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Chairman : Raymond BORNECK

Reporter : Livia PERSANO ODDO

MELLIFERA DEVELOPMENT IN FARMING AREAS EXAMPLE : HEDGEROWS

BRUNEAU E., VAN NITSEN L., ANDRE P.,
Centre Apicole de Recherche et d'information, asbl,
Place Croix du Sud 4
Louvain-La-Neuve
Belgique

ABSTRACT

In the current agricultural context and in the framework of the elaboration of a new Common Agricultural Policy, what steps can be taken in farmland areas to encourage a sound equilibrium between the pollinating requirements of entomophile crops and wild flowers, and the presence of pollinating insects ? A first steps in land developemnt would be to improve melliferous flora, and to plant, as well as to upkeep refuge areas. With regard to hedgerows and wooded areas, they should be further developed. A second step would consist of changing farming methods and agricultural crops, which would be more oriented towards the safeguard of pollinating insects.

I. CURRENT SITUATION

Agriculture is presently faced with numerous problems, on one hand of an economic nature, and on the other hand, of an environmental one. Due land consolidation, uprooting of hedgerows and other ecologically sensitive areas, as well as intensive farming, many animal and vegetal species have become rare, some have even disappeared in a bland and featureless environment. In essence, mellifera flora has on the whole become extremely impoverished (semi-natural areas have been farmed, intensive use of fertilisers have destroyed varieties of flowers,...) and a shortage of suitable nesting areas has resulted in a decline of pollinating insects. However, the pollination requirements of certain crops during their growth period (sunflower, rapeseed) and of many wild entomophily plants must necessarily be fulfilled. The latter could even be in jeopardy in the medium term. Faced with this overall state of affairs, the current agricultural policy is striving to re-define production from another angle. One of the measures of this policy is of an agro-environmental nature, which encourages farmers to use less intensive and more ecological farming methods, and also to plant their farmland.

II. AIMS

The aim of this survey conducted in the framework of an experimental project is to set forth a basic structure of action steps to be undertaken in pilot plans representative of major European regions and able to fulfil pollination requirements whilst ensuring pollinating insects can thrive.

These steps come within the scope of the new agricultural policy. In actual fact, 2 types of steps can be taken :
- on one hand, a land management policy should be implemented ; it would consist of creating and upkeeping refuge areas. This type of habitat must meet agricultural constraints and must encourage diversification and valorization of products. A feasible solution would be to develop refuge areas in the shape of hedgerows or woodlands.
- on the other hand, farming methods should be adjusted with a view to improving crop quality and protecting the environment, for instance, grassland sowing should be comprised of many different species of grass.

III. GENERAL CHARACTERISTICS / WORK BASE

The project is based upon 3 pilot plans in Belgium which are representative of the farming landscape in Central EEC. The first one is located in a breeding area (Bastogne plateau), the second, in a mixed - crops + breeding - area (Entre Sambre et Meuse area) and the third one in a crop farming area (Hesbaye). If the action plans are to be established in a satisfactory way, a thorough knowledge of the various areas is essential. The relevant data is not only of a physical (mapping, soil,...) and of an agronomical (type of farming, speculation,...) nature, but also of a social (population, social-economic factors,...) and environmental (ecological assessment of the various landscape elements) one. Hereunder, you will find a table which summarises the different aspects of the 3 selected areas.

ZONE	FERNELMONT	NIVES	CHIMAY
Agricultura zone	Silt-laden	Ardenne	Grazier-Famenne
Area	± 1000 ha	± 1000 ha	± 5000 ha
Soil	Silt	Schist	Schist-calcareous
Altitude	± 100 m	± 450 m	± 200m
Speculation	Great cultivation	Pasture	Pastureculture
Exploitation may	Intensive	Semi extensive	Extensive
Type of population	Péri-urban	Rural	Rural-forest

IV. POSSIBLE ACTION PLANS

You will find a concise description of the different actions plans envisaged for the pilot plans. One particular aspect will be especially enhanced, i.e. the planting of hedgerows.
The action plans can be broken down into two main categories. The first group will deal with land development in order to improve the quality of mellifera flora, to create and to maintain nesting sites.

The second group consists of recommendations and actions to be taken into consideration when dealing with the farming community, to encourage them to adopt an ecologically and environmentally sound land management, in particular where pollination is concerned. Also included in this second category are ways and means to diversify and enhance the value of new productions.

1. Land Management and Development

Several landscape elements can be considered as refuge-areas. Management and development modalities will have a considerable impact on the quality of these habitats. Grass verges are part of a network of refuge areas whose value and resources will depend on what kind of upkeep modalities are implemented. Thus, several priorities have been defined for the pilot plans :
- the use of herbicides is prohibited ;

- compulsory mowing after flowering ;
- compulsory exports of cut grass.

This should encourage the development of specific embankment flora of a comparable nature to weeds encountered in crops. It should also provide a satisfactory nutrients for pollinating insects and have an anti-erosive impact.

The people in charge of land management and development will be directly informed about this kind of maintenance method.

Many sites of ecological interest can be found in the pilot plans : wet areas, limestone pastures,... In addition to the role they play in safeguarding vegetal and animal species, there is a profusion of flowers in these zones, in other words, a vital source of pollen and nectar and a suitable nesting place for certain species.

These areas are sometimes classified as natural parklands and are administered as such, i.e. a specific management programme is applied.

In order to protect ecologically sensitive areas which are not considered as natural parklands, it is vital to develop some form of legislation, with rules and regulations and to encourage management by nature protection societies and by farmers.

Action plans for creating new refuge-areas will be developed latterly (cf. chapter "Concrete example of hedgerows").

2. Action plans linked to crop production

Within the crop areas of the pilot plans, it is important to encourage to the sowing of entomophily crops. Entomophily crops are a local source of nutrition for the insects of the area. At present, rapeseed is the most widespread in Belgium (7,000 ha). Sunflowerseed and buckwheat experiments are currently underway. Further development of these crops will depend on whether they lead to other economic outlets, for instance, producing non fossil fuel from rapeseed. In breeding areas, the qualitative value of pastures could be further enhanced by adding leguminous and other mellifera species to grass seeds. An illustration of an interesting variety is the white clover. By introducing this type of mellifera plant, one can obtain yields equivalent to those achieved on pastures composed of graminae only, with an extremely low amount of nitrogen fertilizer. In major crop areas, the actions would especially focus on the phytosanitary treatments which are used (choice of products, period of treatment), whilst ensuring refuge areas and new developments are carefully respected.

Integrated protection schemes should be encouraged. Green manure which covers the soil during the winter is an important nutritional complement at the end of the season (phacelia,...) Crop combinations, such as sugar beet or corn in association with green manure, are currently being analyzed and could be an important contribution in the future. Longer crop rotations (4 or 5 years) would enable to plant more mellifera crops such as peas and beans,.... With regard to the provisions for fallow land in the framework of the new measures of the Common Agricultural Policy, recommendations should be given for sowing non productive mellifera crops such as phacelia, melilot, clover,...

3. Computer Management

In order to monitor and subsequently manage the refuge areas efficiently (steps to be taken and recommendations for the pilot plans), a computer based management method is currently being examined. On the grounds of the data currently at our disposal for mapping (1/10.000) and for pilot plans characteristics (agricultural and ecological), we are in the process of developing a model for managing land development. The aim of this type of model is to assess economic and ecological consequences when allocating different kinds of land uses (impact for pollinating insects). Our model is based on a Geographic Information System (G.I.S) developed by the association of a computerized data bank and a computer mapping software system.

V. HEDGEROWS AND WOODLANDS

Amongst the various possible action steps to be taken in the pilot perimeters, we have chosen to develop the following : plant new hedgerows and woodlands and maintain existing ones. This way we will be able to approach and understand land development constraints better. This course of action will require approaching both the authorities as well as the farmers with a series of different steps.

The choice of planting or "restoring" woodlands set in the farming landscape fulfils the objectives of the project. These landscape factors present an agronomical interest (shelter for cattle, wind breaks, anti-erosive effect,...), an economic interest (timber for building, for heating or for compost purposes), and an ecological interest. In order to enhance the ecological aspect, it is important to plant hedge networks which will enable plants and insects to move around and will also serve as a link between the different types of habitat. Pollination needs can be fulfilled by introducing mellifera plants which blossom at different times, thus providing adequate and continuous nutritional supply to pollinators.

1. Ecological assement of woodland

As previously indicated, assessment is one of the first phases of the project. For the time being, we have confined the analysis to ligneous factors (a quick and easy-to-use assessment method) whilst bearing in mind that other elements such as entomological, floral, faunal ones are also part of the overall picture. We are of the opinion that planting trees, shrubs and hedgerows will have a good long term impact on the landscape and therefore on the pollinating insects which thrive in such a habitat.

