8. THE VALUE OF BEES FOR CROP POLLINATION

It is estimated that about one third of all plants or plant products eaten by humans are directly or indirectly dependent on bee pollination. More than half of the world's diet of fat and oil comes from oilseeds such as cotton, rape, sunflower, coconut, groundnut and oil palm. Even though some of these have special pollinators belonging to other types of insects, these plants all depend on, or benefit from bee pollination to some extent. In addition, many food crops and forage for cattle are grown from seeds of insect-pollinated plants. The great value of bees as pollinators has been known for many years, but unfortunately, this knowledge is not widely appreciated and understood.

The value of bee pollination in Western Europe is estimated to be 30-50 times the value of honey and wax harvests in this region. In Africa, bee pollination is sometimes estimated to be 100 times the value of the honey harvest, depending on the type of crop.

In a country like Denmark, about 3,000 tonnes of honey is harvested every year. It has a value of 60 million DKK or about €7.6 million. However, the value of oilseeds, fruits and berries created by the pollination work of bees is estimated to be between 1,600 and 3,000 million DKK, equivalent to €200 and €400 million.

Some types of crops have flowers that may only be pollinated during a short period. If such a crop is not pollinated during that time, the flowers will fall and no seeds, berries or fruit will develop. There have to be sufficient numbers of bees in the pollinated crop. This is especially important in crops where the single flower may only be pollinated in a restricted time or in crops where the nectar production, or bee visits only take place during days where the temperature is at a certain level. In such a crop, the pollination in some years has to take place within three or four days. This can be the case in growing white clover seed. The flowers only produce some special smelling products attracting the bees to the flowers when the ground temperature is above 15° C. When the temperature is lower, only a few bees are interested in visiting the clover flowers. It means that the whole pollination work in some years has to be done in a very few days, where thousands of worker bees are needed to do the job. If the farmer does not provide fields with honeybees or other bees for pollination, the whole harvest can fail. In years with plenty of hot days during the blooming season, bumblebees, solitary bees and the few honeybees will have time to do the pollination and the farmer can get a good harvest, even without bringing in pollinating bees. The risk for the farmer is the unpredictability of the weather in temperate areas where white clover is grown for seed production. The white clover flower has evolved so that the bees can reach and collect the nectar. A honeybee can therefore visit 18-20 flowers in one minute.

To measure the need for honeybee pollination, crop areas in Russia with white clover were covered during blooming, so that no bees could enter. In the covered square only one gram of seed was harvested, but in the uncovered area of the same size 331 grams of seeds could be harvested.

Lack of bees for pollination can mean a loss for the farmer of maybe 75 percent of the crop. It is recommended to white clover growers that they provide their fields with two to three colonies per hectare to secure the best pollination. A single coffee flower is only open for three to four days when blooming. If a bee or another insect does not pollinate the flower during these days, it will wither, and no coffee bean will be produced. Clever coffee farmers take care that there are plenty of honeybees or stingless bees for pollination in the farm.

Insect pollination and pollinator protection are not included in most of the training books for agronomists, extension officers and farmers. Many farmers all over the world do not recognize the need for bee pollination and consequently many bees are killed by careless use of pesticides. Even many beekeepers and honey hunters do not know about pollination and cannot inform the farmers about the need for protection of bees.

In Europe, Australia, New Zealand and North America, fruit and berry growers, and white clover growers pay beekeepers to bring bees for pollination in the blooming season. They know this will give a far better chance for a good harvest. Some farmers believe that the beekeeper will get a big honey harvest when moving bees to fields for pollination, and therefore they do not want to pay for the work. However, this is not necessarily the case. The beekeepers often lose many bees when moving hives for pollination purposes, and they often do not get a worthwhile honey harvest from pollination work. It is therefore necessary for beekeepers to be paid for the service. In Denmark, there are rules for payment for pollination concerning the size of the bee colony being rented. It is recommended that there should be at least four combs with unsealed brood, to ensure that bees have to collect a lot of pollen for feeding the brood.

It is sometimes found that the farmer or owner of a plantation wants the beekeeper to pay to place the beekeepers' hives in the farm. If neither beekeepers nor farmers are aware of the pollination value of the bees, this situation will never change. The farmer receives a smaller harvest and the beekeeper does not gain access to a good site for the bees. The pollinatory value of bees, even in the same crop, can vary from one place to another. This is because there are many variables: the temperature, the water table, the other pollinator insects in the environment, and other available forge for bees, etc. For example, opinions differ on the value of bees in coconut pollination: one example from India mentions a double harvest of coconut because of bee pollination.

