerwortel esdoorn wilg	koolzaad 5% paardekastanje rosaceae (prunus) smeerwortel esdoorn wilg	koolzaad 5% paardekastanje rosaceae (prunus) smeerwortel esdoorn wilg
Geregeld			
Enkele	lonicera pinus	lonicera pinus hondsdraf kornoelje	lonicera pinus hondsdraf kornoelje

Sunflower

Zonnebloem		11-7-2007	
	L	M	R
Voornamelijk	zonnebloem 60% esparcette	zonnebloem 90%	zonnebloem 80%
Geregeld	klaver luzerne		(luzerne)klavers
Enkele	ligustер haagwinde koolzaad of herik lactuaceae	distel esparcette asteraceae	liguster boekweit kattestaart pompoen malvaceae
		16-7-2007	
	L	M	R
Voornamelijk	zonnebloem 60%	zonnebloem 75%	zonnebloem 50-60%
Geregeld	asperge (luzerne)klaver	liguster asperge	(luzerne & witte) klaver esparcette

Enkele	koolzaad of herik smeerwortel liguster pompoen haagwinde kornoelje	koolzaad schermbloemige luzerneklaver haagwinde distel bijvoet	melkdistelfamilie herik koolzaad liguster distel bryonia kattestaart kornoelje
		18-7-2007	
	L	**M**	**R**
Voornamelijk	zonnebloem 50% asperge	zonnebloem 80% luzerneklaver	zonnebloem 40%
Geregeld	(luzerne)klaver		(luzerne & honing)klaver esparcette kornoelje lactuaceae
Enkele	distel liguster composiet pompoen smeerwortel kornoelje		herik of koolzaad boekweit klis malvaceae
		23-7-2007	
	L	**M**	**R**
Voornamelijk	zonnebloem 80%	zonnebloem 50% asperge	zonnebloem 50%
Geregeld	asperge klavers	klavers honingboom?	hypericum? luzerne herik of koolzaad
Enkele	herik of koolzaad liguster venkel kornoelje melkdistel boekweit wilde kamperfoelie	(melk)distel bijvoet zuring boekweit kornoelje mahonia of berberis	distel kornoelje haagwinde pompoen asteraceae look of ui
		25-7-2007	
	L	**M**	**R**
Voornamelijk	zonnebloem 70%	zonnebloem 50%	zonnebloem 50-60%
Geregeld	klavers	honingboom?	herik (witte & basterd)klaver
Enkele	schermbloemige lactuaceae wikke pompoen	boekweit (luzerne & witte) klaver distel	honingklaver distel solidago