The analysis of ligneous elements was carried out by developing and implementing a method based on an ecological assessment of ligneous factors, which was easy to database, even to encode onto a Geographic Information System. Each ligneous element of the countryside (individual tree, hedge,...) is analyzed (structure, size, diversity, adaptation, melliferous quality, flowering period,..) An in-depth explanation of this method of analysis can be found in annex 1.

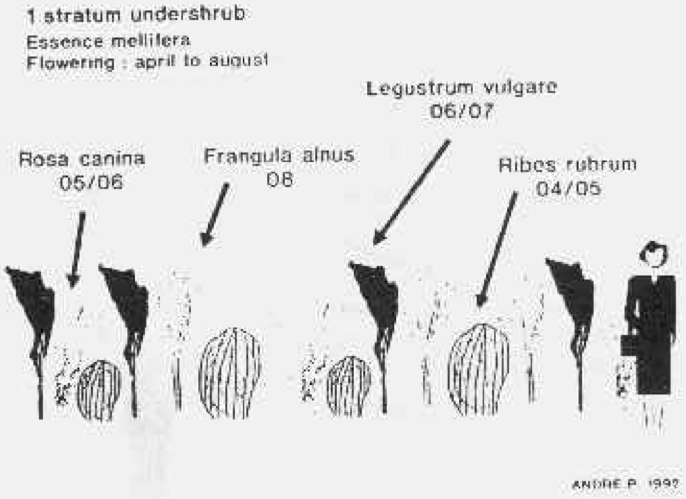
2. Different types of hedgerows

The concept of hedgerows is perceived differently by each and everyone. For some, a hedge is small and well trimmed, whereas for others, it is arborescent and trimmed width-wise only.

Hereunder are 3 types of ligneous elements which are consistent with the aims of the project. Only indigenous or mounted species are taken into consideration. The choice of species for planting is based on mellifera quality and flowering periods. This criteria will be used for setting the maintenance calendar. Hereafter are 3 examples which can be implemented in the pilot perimeters.

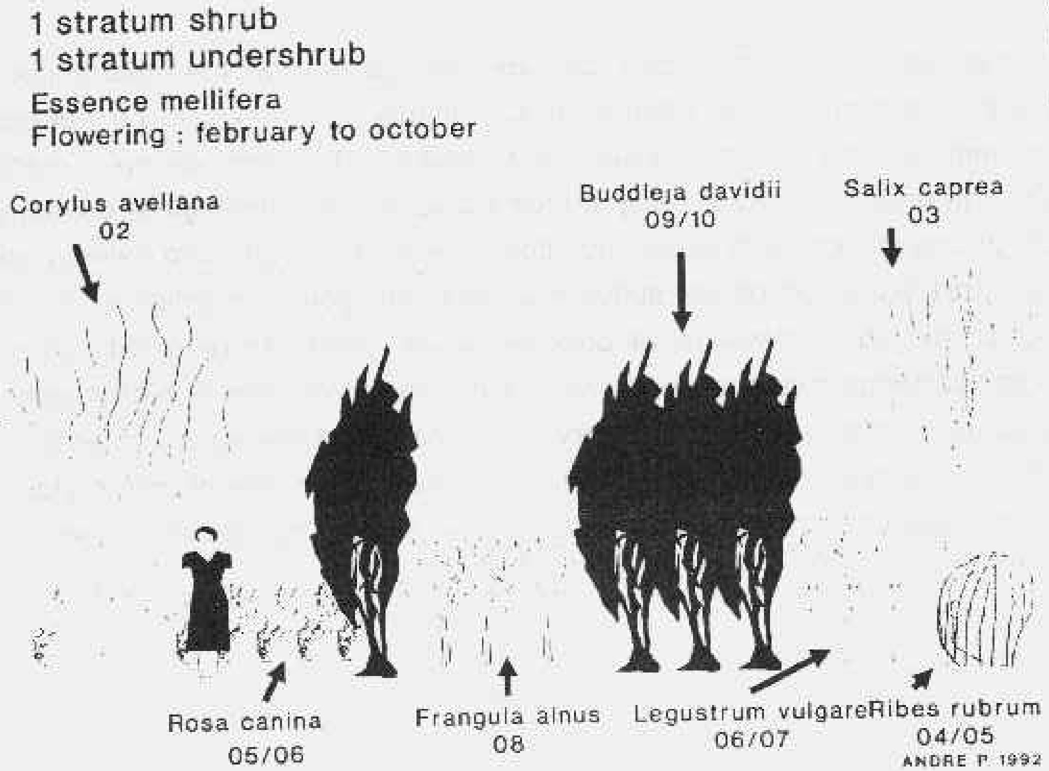
First Example

Shrubs composed of 4 melliferous species, that flower from April to August.



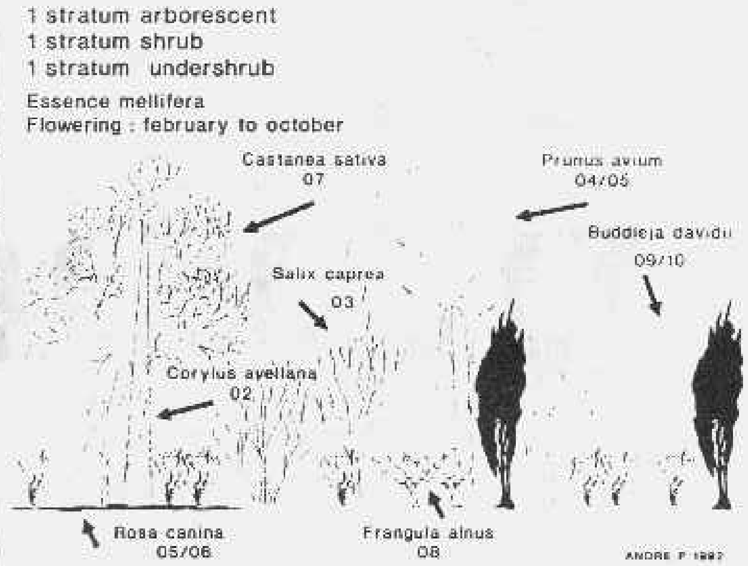
Second Example

Two-layered hedge (shrubs + bushes) consisting of 7 melliferous species, that flower from February to October.



Third Example

Three-layered hedge (trees, bushes and shrubs) composed of 8 melliferous species, that flower from February to March.



3. Economical factor

In our opinion, the economical factor are perhaps one of the most important for upkeeping, restoring and planting areas. In this light, it would be necessary to encourage a policy for planting farmlands, based on the new concept of hedgerows along the lines of agro-forestry principles (combining biological diversity, self-ecology and increased financial income). If farmers, private land owners and local authorities derive economical satisfaction from this type of forestation, the latter will gradually develop and will not be confined to pilot plans. More specifically, by "new concept of hedgerows in agro-forestry " we mean production of high quality broad-leaved trees (maple, ash, wild cherry,...) in short-term revolution, spread over 8 to 10 metres in multi-layered woodlands. For instance, if wild cherry is planted, the third example of a hedge can have an updated yield calculated as follows :

Update yiedl = $\sum_i (R_i - D_i)\,(1{,}0\ ta)^{-i}$

Ta = updated rate

Ri = updated yield

Di = updated expense

i = time

Final felling of 100 metres of linear trees after 60 years (11 wild cherry trees) gives an updated yield of 1650 ECUS.

4. Planting process

After checking that all the different elements are present, the following step is to arrange a meeting with the council authorities and the farmers of the pilot perimeters. The purpose of this meeting is to introduce the project and its objectives and listen to their comments, wishes and constraints. Based on the actual situation, it is possible to single out critical issues which need solving.

In fact, the constraints vary, depending on whether the land is private or public property.

4.1. Planting on public land

Importance of land consolidation

Two of the pilot plans are currently undergoing land consolidation operations. Surplus land, small plots of public land and river banks are privileged areas for planting hedgerows or woodlands. However, these areas are generally spread out over the countryside, and setting up a network would not prove an easy task. This is why land consolidation seems to be a good solution. It is interesting to point out that other countries (Germany, the Netherlands,...) have already implemented land consolidation for such a purpose. Indeed, in doing so, public land along the roadsides or fields is widened where it is of interest to plant trees, hedgerows,.... The use of Council-administered property (greater land acquisition along the roadsides) is particularly useful in areas under cultivation. Individual farmers, who generally only perceive the negative aspects of planting (competition between roots, land loss, shade,...) are extremely reluctant to this type of approach and are not yet ready to plant their land. We will therefore endeavour to develop a network of primary hedgerows on council property.

Position of Councils

In Belgium, the councils are quite autonomous when it comes to taking decisions and they are responsible for the maintenance of plants on council land. In general, they regard any additional task such as hedge trimming (despite the modern equipment available) with apprehension. It is necessary to make them aware of the environmental issues at stake or to ensure that the pressure exerted by the inhabitants of the area is sufficiently strong to prompt them to take on the management of plantations. The council's involvement in improving and planting hedge networks is therefore a decisive factor in the success of such a project.