The best arrangement can be a permanent apiary inside a fenced area of a plantation, to ensure adequate pollination. It can be an agreement between the farmer and the beekeeper, so that the farmer provides the beekeeper with a protected site, and the beekeeper provides the farmer with permanent pollination. The space needed for ten hives would only need to be between 10 and 60 m^2, and this can be any scrap of otherwise unusable land. See Chapter 5 for details of choosing a place for bees. A good place for an apiary is where there is forage for the bees outside the blooming of the crop: if this is the case, the bee colonies will be strong for the crop pollination period.

BEE POLLINATION GIVES BETTER QUALITY AND QUANTITY OF HARVEST

Bee pollination not only results in a higher number of fruits, berries or seeds, it may also give a better quality of produce, and the efficient pollination of flowers may also serve to protect the crops against pests. The better weight due to sufficient pollination arises from the development of all seeds in a fruit. An apple, for example, will only develop all the seeds inside if it has been pollinated by several bees and fully fertilized. It is possible for an apple flower to develop about ten seeds. If all the seeds do not develop, the fruit itself does not develop where the seeds are not developing. This results in poorly shaped apple of low weight. The same can be the case with strawberries, where a fully developed strawberry needs about 21 visits of bees: at least this is the case for the old varieties of strawberries; some new ones are not so dependent on bees. A single strawberry can have 400-500 seeds (or actually small nuts) sitting on the surface of one berry. The higher number of seeds developing fully – the bigger and more even shaped the berry will be.

Research with bilberries showed the following interesting result: in bilberries grown close to an apiary, fertilization and berry production occurred in 89.1 percent of the flowers. In an area without bees, fertilization and berry production was only 47.5 percent. The average weight of a berry was 0.578 grams for the bilberries close to bees, and 0.348 grams without bees. Harvest of berries from 100 flowers was 51.1 grams with bees in the neighbourhood, and only 16.8 grams where the bees were not present.

The bee pollination in *Brassica* oilseed production creates a higher content of oil in the seed. Sufficient bees will also take care that all the plants in the field are pollinated in the same period, so the seeds ripen at the same time. This allows harvest of a uniform crop, with less green and unripe seeds among the ripe ones. That will give the farmer a higher price.

A sufficient number of bees for pollination can also protect the crop against serious pest attacks. A single *Brassica* flower is waiting for pollination and fertilization before it closes and falls off. If bee pollination is needed, yet there are not enough bees present, pollination can take many days. In that time the flower is attacked by different pests eating the pollen, sucking the sap, laying eggs in the flower, or spoiling it in other ways. If there are sufficient bees in the field, the flowers will only have to be open for a short time, and the different pests will not have so much time for their destruction. In that way, adequate numbers of bees ensure rapid and efficient pollination and protect crops against pests.

WHERE TO PLACE HIVES FOR POLLINATION

It is important that colonies of honeybees can be moved quickly to a crop that is ready for pollination. It is not possible to have readily available, high populations of transportable colonies of other pollinating insects, except the small bumblebee colonies used in greenhouse pollination. If honeybees are placed in a crop for pollination, they will be working in the field, even in relatively bad weather, because of the short flying distance. The hives of honeybees have to be moved at night-time or at least when all the bees have returned from foraging. The hive entrance must be closed, and some ventilation provided with a net screen at the top or bottom. When the hive is transported, the bees inside start moving around and produce much heat. If they are moved in the tropics in day-time, they must be kept cool with wet sacks placed over the hives. They always have to be moved with soft and slow movements. It is also recommended to feed the bees with water. If a hive with bees is not handled carefully, or it is too hot during the transport, the temperature inside can become so high that the combs start melting and the whole colony can collapse. The melted wax mixed with honey is extremely attractive for stingless bees, other honeybees and ants and they will start robbing the melted colony as soon as the entrance is opened. The result can be the death or absconding of a good honeybee colony.

When moving bees some forager bees are always lost. Maybe they do not orientate when they fly out in the morning in the new place. If a hive is only moved a few metres the forager bees will return to the place where the hive entrance used to be. When they do not find their hive there any more, they try to enter into other colonies, with the risk of being killed. Therefore colonies should never be moved a distance of less than two kilometres. It is better to have greater distances and longer moving times: then the bees will be more aware that something has happened, and they will orientate when the hive is opened in the new place. If it is necessary to move a colony a shorter distance, it should only be moved one metre a day. It is also possible to tranquilise bees with a special smoke with “laughing gas”. After receiving such a treatment the bees seem to lose their memory and start over with orientation flights after the hive is moved and opened again.