4.2 Privately-owned farmlands

There is presently a tendency to uproot hedgerows as they are often perceived by farmers as a low-key production factor on account of the upkeep they require. The remaining hedgerows are either not trimmed and hinder farming activities or they are trimmed with chain saws and hand shears during the winter months and represent a considerable amount of extra work for farmers. Yet in breeding areas, the majority of farmers is aware of the benefits to be derived from hedgerows, i.e. shelter for cattle, but the upkeep remains too time-consuming and fastidious to ensure they are properly trimmed and restored. In cultivation areas, however, farmers who believe that hedgerows increase yields by acting as wind breaks are far and few between, most farmers consider them as having the opposite effect. They are not aware of the refuge-role and the possible contribution of pollinating insects to their crops. On privately-owned land, hedgerows are chiefly found surrounding well-positioned pastures, as shelter against cold winds, gusts of rain or as shade from the sun, providing their upkeep can be dealt with.

5. Aids and Incentive Schemes

Let us examine the different types of aids and incentive schemes which could be conceivable for replanting and the upkeep of hedgerows, in order to retain the solutions which apply to the pilot plans in question.

5.1. Subsidies granted for the upkeep of hedgerows

Subsidies are granted in several Member States for the upkeep of hedgerows. They are quite often restricted to particular areas which are acknowledged as being ecologically sensitive (natural parkland Hautes-Fagnes-Eifel and the communes of Ham and Bilzen in Belgium, the North-Eifel park and the Nordeheim-Westfhalen land in Germany and South Limburg in the Netherlands).

The generalisation of such subsidies would indeed guarantee the survival of hedgerows. These subsidies could be extended as bonuses under the regulations of the new Common Agricultural Policy to all those who implement farming methods compatible with environmental protection requirements as well as to those who upkeep natural areas, providing of course that hedge maintenance and upkeep is considered as one of these practices. The advantage of granting a direct aid to farmers makes them aware of the issues at stake. The implementation of such an aid depends entirely on the will of the Member States to forecast budgets for such achievements.

5.2. Hedge maintenance with efficient equipment

Nowadays, there is a whole range of equipment (shears, mowers, flails) which enables to upkeep hedgerows in fast and inexpensive way. Yet even in bocage (wooded) areas, it is rare to find farmers or farming cooperatives that are equipped with such tools. The total lack of interest for this "indirect" sector of farming acts as a break upon this type of investment.
Nevertheless, management and purchase structures for this type of equipment should be put into place and farmers should be encouraged to use it, i.e. shared purchase, group management of equipment, council-administration of equipment (cf. annex 2).

5.3. Establishing rules and regulations with regard to the protection of hedgerows

Several legal texts can prohibit or at least curb the uprooting of hedgerows. Thus, these decrees have been adopted in certain districts in Belgium, whereby no hedgerows or shrubs can be uprooted without prior agreement. Nevertheless, experience has shown that this means of protection is not sufficient for several reasons :

- prior to the date the decree was enforced, massive uprootings took place ;
- farmers who are unaware of the issues at stake consider this decree as a constraint to their freedom and an attack on their private property
- on the whole, the implementation of the decree was poorly monitored by the local authorities.

It is therefore vital that both the public and the farmers should be made aware of the issues at stake if the scheme is to have a long-term impact.

5.4. Recess of arable land

The recess of arable land appeared to be a possible solution as a financial compensation for the loss of land intended for planting hedgerows. However, despite the fact that the bonuses granted for recess of arable land are insufficient and do not appeal to farmers, the current regulations do not provide for a recess of arable land for hedge planting purposes. It is time to introduce a scheme which would enable long-term recess of arable land for environmental purposes (current temporary recess period of 1 or 5 years), and would also provide the possibility of recessing smaller surfaces (currently 15 %).

The solution would seem to be particularly interesting as it effectively combines environmental protection concerns (planting of hedgerows) and reduction surplus production issues.

5.5. Planting of arable land

Still in the framework of the Common Agricultural Policy, aids are granted for the planting of arable land. This incentive scheme is of interest for 2 reasons : on one hand, it encourages diversification of production and on the other hand, if such a scheme is successful the considerable deficit in the "wood" trade balance of Member States could be reduced.

Unfortunately, in Belgium, the choice of plants for such a programme is restricted to *Salix* sp., *Populus* sp., *Alnus* sp., which are marginal species in the "wood sector". The new Common Agricultural Policy should grant linear afforestation aids (tall hedgerows). Likewise, it would seem necessary to extend the range of production species (*Prunus, Fraxinus, Quercus, Acer,...*).

CONCLUSIONS

At present, only the small-scale solutions, which are prompted by privately-taken initiatives on account of the growing public awareness, will encourage the implementation of a land management policy focusing on planting and upkeeping of refuge-zones for pollinating insects.

For instance, creating structures for managing and purchasing equipment would solve the hedge maintenance issue and land consolidation enables sporadic planting (80 % funding).

Due to crop diversification, the need for pollinating insects will probably increase. In the future, new crop development techniques should reconcile the quality of the environment (i.e. respect for pollinating insects) with farming incomes.

Nevertheless, in the short or medium term, the revised Common Agricultural Policy should necessarily provide for extending certain action plans (aids for maintenance, for planting,...) to all farming areas.

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ANNEX I.

Ecological assessment of woody elements in the landscape

Structure of the element : the number of layers
There can be up to 4 layers :
- a layer of trees higher than 10 m ;
- a layer of bushes lower than 8 m ;
- a layer of shrubs lower than 2 m ;
- a layer of grass (ground level) ;

Development by layer : classification for a particular species, with regard to maximum growth and thickness (greatly developed).

A. underdeveloped ;
B. poorly developed ;
C. medium developed ;
D. greatly developed.

Diversity by layer : number of different species.

A. less than 2 species ;
B. 3 to 5 different species ;
C. 6 to 10 different species ;
D. presence of rare species ;
E. over 10 different species.

Adaptation of species per layer : on one hand, the presence of indigenous or non indigenous species, or even both ; on the other hand, the fact that the species are in station or not in station. ("in station" means that the species is in optimum climatical, hydric and trophic conditions with regard to the natural habitat of the species).

A. indigenous, in station ;
B. indigenous, not in station ;
C. combination of indigenous and non indigenous species, in station ;
D. combination of indigenous and non indigenous species, not in station ;
E. non indigenous, in station ;
F. non indigenous, not in station.

ANNEX 2.

Purchase and management structures for hedgerow maintenance equipment.

A. Association of several farmers

In Belgium, it would seem that only the small associations of 3 to 6 people function efficiently, contrary to what happens in France where farming cooperatives are much more prevalent. Therefore, the return on investment for equipment which is purchased by small farming communities will not be easy and only those who are aware of the issues at stake and who can afford to buy, will do so. Furthermore, as the equipment deteriorates fairly quickly and is rather difficult to use, therefore not easily handed over from one person to another, it is somewhat hard to build up bigger groups.

B. Creation of a structure similar to a non-profit making association

This organization would have suitable equipment and a qualified workman to ensure the upkeep of hedgerows for farmers, at minimal cost. This type of management has the advantage of making the most of the machine but would inevitably compete with private companies.

However there are not many farmers who use these private companies as the prices are high.

C. The Councils should put at the disposal of farmers equipment such as rotors which would be used for the upkeep of hedgerows.

The councils are reluctant to lend their equipment to individual farmers. It is difficult to get public employees to carry out maintenance tasks on private land. Nevertheless, lateral hedgerow maintenance (along the roadsides) is a considerable help to farmers.

IMPACT OF THE SYNERGISM OF PESTICIDES ON BEES : BIOLOGICAL EFFECT OF A COMBINATION OF AN INSECTICIDE WITH A FUNGICIDE

M.E.COLIN * & L.P.BELZUNCES **
I.N.R.A. Centre de Recherches Agronomiques d'Avignon,
*Station de Zoologie-CNEVA,
**Station de Phytopharmacie,
Domaine Saint-Paul,
84143 Montfavet Cédex
France

In 1986, serious damage to bee colonies was observed in the north-east of France following the aerial spraying of a mixture of two agrochemicals (fungicide and insecticide), both classified as non toxic for bees. The active matter of the insecticide was deltamethrin, belonging to the pyrethroid family, which acts mainly on the nerve transmission (see Soderlund and Bloomquist, 1989). Prochloraz, an azole derivative used as fungicide, modifies the cytochrome P-450 enzyme activity (Snegaroff and Bach, 1989). Previously, Johansen et al. (1983) pointed out the toxic hazard to bees of an acaricide, essentially nontoxic when used alone, added to an insecticide in spray mixture. However, foraging bees can be into contact or carry into the hive small quantities of different agrochemicals spread on crop and consequently risk noxious effects of a synergy between two or more active matters.

To simulate the field treatment conditions, adult foraging bees were submitted to a fine spray, in a Burgerjon (1956) spraying tower (fig.1). All deltamethrin and prochloraz solutions were prepared in distilled water containing final concentrations of 1 % (v/v) acetone and 5 % (w/v) emulsifying agent. According to the International Organization of Biological Control recommendations, deposits of agrochemicals on the rotating disc were 1.79+/-0.10 mg of solution/cm^2 at 7240 Pa pressure (Hassan et al., 1985). Immediately before treatments, bees were CO2 anaesthetized and put on the rotating disc by set of 50 individuals. They were then stored in small cages in a thermostated chamber at 24+/- 1°C and 60+/- 10 % of relative humidity and fed with a sugar honey (4/1, w/w) paste. The lethal rate was first established from doses of active ingredient/ha recommended for wheat or rapeseed (i.e. 6 g deltamethrin/ha and 600 g of prochloras/ha). Second, sub-lethal doses, corresponding to applications producing a mortality similar to that of control, were sprayed alone and in mixture. The doses were respectively 0.125 g/ha for deltamethrin and 25 g/ha for prochloraz.

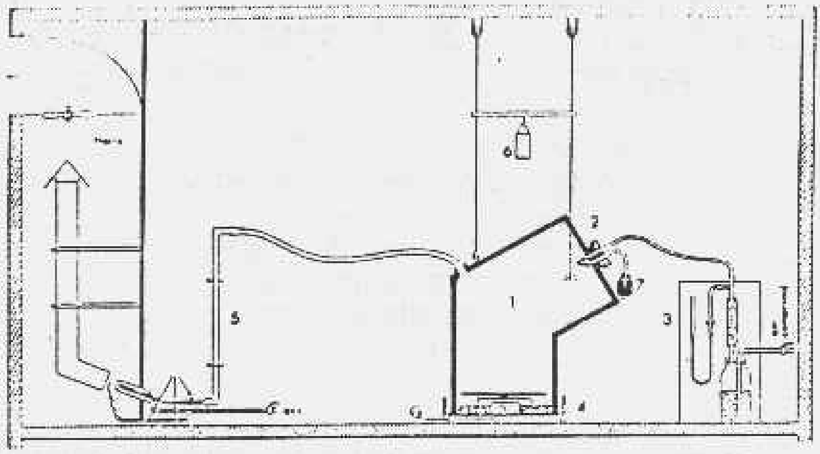

Figure 1. Laboratory and Burgerjon's sparaying tower 11 : plexiglas tower 30 cm in diameter; 2 : spraying nozzle; 3 : manometer; 4 : basin and rotating disc; 5 : eduction pipe; 6 : counterweight; 7 : spraying solution.

Deltamethrin and prochloraz, sprayed alone at the doses recommended in field treatment, produce 100 % of bee mortality within 24 hours in our experimental conditions. At sub-lethal doses deltamethrin and prochloraz sprayed alone did not cause a significantly different mortality rate from that of the control during 96 hours observation. This result confirms the right choice of the two sub-lethal doses. The mixture of the chemicals at the precedent doses, produced 73.2 % of mortality within 24 hours (fig. 2).

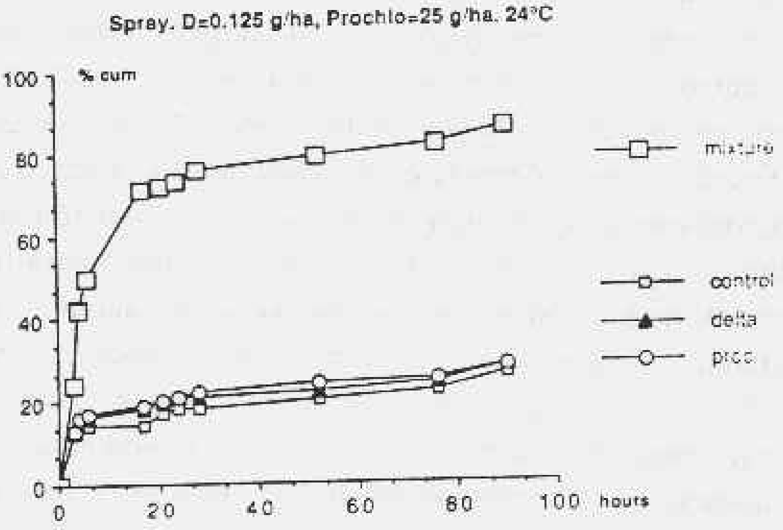

Figure 2. Evidence of a synergism between deltamethrin and prochloraz. Deltamethrin and prochloraz separately sprayed cause a bee mortality similar to that of control. The mixture of the two chemicals elicits high mortality of bees.

In conclusion, we stated that deltamethrin and prochloraz, sprayed alone at the recommended field doses, were seriously toxic to adult bees in our experimental conditions. The synergism was evident at sub-lethal doses of each chemical. The doses per adult bee are considerably lower than the LD50. Atkins et al. (1981) gave 0.067 µg/bee for deltamethrin, whereas the estimated sub-lethal dose was 0.001 ug/bee in our experiment. We did not find the LD50 of prochloraz in the literature, because fungicides are generally considered as non toxic for bees (see Fell et al., 1983; Mayer and Lunden,1986). Sub-lethal doses of deltamethrin (0.001 ug/bee) could not easily be detected on a sample of one hundred dead bees, because the amount of residual active indredient is very close to the detection limit of the analytical method using gas chromatograph, even without considering the output method or to the natural degradation on field conditions (see de Cormis et al., 1987). Thus, in the case of synergy between two pesticides, a positive diagnosis of bee poisoning based on chemical analysis, seems sometimes difficult to establish.

Consequently, we must endeavour :

(i) to improve the sensitivity of the residues detection techniques
(ii) to adapt cellular toxicity tests to honey bee
(iii) to develop sensitive biological tests, based on social or cognitive behavior.

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IMPROVING THE QUALITY OF MELLIFERA FLORA BY DIRECTDISTRIBUTION OF PLANTS TO BEEKEEPERS

Carlo CONTER
Administration of the Technical Services for Agriculture,
Agriculture Division - Horticulture Service,
Great-Duchy of Luxembourg

There is no doubt that the actual life of wild fauna and flora is more and more threatened by the activities of mankind.

Since the end of the second World War, there has been a tremendous boom in industry and agriculture, urban areas have developed and communication networks such as roads have expanded. One of the consequences of this development was the transformation of the countryside, bringing about a major change, i.e. impoverishment of the flora. This situation has had a direct and harmful impact on pollinating insects, namely on the honeybee.

It seems obvious that the safeguard of the bee and other pollinators is inextricably linked to keeping their nutritional environment intact, in other words, protecting the mellifera flora.

In this perspective, the horticultural department ASTA (Administration des services techniques de l'agriculture - Administration of agricultural technical services) which deals, among other things, with certain aspects of apiculture, as well as managing the national brand of honey, already implemented in 1965 an action plan aiming to improve and diversify mellifera flora.

This plan consists of distributing mellifera plants to beekeepers.

The distribution is organized in the following way :

1. Within the limits of our budget, wood honey source plants are free for beekeepers who are interested. Beekeepers must plant them as hedges, copses, clusters of trees or individually, either on their own piece of land or in cooperation and agreement with local administrations or private partners. They are to be planted on embankments, along river banks, along byroads, on plots of land which are of no significant agricultural value.

2. The official body of the Luxembourg Federation of Apiarists is responsible for informing beekeepers each year of the date mellifera plants will be distributed by our department. In the same publication, there is a detachable voucher mentioning what type of plants are available. Those who are interested in receiving plants can thus indicate how many they would like. These vouchers are collected by district bodies, in charge of sending them to us in due course.

3. As soon as we receive the orders, our technicians can proceed accordingly. It is up to the relevant district bodies to ensure local follow-up.

4. Surveys are conducted throughout the year to check whether the trees have effectively been planted.

5. Thanks to this system of distribution, thousands of plants were planted. (25 plants/apiarist/year)

6. Over the last few years, demand has outstripped supply, to such an extent that we are no longer in a position to fulfil all requests on account of budgetary limits.

7. It should be noted that for phytosanitary reasons, no host-plants of bacterial fire (*Erwinia amylovora*) have been distributed since 1984.

COULD THE SAME COURSE OF ACTION BE IMPLEMENTED IN OTHER MEMBER STATES OF THE EUROPEAN COMMUNITY ?

The primary aim is of course to improve and diversify mellifera flora. Subsequently, this also has a positive effect on nature and landscape as the rural areas retain their character whilst attracting birds and small animals to nest, feed and stay.

In our opinion, this plan is easy to implement in a similar fashion on a regional scale as well as in other countries of the European Community, i.e. :

in France : by department
in Belgium : by province
in Germany : by "Länder" or "Berzike"

We think that the European Community could perhaps financially shoulder such a project by granting specific aids which could be based for instance on the number of beekeepers or bee colonies.