The beekeeper can guide the bees to special crops for pollination. By feeding the colony inside the hive with sugar syrup mixed with flowers from the crop. To a certain degree, this will make the bees search for that scent and find the crop concerned. The feeding has to take place inside the hive to prevent fighting between bees from different colonies. It is important not to spill any sugar water on the ground because it will attract ants to the area.

It is important to place colonies for pollination inside or as near as possible to the crop requiring pollination. If there is another crop also attracting the bees, the hives must be placed so that they have to cross the field the farmer wants pollinated, before they can reach the other attracting crop. If possible, the hives should be spread out within the crop.

If we consider that maximum harvest of seeds or fruits require maximum pollination, it is clear that there is a potential lack of bee colonies in many areas of the world. This lack is much bigger than the number of existing bee colonies, and even if all hives were easy to transport and could be placed in the fields for the most effective use, still there would be a lack of many millions of bee colonies.

WHY HONEYBEES OFTEN ARE THE MOST IMPORTANT CROP POLLINATORS

The effectiveness of honeybees is due to their great number, their social life and their ability to pollinate a broad variety of different flowers. A colony can consist of 20-80 000 bees, and they will normally be visiting flowers over a distance of two kilometres when they are collecting pollen and nectar. If nothing is to find in the neighbourhood, they can fly even seven kilometres. A normal *Apis mellifera* honeybee colony will make up to four million flights a year, where about 100 flowers are visited in each flight. The honeybee's pollination effectiveness also arises from the special constancy to flowers of one species. Scout bees communicate to other bees in the colony which species to visit, and even give small tastes of nectar and scent from that flower.

When the pollen loads of honeybees are investigated, pollen mixed from different species of flowers will only be found in three percent of loads. The rest will be with pollen from just one species. If pollen loads from bumblebees are investigated, about 40 percent of the loads are of mixed pollen. This clearly indicates the flower faithfulness of honeybees.

Honeybees do not waste their time visiting flowers not yet ready for pollination. Some flowers can only be pollinated during a certain time of the day; they guide the bees to come at that time by restricting their nectar production to that time. Individual bees learn when the different flowers produce most nectar and apparently 'remember' it from day to day. As mentioned before, a worker bee remembers "opening hours" for 7-10 different types of flowers.

In Northern Europe, it is estimated that 75 percent of all wild blooming plants depend upon insect pollination, and most of the flowers are pollinated by honeybees and bumblebees. All the crops, fruit trees and wild flowers blooming before midsummer are dependent from visits of bees to be able to develop their seeds, berries and fruits. The economic value of bee pollination in nature and the great ecological importance of that cannot be counted, but for sure, it must be much greater than the economic value of crop pollination.

HOW TO SEE IF A CROP IS ADEQUATELY POLLINATED

It is difficult to give exact numbers for how many colonies a particular crop requires for the best pollination, but at the time of harvest, it can be judged if there have been sufficient bees, and that experience must be used for the next season. At harvest time, a well-pollinated crop has:

- well-shaped fruits;
- well-filled seed pods;
- a uniform seed set; and
- tight clusters of fruits or seeds.

From research and experience, it is possible to recommend a certain number of bee colonies per hectare when growing a crop, but many other factors can influence if it is right. It should be known how many wild colonies or apiaries there are nearby and if there are other fields in the neighbourhood with attractive crops competing for the bees. This estimate is partly a matter of experience.

It is possible to measure the need for bees directly in some crops. In cotton, for example, at the flowering time there should be one honeybee to every ten open cotton flowers to provide adequate pollination. Every time it is possible to count ten flowers when walking in the field, there should be at least one honeybee observed among them. If it is possible to count 20 flowers before one bee is seen, the number of hives for pollination should be doubled.

It is recommended to use between five and 12 colonies of bees for pollination of one hectare with cotton. The case with cotton also illustrates a great problem. Cotton needs many bees for pollination, yet at the same time, cotton is one of tropical crops on which most pesticide is used. Cooperation between farmer and beekeeper is essential if both are to benefit from each other.