SEEDING ARABLE FALLOW LANDS WITH MELLIFERA PLANTS

On account of the current agricultural situation which is not highly satisfactory, the EEC has adopted regulations with regard to improving the efficiency of agricultural structures. In the framework of this regulation, aids are to be granted to support and encourage the recess of arable lands.

Some farmers have taken advantage of this programme by turning part of their arable lands into fallow lands. The State of Luxembourg currently grants a subsidy of 10,500 frs/ha to farmers who nevertheless have to upkeep the plot of land which has been withdrawn from their production.

Bearing in mind that the landscape should retain its rural character and also for ecological reasons, our department launched a project in 1991 which consists of sowing fallow lands with crops which provide food and shelter for fauna. It is first and foremost intended for bees and other pollinating insects, but subsequently ensures food, shelter and reproduction areas for game.

Tests carried out on 3 ha were extremely convincing and aroused the interest of ecologists, beekeepers and hunters. Although the farmers were not so enthusiastic, we are hopeful that by organizing information sessions, they will become more alive to this project.

In the framework of this project, seeds or mixed seeds (phacelia, mallow, white melilot, white clover, vetch, sunflower, buckwheat, mustard, etc.) are put at the disposal of farmers who are interested.

To further enhance the appeal of this type of farming, the State will provide an additional aid of 1,000 frs/ha.

IS IT FEASIBLE TO IMPLEMENT THIS ACTION PLAN IN OTHER MEMBER STATES OF THE EUROPEAN COMMUNITY ?

As for the previous plan, we are of the opinion that other countries could quite easily implement a similar incentive, with some adjustments to suit their local needs. It might be possible to obtain financial support from the European Community.

WILD BEES FOR POLLINATION IN THE AGRICULTURAL LANDSCAPE

Sarah A. CORBET
Zoology Department, Downing Street,
Cambridge CB2 3EJ,
U.K.

ABSTRACT

The pollination service provided by bumblebees and other wild bees can be essential on some crops, particularly in poor weather. Since 1960 bumblebee species have been lost from arable regions of Europe, notably in UK, France and Belgium, perhaps largely because of decreased availability of flowers in fields of forage legumes and in field margins and other uncultivated areas. Recent studies show that bumblebees visit pernnial forbs in established vegetation much more than the annuals that colonies newly-ploughed land. Therefore, because the proportion of suitable flowers increase in the first years of succesion after disturbance, continuity of vegetaion is important. Uncultivated vegetation must be left undisturbed for several years to allow pernnial herbs to establish if it is to provide the flowers needed to support bumblebee colonies throughout the season. It may also provide nest sites for wild bees, and harbour wildlife and the natural enemies of crop pests. An alternative source of forage for the valuable long-tongued species of bumblebee would be a planned seasonal succession of suitable flowerin crops complemented by sown strips of carefully-selected plant species.

INTRODUCTION

Many people are concerned about a decline in the numbers of honeybees and wild bees in Europe. This is expected to cause problems for the pollination of crops and wild flowers. The Scientific and Technical Options Assessment, European Parliament, commissioned a report on the decline, its possible causes and its predicted consequences (Corbet, Williams and Osborne, 1991a,b; Osborne, Williams and Corbet, 1991; Williams, Corbet and Osborne, 1991).

Changes in the economics and practice of beekeeping are expected to reduce honeybee numbers, precipitating a pollination crisis. Honeybees are considered by other speakers. Less widely recognised is the threat to wild bees, and the pollination problems for agriculture and habitat conservation that would result from their loss. My concern here is with these wild bees, and particularly with bumblebees, which are often more effective and more numerous than other wild pollinators. I ask five questions. Which insects contribute to pollination in different EC countries? What resources do wild pollinators need? Are these pollinators threatened? What will happen if we lose them? And what can be done to help to save the pollination systems that depend on them ?

WHICH INSECTS CONTRIBUTE TO POLLINATION ?

Usually, flowers of a crop or a stand of wild vegetation are visited by insects of many different types, including honeybees, several species of wild bees, and flies and other insects. Among pollinating insects, bees are important because of their hairy bodies and because each bee visits many flowers, to collect nectar and pollen for the next generation as well as for herself. Among bees, social bees (honeybees and bumblebees) are particularly effective because very large numbers of workers may operate from each colony, and the colony lasts throughout the season. Because the colony's needs are so great, and because the foraging season lasts for several months, each type of social bee must visit many different types of flower. Therefore most social bees are generalists. In Europe we have one species of honeybee and scores of species of bumblebee. We also have hundreds of species of solitary bees (Day, 1991). Solitary bees are rarely as numerous as social bees, and many species are specialists, with a short flying season and a restricted diet of only one or a few types of flower. A specialist like this may be essential for the survival of particular wild plant species, and it may be a precise and effective tool for the pollination of one type of crop. Specialist solitary bees are already used to pollinate lucerne and are being developed for blueberries. These specialists play an important parat in the survival of wild plants and some crops, but in a landscape with a variety of different crops and wild flowers, some of the social bumblebee species are more generally useful as pollinators (Corbet, 1987; Corbet, 1991). Among bumblebees, long-tongued species are particularly important on many crops because honeybees, with their shorter tongues, cannot substitute for them.

Even bumblebees and honeybees are not perfect generalists. Each species has its own preferred range of flower types, and these preferences must be taken into account when selecting a pollinator for a particular crop, and when managing a habitat to provide the seasonal succession of flowers required to support the pollinator colony when that crop is not in flower.

The floral diet of a species of insect depends in part on the length of its tongue. A short- tongued insect cannot reach the nectar in a deep flower. In general, flies and some solitary bee species have short tongues and visit flat, open flowers such as carrot or onion; honeybees and some bumblebees and solitary bees have medium-length tongues and visit flowers of moderate depth such as oilseed rape or white clover; and some bumblebees and a few solitary bees have very long tongues and can visit very deep flowers such as faba beans or red clover (Fussell, Osborne and Corbet, 1991). The species-specific flower preferences of the common British bumblebee species have been investigated using information from a national public survey (Fussell and Corbet, 1991; Fussell and Corbet, in press, a).

Generally, a bee will not make repeated visits to a flower unless it gains a good profit, so the most reliable pollinators are species that can easily reach the nectar or pollen. On some crops with short or medium-length flowers, honeybees can reach the nectar. But on other crops they cannot. Faba bean and red clover have very deep flowers accessible only to long-tongued bumblebees. Tomatoes and blueberries require vibration by bumblebees or solitary bees to release the pollen. Lucerne requires specific flower-handling behaviour by leafcutter bees to trip the flowers. Thus flower structure can limit the choice of pollinators for a particular crop.

So can the weather (Corbet, 1990). To fly from flower to flower, a bee needs to be warm enough. Small bees need warm, sunny weather to fly, but some large bees can fly in very cold weather because they warm up, and keep warm, by muscular activity (Stone and Willmer, 1989). Therefore bumblebees, which are large and well insulated, are active early in the morning, and honeybees, which are smaller, become active as the day warms up, to be replaced by bumblebees again in the cool of the evening. Such temperature-dependent patterns of activity through the day are well illustrated by Herrera's (1990) field studies in Spain.

Temperature dependence also influences patterns of distribution with altitude and latitude. Bumblebees often work for long hours in bad weather when honeybees cannot fly. In northern Europe the weather is often too cold and overcast for honeybees to forage, and large bumblebees are correspondingly important as pollinators. Further south, the weather is more often warm and sunny, and honeybees become relatively more important. In the far south, even the smallest solitary bees often find suitable foraging weather. Thus red clover pollination depends largely on bumblebees in Northern Europe, but the contribution of honeybees increases towards the south (Akerberg and Stapel, 1964; Holm, 1966).

Temperature dependence also influences habitat distribution. Bees in sunny, open habitats are often active at times when bees in the shade are too cold to fly. It is therefore necessary to consider climate, as well as flower structure, when selecting a pollinator for a particular crop. A crop pollinated effectively by honeybees in Spain may need bumblebees in Denmark or Britain. Similarly, a crop suffering inadequate pollination due to loss of wild pollinators might be rescued by introducing colonies of honeybees in a warm year but not in a year when the weather is cold and wet at flowering time. If bumblebees are present they may provide a steady background pollination service in all weathers, but if they are absent crop yield may show severe weather-related fluctuations.

The pollinating role of any one species depends on its interactions with other members of the assemblage of insect species visiting the same flowers. These interactions make it difficult to evaluate the relative contributions of all the different potential pollen vector species that are present. Because of local variation in factors such as weather, or the composition of the pollinator assemblage, even perhaps between the edge and the centre of a single field, a separate analysis is required not only for each type of crop, but also for each local situation.

Sophisticated evaluation has been attempted in individual cases (e.g. Stanton et al., 1991), but perhaps a simpler approach is needed for general application. From all-day observations it is possible to compile a short list of potential major pollinators, comprising only those species that make numerous visits to the flowers and contact the anthers and stigma. To evaluate the potential role for each as sole pollinator requires experiments in which individual flowers are bagged to exclude insects, then unbagged briefly to allow a known number of visits by the putative pollinator species, rebagged, and later scored for fruit set (e.g. Donovan and Read, 1991). Such experiments are labour-intensive, and their interpretation is complicated by patterns of resource allocation and abortion within individual plants (Stephenson, 1981). Further, they deal only with the unusual situation of a single pollinator species working the crop alone, and they give no information about interactions among species of insect visitor. Recent studies indicate that these interactions may be very important. Honeybees often increase pollen transfer when added to a crop on which there are no other pollinators, but in the more usual situation of a mixed pollinator assemblage they sometimes reduce the pollinating effectiveness of other pollinators without themselves transferring enough pollen to compensate for this reduction (Wilson and Thomson, 1991; Stanton et al., 1991). This recent discovery is important and deserves further investigation, because in practice, managing the pollination system of an inadequately-pollinated crop usually means adding pollinators to an existing assemblage; and the added pollinators are usually honeybees, because at present honeybees are the only managed pollinators readily available to most growers.

As a basis for practical management, it is appropriate to ask to what extent yield could be increased by increasing pollen transfer, and to what extent yield could be increased by introducing extra honeybees.

TO WHAT EXTENT CAN YIELD BE INCREASED BY INCREASING POLLEN TRANSFER ?

This question can be answered by relatively simple experiments, in which the yield of open- pollinated flowers is compared with that of flowers in which pollen transfer is maximised by hand-cross-pollination (Free and Williams, 1976; Corbet, Williams and Osborne, 1991b). Much more information is obtained if the experiment also includes two further treatments: flowers bagged to exclude cross pollen, to show whether insect vectors are increasing yield at all; and flowers bagged and hand-pollinated, to separate the effect of bagging from the effect of insect exclusion. By repeating these experiments in different regions of a crop it is possible to detect pollinator limitation in, say, the centres of large fields inaccessible to boundary-dwelling pollinators (Free and Williams, 1976). By repeating them at intervals through the flowering season it may be possible to identify seasonal patterns in the quality of pollination. By repeating them in regions at different distances from beehives, it may be possible to see whether honeybee introduction increases or decreases yield.

To reveal patterns throughout Europe, region by region and crop by crop, would require a coordinated network of experimental studies. This might seem impossibly ambitious. But the simple approach advocated here has two interesting features. First, the experiments are conceptually straightforward and require no expensive equipment; they could be done by any intelligent and motivated person. Second, they would give results immediately useful in the locality where they are performed.

Perhaps a package could be produced for each crop type, containing simple equipment which needs to be uniform throughout the programme, such as insect-exclusion bags, with data forms and explicit instructions that would enable a local agricultural institute, or even an intelligent farmer or student, to perform standard and comparable experiments in his own locality. The results could be interpreted and used locally, but if they were also submitted to a central collating agency, maps could be compiled showing regional variation in the quality of pollination, with or without supplementary honeybees, for selected crops.

Some insect-pollinated crops yield well without pollinator management. When natural pollination is adequate the pollinators are rarely investigated, so in many cases we do not know whether or not the reliable yield of these crops depends on the background pollination service provided by wild bees. Experiments of this kind would show whether a further decline in wild bee populations would result in pollination problems for those crops. This knowledge might enable individual farmers to appreciate the value of wild bees before their numbers decline much further, providing a spur for conservation.

WHAT RESOURCES DO WILD POLLINATORS NEED ?

Wild bees need areas of seminatural vegetation for nesting places and as sources of pollen and nectar. For nesting, continuity of the soil surface and established vegetation is important, because many wild bees habitually nest in sites used in the previous year by other animals. Bumblebees often establish colonies in the disused nests of small mammals, or close to sites where the same species of bumblebee nested the previous year (Fussell and Corbet, in prep.). Solitary bees often nest in the soil where other bees of the same species have nested before. These traditional nesting aggregations may persist for decades or centuries if they are not destroyed by ploughing. New ones are rarely established. Disturbance should therefore be avoided. The bumblebees that pollinate deep-flowered crops and operate in bad weather are the large, long-tongued species, and to supplement the transient resources provided by crops they need wild flowers with deep corollas and large supplies of energy-rich nectar to fuel their flight and central heating. A recent survey in the UK has shown that the wild flowers visited by bumblebees and honeybees are nearly all perennials; most annuals do not yield enough nectar to repay a visit by a large or medium-sized bee (Fussell and Corbet, in press, a,b; N. Saville, personal communication). For both feeding and nesting, therefore, wild bees need undisturbed areas of established perennial vegetation. Large areas of seminatural vegetation, such as nature reserves, form essential reservoirs for wild bee populations, which must have been diminished by the alarming losses of seminatural habitats of this kind in the European Community (Corbet, Williams and Osborne, 1991b). Nature reserves will be even more important as reservoirs if the impact of honeybee competition on wild bee communities is shown to be deleterious. In Australia, domestic honeybees are banned from national parks. Perhaps we should consider providing honeybee-free refuges in Europe, too. Research is needed on the impact of established hives, or migratory honeybee colonies brought in for pollination or honey production, on local wild bee communities and the pollination of wild plants.

Even if major nature reserves support a reservoir of wild bee populations to buffer short-term fluctuations in the managed landscape, they cannot provide the day-to-day supply of wild pollinators for crops, because they are often remote from arable areas. If bees are to pollinate crops, their nests must be within flying distance of the crop. In the agricultural landscape, uncultivated areas such as field boundaries and waysides can be valuable sites for feeding and nesting of wild pollinators, if they are properly managed.

In the first year after ploughing or herbicide application, nest sites will be few and most flowers will be annuals which are of little use to bees. The vegetation may need frequent cutting to control annual arable weeds unwelcome to the farmer. Any perennials present will not yet be in flower. If the area is left unploughed in subsequent years, management costs fall as annual weeds are replaced by perennial vegetation, and as vegetation succession proceeds this habitat will offer increasingly valuable forage and nesting sites for wild bees. Wide field boundaries that are unploughed, and cut only infrequently to prevent scrub invasion, can harbour a diverse multifloral seasonal succession of perennial wild flowers that will help to support wild pollinators, so long as the floristic diversity is not reduced by fertilisation or overgrazing (Fussell and Corbet, in press, b).

Such management of seminatural vegetation is a cost-effective way to encourage wild bees on the farm, but where existing habitats are unsuitable, for example because they are dominated by plants unsuitable for bee forage such as stinging nettle *Urtica dioica*, it may be necessary to establish new habitats. This can be done by sowing carefully selected species of wild flowers, and managing for annual weed control until the perennial sward is established (MacDonald and Smith, 1991). A quicker alternative would be to plant areas of nectar-rich flowers selected for their value as bee forage. Annuals are desirable, because they flower in the first year, but only a few species of annual have enough nectar to provide useful forage for long-tongued bees. These unusually nectar- rich annuals include borage and *Phacelia tanacetifolia.* Promising perennials include red clover, which is particularly valuable to long-tongued bees.

Further research is needed to refine our understanding of pollinator requirements and to produce habitat management recommendations appropriate for each region, but some guidelines are needed now. It is probably safe to regard continuity of vegetation as an essential element in a landscape managed for bees. In practice, management must provide habitats suitable not only for bees, but also for other organisms important to farmers and conservationists, including the natural enemies of crop pests (such as hoverflies and carabid beetles, game, and butterflies (Firbank *et al.*, 1991). Ideally, management of uncultivated areas on farmland should integrate the requirements of these different groups.

ARE WILD POLLINATORS THREATENED ?

Although honeybees are very important to apiculture and agriculture, their numbers and distribution are not adequately monitored and recorded in Europe. The status of wild pollinators is even less well known.

In Britain, the distribution of bumblebee species has been recorded by amateur entomologists for many years. It has therefore been possible to map the distribution of each species for two time periods : before 1960, and after 1960. By comparing the two sets of maps, Paul Williams (1986) showed that several species of bumblebee had disappeared since 1960 from certain regions of the UK; the intensively arable regions of east central England supported 14 species before 1960, but only 7 after 1960. In Belgium and France, Rasmont (1988) has documented comparable recent losses of valuable long-tongued bumblebee species, particularly those inhabiting open areas and associated with clover and other forage legumes. The environmental changes responsible for their decline have probably also reduced the numbers of other species of wild bees which have not been monitored.

From these studies of bumblebees, and fragmentary information on a few species of solitary bees (Day, 1991; Falk, 1991), we infer a serious decline in wild bee populations. There is an urgent need to monitor changes in the distribution and abundance of wild bee species and of the vegetation on which they depend. If it is impracticable to do this for all important species, research could focus on selected 'indicator species' (Day, 1991).

WHAT WILL HAPPEN IF WE LOSE THESE POLLINATORS ?