TABLE 16
Examples of cultivated plants that need honeybee pollination

Crop	Bee colonies* to 1 ha
Alfalfa (Lucerne) seed	8 colonies or 70 000 leafcutter bees
Apple	4
Apricot	2
Asparagus seed	4
Avocado	5
Bean (Lima)	3
Blackberry	7
Blueberry	8
Cabbage	5
Brassica (canola, oilseed rape)	5
Carrot seed	8
Clover seed (White)	4
Citrus	2
Cotton	8
Cucumber	7
Eggplant	3
Gourds	4
Kiwifruit	8
Mandarin	4
Mango	15
Melon	7
Onion seed	17
Peach and nectarine	2
Pear	4
Pepper (Green, Sweet)	?
Pumpkin, squash, gourd	4
Strawberry	8
Watermelon	5
Safflower	2
Sunflower	2
Onion seeds	36

* Number of colonies refers to colonies of *Apis mellifera.*

USE OF OTHER BEES FOR POLLINATION

Solitary bees play a great role in the pollination of wild plants. They also pollinate many cultivated plants. The sizes of natural populations of solitary bees fluctuate greatly from year to year and from place to place, and this makes them difficult to rely on for the pollination of crops. A few species are utilised by farmers for the pollination of special crops. The availability of suitable nesting places seems to be a regulating factor for many solitary bees and a simple way to increase the bee population is by creating artificial and better nest places. In many countries where industrial farming is dominant, the natural population of solitary bees has declined as their natural habitat was destroyed. Nevertheless, some farmers and beekeepers try to use these bees for agriculture.

The most commonly used solitary bees are Alfalfa leaf cutter bees *Megachile rotundata*, *Osmia* species of bees including *Osmia cornifrons* and others, and Alkali bees *Nomia melanderi*. The bees are solitary,

which means that the female bee alone takes care of the next generation. However, these species are all gregarious, meaning that they like to nest close to each other, and that seems to stimulate their activities. Bumblebees *Bombus* spp. are social bees like the honeybees, and are used for specialized pollination work.

The use of all these bees is for pollination only: no honey can be harvested from them. The use and study of solitary bees first started and became an industry in Japan after the Second World War. The problem was that many farmers were lacking bees for pollination because the honeybees had been killed from heavy use of pesticides. Some solitary bees are especially well adapted for pollinating fruit trees. The *Osmia* bees for example, develop so that they emerge just at the blooming time of the trees, and they live as flying adults for just a few weeks. The possibility to spray trees just before and after blooming was one of the ideas behind the great interest in using these bees.

The use of solitary bees for pollination is not a new invention. Farmers in Egypt have long used bundles of dry straw, or rolled straw mats as artificial nests for leaf cutter bees. 'Bringing the "mat-bees" to the fields' was when bundles with larvae and pupae inside were taken from old cultivations where bees are present, to new irrigated areas in the desert to ensure sufficient pollination of new crops of tomatoes, alfalfa and others.

Leafcutter bees *Megachile rotundata* are only half the size of a European *Apis mellifera* honeybee. They are black with white stripes. The males have green eyes when they are young. They occur naturally in the countries around the Mediterranean Sea, and have now been spread to other continents. Leafcutter bees nest in straw or other organic horizontal tunnels with a diameter of about six millimetres and about 10-12 centimetres long. When the bees come out of the straw cell after about 21 days of development (dependent on the temperature), they mate and the females start building new leaf cells inside the straw. The cells are like small hollow cigars made of pieces leaf, and two thirds filled with pollen and honey. When an egg is placed in the cell, it is sealed with other leaf pieces and a new one is built outside the first. There can be 10-13 cells in a row before a new straw is used. When a tunnel is finished and filled with cells, the bee closes the entrance hole with up to 100 round pieces of leaf. This protects against parasitizing wasp and other insects that want to attack the larvae. The eggs in the first two to three cells develop to females, the rest into males. The males develop some days faster than the females, and in that way the tunnel is clear when the female bees are ready to emerge. They prefer to nest in tunnels where the entrance is a little lower than the other end. The females can fly around for about nine weeks, and then they die. The male bees are only flying for about two weeks. Nests can be made artificially from poles with drilled holes six millimetres in diameter, but when working with bigger populations it is necessary to use a nest type where the tunnels can be opened to remove the cells for storing and artificial hatching next year. The farmer can arrange the hatching time, and most of the small parasite wasps can be removed before they are spread to the new breeding place in the field. Leafcutter bees do not need any water throughout their life and they are therefore excellent pollinators in arid areas. The cells with larvae inside can be kept in cool rooms with a temperature of 3-5°C until they are needed for pollination. Then they are placed in a hot room at 30°C with high air moisture, and they will hatch in 17-26 days. These bees are used extensively in Russia, Canada, USA and New Zealand – especially for pollination of alfalfa (lucerne). Canada exports US$1 million worth of leaf cutter bees every year.