There are some crops which are known to need cross pollination, but on which adequate pollination is usually achieved without intervention by the grower. If wild bee populations decline further, the yield of these crops may become unreliable. In some cases, introduction of honeybee colonies will restore yield, at least in warm seasons, at a cost to the grower. In other cases, introduced honeybees may compete with the remaining wild bees by depleting nectar and pollen without themselves achieving as much effective pollination as the wild bees would have done (Wilson and Thomson, 1991; Westerkamp, 1991). If honeybees cannot be used, either because demand for honeybee pollination units outstrips supply or because they do not restore yield in a cost-effective way, farmers may stop growing those crops. Instead they will grow crops such as cereals or beet that do not require insect pollination and do not provide resources for pollinating insects.

This leads to a vicious spiral. Insect-pollinated crops produce pollen and nectar. Although this bounty is transient, and crops alone cannot support a colony through the season, a succession of appropriate insect-pollinated crops may supplement the dwindling resources provided by seminatural vegetation, and so contribute to the survival of colonies of social bees in an agricultural landscape. If those nectar-rich insect-pollinated crops are abandoned as uneconomic, populations of wild pollinators may decline ever more rapidly, exacerbating pollination problems and pushing growers further towards crops such as cereals or beet which do not require insect pollination. Reduction in wild bee populations will affect the wild plants that depend on them for pollination, and the loss of this natural forage will further exacerbate the decline of wild bees. Once the wild pollinators have gone it will be too late to restore those pollinators and the wild vegetation that helps to sustain them.

Many seminatural vegetation types, of conservation value, are at risk because they are dominated by bee-pollinated plants, including Atlantic and Mediterranean heathland, garigue, and ancient meadows. Without bees, insect-pollinated crops such as beans and forage legumes, oilseed crops and fruits would become impossible to grow without managed pollination, which may be prohibitively expensive.

WHAT ACTION CAN WE TAKE TO RESCUE THE POLLINATION SYSTEMS ?

Research is needed to discover which pollinators are important, and which are available, for each crop in each region, and to formulate recommendations for habitat management to enhance wild bee populations (Corbet, 1991; Torchio, 1990).

The difficult tasks of evaluating the contribution of different wild pollinator species to the pollination of particular crops, and the possible deleterious competitive effects of honeybees, have been considered above (and see Corbet, Williams and Osborne, 1991b; Westerkamp, 1991; Wilson and Thomson, 1991). I have advocated a carefully planned network of experimental studies, coordinated through the EC, to reveal changes from year to year and from country to country, showing which crops require pollinator management to maximise yield, the extent to which introduced honeybee colonies can be used to supplement pollination, and which wild pollinators merit management or conservation. Such a programme could provide the information needed by policy makers.

The distribution of wild bees and the vegetation types on which they depend should be monitored to draw attention to any decline related to land use or climatic change. Again, a coordinated programme throughout the EC would be appropriate. In some countries, a ban on the collecting of wild bees may make it difficult to acquire the distribution records that are needed.

For long-tongued bees, we believe that the quality of vegetation as bee habitat depends in part on its successional age since disturbance. In a managed landscape, much of the land surface is disturbed, often by heavy machinery or by herbicides, each year. Perhaps an estimate of the 'mean number of years since disturbance' in each local area would provide an index related to the quality of habitat for bees; changes in this index could be monitored.

For bee forage and nesting, it is important not to reduce the successional age of seminatural vegetation too much. This successional age is reduced by reworking of the landscape with disturbance of the vegetation and soil, such as results from frequent changes of agricultural policy. The earth's skin, the soil profile and its living coat of established vegetation, can be destroyed in five minutes by heavy machinery but may take five, ten or a hundred years to recover the ability to support wild pollinators and other wildlife. It is desirable to achieve a policy for managment of the agricultural landscape that would discourage destruction of even apparently trivial habitats such as field corners, perhaps with a penalty related to the opportunity cost of pollinator loss and of keeping the land uncultivated and suitably managed for as many years as are required to restore good habitat.

The need for research should not be be allowed to delay remedial measures to prevent irreversible decline of valuable species. We already know that long-tongued bumblebees are the sole effective pollinators for some crops, and we can identify aspects of habitat management that will help to preserve and enhance these and other wild bees, as well as honeybees. Uncultivated areas are important also for other organisms valued by farmers and conservationists, and their management should be coordinated to accommodate these different objectives. An experimental programme in Germany has shown that even for a wind-pollinated crop sensitive management of this kind need not reduce the farmer's profit, and may even increase it (El Titi, 1991).

A prime aim of conservation is to ensure that the environment offers future generations as many options as it offers today. If future generations are to retain the option of growing insect- pollinated crops, the landscape must be managed in a manner compatible with the persistence of wild bee populations.

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MANAGEMENT OF AGRICULTURAL SPACE AND DEVELOPMENT OF THE BEEKEEPING SECTOR

Livia PERSANO ODDO
Marco ACCORTI
Istituto Sperimentale per la Zoologia Agraria,
Sezione di Apicoltura
Via L. Rech 36
00156 Roma
Italy

ABSTRACT

Historical and civilisation changes have influenced the role of the honeybee. In places where and when honey is still an important nutrient, it is considered as a primary income product. However, when countries develop further, honey is regarded rather as an indirect income product, through pollination. In industrialised nations, where activities of mankind have destroyed biological patterns, the role of the bee is twofold : on one hand, as a pollinating insect, it is considered as a direct producer, just like other production methods ; on the other hand, it is an indirect producer where environmental protection is concerned. Furthermore, with regard to environmental quality research, the bee has proven its usefulness as a biological indicator (the presence of the honeybee enables to measure the minimum conditions for the survival of biological forms). It can sometimes also be considered as a cultural indicator. : the factor which enhances the honeybee's role is the dramatic decline of wild pollinating species, due to the changing eco-systems. As a result, the need for bees increases, as further assessments are required for defining agro-forestry crops. which are compatible with environmental protection This should be taken into consideration when planning a development policy in each country. With a view to introducing an appropriate land management and development policy which would generate a thriving beekeeping industry, a survey has been launched in Italy to assess the cost of converting parts of agricultural land into pasture areas, rich in melliferous flora.

The degradation of the environment and the over-exploitation of natural resources and sources of energy constitute a reality that must be dealt with at both the technical and political levels.

Management of the agricultural sector today is subject to political decisions where priority is given to the industrial and tertiary sectors, which means that the most elementary principals of respect for the ecosystem and the effective food requirements of human beings are neglected.

In the absence of an appropriate agricultural and environmental policy, producers have to rely on technical information and support that is virtually controlled by the manufacturers of fertilizers and chemicals, with no support whatsoever with regard to their choice of what to produce.

The beekeeping sector is also affected by this situation. Indeed, beekeepers receive no help in coping with their numerous problems and they only have the outlet of selling the honey. In most cases beekeepers are simply unaware of the enormous benefits deriving from bees and of which all of us (more or less unwittingly) take advantage. The role of bees, and their economic importance, take on a completely different connotation depending on the historic and social context considered.

Bees are initially producers of direct income, in that they supply honey, but as the level of development increases they gradually become indirect producers, through pollination. Their role is essential and unreplaceable in industrialized societies, where drastic environmental change has led to the scarcity or sometimes even the disappearance of wild pollinators. Since honey bees are practically the only pollinators available, they have become a decisive factor in agricultural production and therefore play an important role in the direct production of are to some extent dependent on entomophilous pollination, with an increase in production that leads to a direct income from agriculture that can be estimated at around 2,000 billion lire (ACCORTI and CERRETELLI, 1991). To this we must add the indirect income, represented by the bees' role in the conservation of the environment: in Italy, bees are among the potential pollinators of 85 per cent of the spontaneous species, which provide shelter and food for wildlife. The same can be said of 60 per cent of endangered botanical species.

It has recently emerged that bees can also function as biological indicators in environmental monitoring studies, and the actual presence of bees in a given environment indicates that the area has the minimum conditions of survival also for other biological forms.

We can say that the socio-economic importance of bees increases with the transformation of the environment by the action of humans, and in particular with the "simplification" of the ecosystem (shorter biological chains and reduction of genetic diversity).

energy required for working the land and for processing the sugar must also be taken into account.

In terms of energy expenditure, there is a deficit of 4,133 Kcal per kg of sugar produced, equivalent to a barrel of petroleum for every 353 kg of sugar (Table 1).

	BEET SUGAR	HONEY
A) FOSSIL ENERGY INPUTS (for production, processing and packaging) Kcal/Kg	7,987	2,703
B) ENERGY OUTPUT	3,854	3,040
OUTPUT/INPUT RETURN DIFFERENCE (B - A)	- 4,133	+ 337
OUTPUT/INPUT RETURN RATIO (B / A)	0.48	1.12

Table 1. Energy balance

The environmental cost for the production of honey is nil: the plants, whether spontaneous or cultivated, use solar energy and in any case produce nectar and pollen. Both bees and plants are renewable energy resources. The only energy expenditure involved is that related to processing and packaging, which can be calculated at around 2,700 Kcal (SOUTHWICK 1980; SOUTHWICK and PIMENTEL 1981).