Mason or osmia bees are indigenous bees of Europe: the most commonly seen in spring is *Osmia rufa*. The female is reddish brown and at 10-13 millimetres long is a little smaller than the European honeybee. The widespread *Osmia lignaria* is indigenous to North America and has the same size but is darker in colour. The males are more slender than the females in both species. Like leafcutter bees, the females collect pollen in the hairs underneath their bodies.

The life cycles are similar to that of the leafcutter bees, but mason bees make their cells from mud, resin, dung, leaves and petals. They can be attracted to nest in bundles of tubes like bamboo sticks. The preferred diameter of the tunnels is 7-8 millimetres. *Osmia rufa* works at lower temperatures than

Megachile spp. and can be used for very early pollination in greenhouses. The *Osmia* cells are kept in refrigerators at the same temperature as the leafcutter bees. They overwinter in their last pupae stage and can be taken directly from the refrigerator to the greenhouse where they will start to emerge the next day. The *Osmia* bees are highly effective pollinators of fruit trees, and are used for almond tree pollination in California. Much development work still needs to be done with these bees.

Alkali bees are black with yellow bands on the abdomen and a light yellow layer of hair over the whole body. They are of same size as the European Apis *mellifera* honeybee, although more slender. Alkali bees are present in many of the north western states of the USA. Their importance as pollinators of alfalfa was first detected around 1940, and from the 1950s, many seed growers started to build nest places for alkali bees. They are used together with leafcutter bees for pollination of lucerne. The alkali bee has been introduced to France and New Zealand where they are used for pollination. The alkali bee makes nests in the ground: they can make their tunnels very close-up to 540 nests in one square meter. The males emerge from the end of June up to the middle of July, with the females emerging one week later. The females and males mate, and the same day the females start digging a nest tunnel. During the night, the tunnel is finished and the next day the first cell is made and supplied with pollen. The following day the first egg is laid and a new cell constructed. The bee will continue building up to 15-20 cells before she dies. The bees overwinter as prepupae and the development continues when the earth becomes warm again the following spring. The alkali bees require a special soil type for nesting: fine salty sand and clay with a moisture content of 25 percent. Artificial nesting areas can be made by digging a one-metre deep hole – one to 20 acres in size. The bottom is covered with a layer of plastic and on top of that is placed a 15 centimetre layer of fine gravel or sand. On top of that is another layer of about 85 cm with a mixture of fine sand and clay. The top layer is mixed with 2-5 kilograms of salt per square meter, to draw the moisture from the bottom layer. The bottom layer is supplied with water to a certain height. A simpler system has been developed with plastic drain tubes supplying the nesting ground with water. Salt is just sprayed on the surface of the ground. Bees can be transferred from one nest place to a new one by transplanting blocks with over wintering pupae. One acre with one million alkali bee nests can pollinate 200 acres of alfalfa.

Small bumblebee colonies are most often used in greenhouses. As with the solitary bees there are no problems with stinging, and people working in the greenhouses prefer bumblebees to fly around instead of honeybees. Cardboard nest boxes with bumblebees can be bought every spring for greenhouse pollination. A box with a colony consists of one queen and about 20 workers in the beginning. The price for the farmer is about €130 (2003), bought from the Netherlands. It has been a significant business in Southern Europe to catch bumble queens during spring for export to the Netherlands or other European countries, but this activity has damaged local populations of wild bumblebees in many places.

PESTICIDES

Bees are living hazardous lives, as farmers all over the world use more synthetic pesticides. Environmental pollution by pesticides continues as an increasing problem, especially in the tropics and subtropics. It arises from the development of large-scale cultivation of single crops or monocultures. The increased use of exotic cultivars of crops is often accompanied by increased use of pesticides. When these plants are growing under new environmental conditions they are often attacked by pests to which they are not adapted, and that problem is often approached by using more pesticides. When bees are in agricultural areas, they often collect their nectar and pollen from cultivated plants – from fields with oil seeds, orchards or vegetable gardens. Farmers are treating these same areas with pesticides and herbicides. Most of these chemicals are poisonous for bees and some are extremely dangerous both for bees and for people. If they are spread even in very small amounts over a blooming field, they can result in serious destruction of many bee colonies.

Some types of pesticides only show their negative effects after a long time or with great doses, but synthetic pesticides can never be used without any risk. Even if they do not kill the bees, they can disturb the normal function of the colony, for example by causing bees to lose their ability to orientate correctly, or to communicate.

We often find heavy use of pesticides in small vegetable gardens, producing food for the family and the local market. The use of pesticides should be banned in these places, because it poisons people eating the sprayed products, and because the local drinking water and other food were contaminated.

Herbicides (used against fungus and weeds) are often thought to be of no danger for bees, but that is not true. If the bees have no fresh water close to the hive or nest, they will collect dew in the morning on the leaves of grasses or other crops, independent of any flowers around. If such a crop has been sprayed, the bees can be poisoned as they are collecting their water.

To prevent this from happening the beekeeper should always provide the apiary with fresh water. It can be given in a tin can with sticks or grass inside where the bees can sit and drink without drowning. If monkeys are a problem because they want the water, the tin can should be secured to a tree or pole and covered with a metal net. The water source must never become dry, as then the bees will immediately start looking for water in another place. Ensuring an apiary always has water has other good functions. The bees do not need to use so much energy for fetching water and can make more honey instead, and if they always have water nearby, they do not disturb people at the wells, who may step on the bees with bare feet.

In Denmark, there was a case where a farmer poisoning the bees around his fields was forced to pay compensation to other oilseed and white clover farmers, because they also suffered because of the lack of pollinating bees. In Denmark, it is forbidden to use dangerous pesticides in blooming crops, and there are laws in many countries against the use of insecticides in flowering fields. If bees are killed by a farmer using pesticides illegally, the farmer must pay compensation to the beekeeper. If the beekeeper has not supplied the apiary with water, it can be a problem to receive the compensation. In one case a farmer who killed many bees by spraying carelessly, had to pay compensation to several beekeepers, but also to the neighbouring seed growers – because their harvests were diminished due to the lack of bees in the area.

Many pesticides forbidden in the industrialized countries are dumped in developing countries: i.e. companies selling their stocks of pesticides to developing countries after the product has been forbidden in Europe or in North America. An estimated one third of all pesticides used in the developing countries do not fulfil international standards for security. FAO has declared that this is a serious danger for the health of people and the environment.

Instead of paying for safe destruction of the pesticides these companies can receive support for exporting them. Even when selling the products at a very low price this is better business for the company than safe storing or destruction. Some of these products have a bad quality and contain chemicals leading to fatal accidents if not used very carefully.

A great problem in developing countries is bad labelling of products. Often the farmer receives a pesticide in old bottles or plastic bags without any hazard warning sign. There are also cases where pesticides containing DDT have been sold as a harmless natural product. When pesticides are delivered in second hand food containers like cola bottles or sugar bags, this results in people accidentally drinking or eating the poison. Often pesticide containers are subsequently used for rainwater containers, and people are poisoned in that way.

Some pesticide producers are more interested in selling their products, than in giving information concerning the dangers of using them. In developing countries, it is often easy to get hold of cheap pesticides, but often impossible to get sufficient protective equipment for use of the person spraying. Some tropical honey hunters have the idea that insecticides made for killing flies and mosquitoes can be used in honey hunting. Instead of using fire and burning the bees, they now use the spray. The honey gets a nice smell of perfume and does not smell from smoke, and they do not know that people eating this honey can be very ill – and even die. The poisoned honey is sold in second hand bottles in

the market and the costumers cannot see if the honey is from a beekeeper or a honey hunter. It should be the responsibility of the producer to take care that the product is used in a way as safe as possible for the farmer. Many farmers in the developing countries cannot read a label, but it is possible by using drawings to inform about their use and danger. There are groups of tropical farmers acting against the import of dangerous and (in industrialized countries) forbidden pesticides, but the lobby of the producers has until now succeeded in preventing such a ban.

HOW TO SEE IF BEES ARE POISONED BY PESTICIDES

The skilled beekeeper will soon know that something is wrong if he or she visits the apiary after bees have been poisoned by pesticides. Among the symptoms are:

- Dead worker bees accumulating at the hive entrance. They will usually represent 10-20 percent of the total number of bees being killed, but ants will often remove them very quickly. The rest of the poisoned foraging bees die in the field.
- The bees are becoming agitated and aggressive – caused by many types of poisons, but especially evident with Lindane and organophosphorus compounds.
- The bee colonies are producing loud and angry sounds, and the bees are showing stressed and nervous behaviour, frantically running around on the surface of the hive.
- If the hive is opened, it is possible to see hive bees performing the special "alarm dance". The returning bees and some of the hive bees run around on the combs in spirals or irregular zigzags. This can stop proper flight activities completely for some time. On the landing board or around the entrance, bees will perform abnormal communication dances.
- Bees will be crawling around on the ground in front of the hive, unable to fly, sometimes for three days before they die, if they are not eaten by ants. Some bees will lay spinning on their back.
- Many of the bees killed by poison will have their tongue extended.
- Especially associated with exposure to organophosphorus insecticides, there will be a regurgitating of the stomach contents.
- Dead and dying light coloured young and newly emerged bees will be seen. That is a sure sign of pollen contamination.
- Some time after the poisoning, the queen will produce only drone eggs. There may be other reasons for that as well, but it will lead to the death of the colony.

Sometimes all bees in a colony die immediately, but often the bees will survive for some time before they die. A poisoned bee colony will lose its forager bees, and most of the young bees will die after some time, because they eat the contaminated pollen in order to produce the "bee milk". This means that no bees are cleaning the empty cells for egg lying, and there are no bees to feed the larvae. After the storage in the comb, the pollen can remain toxic to bees for the next eight months or even a year. Usually the queen will be superseded within the first 30 days after the poisoning, or the colony becomes queenless. When there is a lack of pollen, the hive bees will start feeding on the eggs, but when there are no eggs or young larvae present, the workers can no longer rear a new queen.

HOW TO PROTECT YOUR BEES AGAINST PESTICIDES

The beekeeper can help reduce bee poisoning in different ways:

Bees can be kept at a distance safe from areas where pesticides are being applied. This must be at least seven kilometres to be quite sure. In that case, the farmer gets no pollination from the bees. The beekeeper and farmer can co-operate. If the beekeepers learn about different pesticides and their use, they can discuss with farmers, warn them against the most dangerous pesticides and develop beneficial agreements concerning pollination services and the prudent use of pesticides. It will often be an advance if the beekeepers have an organization, which can help in negotiating with farmers or authorities.

Bees can be moved away before the spraying takes place, and be kept away as long as the poison is still active in the flowers. If pesticides are used on flowering plants, near the hives, and it is too difficult to move the hives away, the bees can be confined inside the hives. That can be done by closing the entrance with a net and cover

the hive by large burlap sacks. In hot areas or hot days, it is necessary to put water on the sacks to cool the bees. The bees should also be provided with water inside the hive, so that they are able to cool the brood.

It may be necessary to apply water to the sackings every one to three hours to keep the colony sufficiently cool during the day in the tropics. If the hives are placed in shade, and the sacking is kept wet, the bees can be covered for up to two days in the tropics. Overheating of a colony of bees may lead to rapid death, as described in connecting with movement of bees. Larger colonies are more sensitive to overheating than small, and it is important that there is plenty of space and good ventilation in the hive.

If the bees are near a water pipe, it can be possible to keep them inside the hive by constantly sprinkling them. Make an agreement with the farmer, so that he or she does not spray in flowering crops or at least that does not spray in daytime when the bees are working in the field. The spraying should only take place during late evening or night. Tell the farmer, that there are some repellent insecticides with a smell that makes bees abandon the flower instantly.

ALTERNATIVES TO PESTICIDES

In discussions with farmers, it can be useful to know that there are alternatives to pesticides – at least in small-scale farming. When using pesticides, a detailed knowledge of the life cycle of the pest is necessary. A pesticide used at the wrong time, in the wrong place and in a wrong manner, can be more harmful than not using it. Wrong use of an insecticide can kill the pest for a while, but it also kills many enemies of the pest. After some time, the pest population will recover, but then there will only be a few natural predators left to eat the pest, because they normally do not recover as fast as the pest. Now the pest population can grow even larger. Then even more insecticides are needed and after some time it often happens that the pest develops resistance to the chemicals, and new, stronger and more expensive pesticides must be bought. It can continue in this way until so much poison has been used, that the environment is spoiled or the farmer ruined. That is what happened in Central America in the cotton growing areas, where the crop had to be sprayed 44 times during the growth. The cotton growing had to stop, and the areas was used for cattle, but the environment was so polluted that the export of the cattle meat to the United States was stopped.

If pesticides have to be used, it must be done in combination with other ways of fighting pests. Often the local farmers have traditional knowledge of how to live with or fight pests, and many of these methods seem to work. In reality, most pesticides used in the tropics are for export crops, and in that way some of the poison returns to the industrialized countries, where they were produced.

There are many ways of controlling crop pests without using imported pesticides. Local conditions are of importance but some few activities useful in gardening and small-scale farming can be mentioned here.

- Make sure that the cultivated plants are properly nourished. Too much or too little fertilizer, water or sun can cause aphid attack.
- Plants can be grown as mixed crops, so that the pest or disease cannot spread so easily as in a monocrop, e.g. maize intercropped with cassava reduces the spread of cassava bacteria wilt.
- Planting with the right density can prevent some pests. For example, groundnut should be sown close to prevent aphid attack to the lower part of the plants.
- All infested fruits or tubers have to be removed from the field, so that pests from them cannot develop a new generation.
- Do not let leaves or fruits touch the ground.
- Prevent flow, splash or runoff of water from infected plants to healthy ones.
- Rotate the cultivation of different plants. Crop rotation is very unfavourable to nematodes.
- Always use healthy seeds, plants or potatoes when starting a new plant generation.
- If possible use resistant plant varieties, e.g. some of the old types of millet in West Africa are better protected against birds and beetles because of their sticky hair.

- Self-made natural products can be used to fight pests without them developing a resistance, e.g. fine ashes to prevent leaf chewing insects. The juice of tobacco stems is poisonous to aphids; vegetable oil or fatty soaps mixed with water combats aphids; earth mixed with salt prevents termites to spoil poles (for a time).
- Do proper weeding and destruction of infested plants. If possible, use the weeds in compost making, so that the high temperature will destroy germs of diseases and pests eggs before the material is returned to the fields.
- Try to organize fields in an environment providing a habitat for a great variety of the farmer's natural allies, such as insect eating birds, spiders, wasps, etc. When clearing new land some areas of trees and bushes should be left between fields.
- Make some biological control. This means to import or cultivate the natural enemies of a pest. It could be parasitic wasps, or by using harmless bacteria which only attack worms and do not poison other creatures.

COOPERATION BETWEEN FARMERS AND BEEKEEPERS

In the recent years, there has been an increasing amount of data concerning the harvest of seeds in bee-pollinated crops. Some crop failures may be incorrectly blamed on poor soil, pests or drought, when in fact the real cause is lack of bees in sufficient numbers to pollinate the crop. Data shows that it is necessary to do something more to protect the pollinating insects, and to continue the study of how they are used in the best way. Use of bees for pollinating crops is to a certain degree developed in Europe, North America, Australia, Japan and New Zealand, but in many countries (also in Europe) the bees are not used effectively, partly because of lack of knowledge and partly because the hives are so big and heavy that they are difficult to transfer to a field.

Knowledge of bee pollination can be so small that farmers try to get rid of the useful bees by using smoke among their orange trees and coffee bushes. They wrongly think the bees are spoiling the flowers, while they actually are helping the farmer.

To help farmers obtain better harvests and to protect the beekeepers' bees, it is necessary to have much more information about the need for bees for pollination of special crops. If the beekeeper is informed, he or she must inform the farmers so that they also take care when using pesticides. If farmers and beekeepers cooperate, it is possible to a certain degree to protect the bees against the chemicals.

MAIN TYPES OF PESTICIDES

Pesticides kill by direct contact, stomach poisoning or fumigation. There are eight main types of pesticides. The most dangerous pesticides for bees are among the insecticides, but some of the other pesticides harm them too. Most insecticides are dangerous for people as well as bees.

TABLE 17
Main types of pesticides

Main types of pesticides	Kill
Rodenticides	Rats and mice
Fungicides	Fungi
Miticides/acaricides	Mites
Herbicides	Plants
Insecticides There are four major groups of insecticides: Chlorinated hydrocarbons (organochlorines) Organophosphates (organophosphorus) Carbamates Pyrethroides	Insects
Nematicides	Nematodes
Molluscicides	Molluscs, slugs, snails
Bactericides	Bacteria in humans and other animals