The final balance is clearly in favour of honey (with double the output of sugar), but if we extend the comparison to the entire economic, environmental and nutritional context, the differences are even greater (Tables 2, 3 and 4).

The transformation of natural ecosystems into agro-forestry systems, together with the processes of industrialization and urbanization, are all changes that involve an expenditure of energy, with a balance that is increasingly deficient as the use of non-renewable sources of energy increases. Indeed, we consume more energy than we produce, and the need to identify new criteria on which to base the exploitation of the environment is now recognized worldwide as irrevocable, as is the ethical obligation to develop renewable and ecologically compatible sources of energy.

Bees and beekeeping offer us the opportunity to suggest a policy for the management of agricultural space which can contribute to reversing this trend.

What we hypothesize is the development of beekeeping by reconverting certain agricultural lands into pastures rich in melliferous species, and to boost the consumption of honey through appropriate advertising.

Today, various proposals have been made to stop production on a consistent amount of agricultural lands in order to reduce surpluses. In Italy, in particular, one of the crops called into question is sugar beet, for which the Interministerial Committee for Economic Planning (CIPE) has recently proposed to reduce areas under this crop by one third, i.e. by approximately 100,000 hectares.

Some sugar beet data have been analyzed and are set forth in the following paragraphs.

In economic terms, the cultivation of sugar beet is profitable only if yields exceed 50 tonnes/hectare (BREGOLI et al 1990). From the data available on Italian production, it clearly emerges that about one third of the area under sugar beet is unprofitable, and is only kept up because of the EEC price support policy (which has little in common with proper agricultural practices and the efficient management of environmental resources).

For each tonne of roots produced, an average of 4-5 kg of nitrogen, 1.5-1.8 kg of sulphur dioxide, and 5.5-6.5 kg of potassium oxide are removed from the soil (VENTURI, 1989), which must be compensated by resorting to the use of fertilizers, the synthesis of which requires the consumption of non-renewable fossil energy (petroleum), as do the pesticides and herbicides required for protecting the crop. The

	BEET SUGAR	HONEY
YIELD	5 t/ha	1 t/ha
LABOUR	MECHNANIZED	BEE
PROCESSING	INDUSTRY	BEEKEEPER
REQUIREMENTS		
Energy	HIGH	LOW
Economic	HIGH	LOW
Chemical	HIGH (fertilizers, pesticides, herbicides	LOW (chemotherapeutic

Table 2. Economic balance

	BEET SUGAR	HONEY
ECOSYSTEM	SIMPLIFIED (agricoltural)	COMPLEC (agricultural, forestry, natural)
LAND USE	HIGH (intensive monoculture)	USE OF SURPLUS, convertion of already used and marginal lands
ENVIRONMENTAL STABILITY	LOW	HIGH

Table 3. Environmental balance

	BEET SUGAR	HONEY
CALORIE CONTENT (kcal/kg)	3,850	3,040
ASSIMILATION	SLOW	IMMEDIATE
COMPOSITION	SACCHAROSE	FRUCTOSE + GLUCOSE (+ approx.300 other substances)
SENSE PERCEPTION	LIMITED (sweet,white, granular)	COMPLEX (olfactory, gustatory, visual and tactile differences)
ORGANOLEPTIC SATISFACTION	LOW	HIGH
CONSUMPTION	HIGH	LOW

Table 4. Nutritional balance

In Italy the direct consumption of sugar (1988 data) is approximately 17 kg per year per person, in addition to around 7 kg of indirect consumption contained in industrial products. It is therefore obvious that there is a high demand for sugar, which in part could be satisfied by developing the beekeeping sector.

Yet honey consumption in Italy is barely 300 g per year per person, and the domestic production does not even cover this demand, which is decidedly lower than in other European countries.

One of the causes of this low production lies, at least in part, in the type of production, predominantly as a secondary activity, and in any case the uncertainty of a market which is marginal, with no political or industrial support (unlike sugar), provides no incentive for investments in the beekeeping sector.

However, one of the major problems is the difficulty in finding suitable environmental conditions characterized by abundant pastures, with flowering staggered throughout the year and not subject to chemical treatments.

Present agricultural practices, in addition to giving preference to monoculture, lead to a drastic reduction of the spontaneous flora, making vast areas totally inhospitable to insects. Even in the forest areas, reforestation gives priority to conifers without developing species of interest to bees.

Given this situation, it would appear to be reasonable for Italy to convert the 100,000 hectares that CIPE intends to take out of sugar beet production, and to use them to plant melliferous species appreciated by bees. At least another 100,000 hectares available for this purpose could be the result of the set aside policy imposed by the EEC to contain agricultural surpluses.

It would be possible to guarantee flowering over the entire duration of the bee season by cultivating melliferous species with staggered flowering (RICCIARDELLI, 1987, PERSANO 1991), in order to obtain results from settled beekeeping comparable to those of migratory beekeeping with high honey yields and an obvious saving in manpower and investments. This would contribute to the partial solution of one of the intrinsic and apparently insuperable limitations of the beekeeping sector: the absence of an economic subject, having the advantage and the right to improve nectariferous pastures (the owners of the land are unmotivated and the owners of the bees cannot make investments on other people's land) (SILLANI, 1988).

Under these conditions we could hypothesize an increase in the number of hives and in production such as to support a demand of 4 kg of honey per year per person (ACCORTI, 1991). This demand should be favoured and encouraged through the implementation of appropriate promotion campaigns.

We realize that it is not easy to make a project of this type materialize, and in any case we are not proposing this as the only possible line of action, but basically as a different, and environment-friendly viewpoint. First of all it is necessary to verify whether the premises are acceptable, and in any case it is obvious that the management of discontinuous land areas which are not publicly owned poses enormous technical and -- above all -- political problems. Then there is the question of whether the beekeepers are capable of bearing the burden of such an enterprise. On the other hand the economic incidence of pollination by bees is so important that it makes us wonder how much longer beekeeping can remain a "private concern".

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AGRICULTURAL PRACTICE : INTERFERING WITH THE POLLINATION PROCESS POLLINATION SERVICE : RESTORING THE POLLINATION PROCESS

J.P. VAN PRAAGH
Director: J.H. Dustmann,
Nds. Landesinstitut für Bienenkunde,
Celle
Germany

ABSTRACT

The grower of an entomophylous crop should learn to understand pollination as a manageme The research in the field of pollination has to produce the data needed for the management decisions. Accepting the fact, that a shortage ofpollinators "at rent" is probable, we should work on optimising of the handling of pollinators and on their protection. This holds for the agricultural world as well as for theconservation of nature. The existing possibilities to screen agrochemicals for their impacts on honeybees should be improved. As flowering agricultural crop is not only visited by pollen gathering honeybees, but also by other pollinators, screeningmethods using those pollinators are needed. If the broodrearing acticity of honeybees can be used as an indicator for the impacts on broodrearing of other pollengathering species remains to be cleared.

INTRODUCTION

Research on the plant-pollinator relationship has a long tradition at the Celle institute.

That honeybees are well adapted for the pollination of entomophilous crop is the "merit" of nature. Haragsim (1974) calls "nature" in this context the coevolution of plant and pollinator. The landuse and the beekeeping practices in a broad sense have their impacts on this coevolution.

In the same way as insects and plants come together for the benefit of both parties, the knowledge of the apidologist and plantphysiologist must come together for the benefit of both parties. We at the Celle institute try to work on both sides of that suture. The crop grower and the seed producing company play some kind of "third party role". It is the "merit" of this third party that working in the field of pollination under present agricultural conditions makes one merely feel more like a troubleshooter then like a biologist.

e. G. The plantbreeder using handpollination to cross entomophilous plant species can destroy the "natural flower signals" of that species. By doing so he can obtain agood cropping plant, but too expensive to cultivate, while handpollination of some hectares/acres is too laborious.

e.G. Modern agriculture protects the adult bees by avoiding to employ pesticides harmful to bees in flowering crop. Thanks to modern developments the market offers diverse precisely targeted formulations to be used in bloom. But are those substances always acceptable for the pollinator, that is collecting food, as well as for its progeny for which the food is collected ? Has the bee biologist the methods to make sure that the pre-registration testing is adequate ?

e.G. How can we evaluate if a pollination system (pollinating species, its density, the crosspollen, etc.) is optimal or sufficient, for the cropgrower as well as for the preservation of nature.

For the moment I would like to comment on a few examples (facets) of the complex diamond consisting of - plant, pollinator, grower, biologist -.

I. POLLINATION OF BLACKBERRIES

The classical approach

In the Hannover area a few commercial American blackberry varieties (*Rubus laciniatus*) have been tested for suitability. We had the opportunity to work on the pollinator question in that programm, using flightcages to control honeybee-activities. Each flight cage contained four plants of the variety *Thornless Evergreen*. We observed twenty branches in each plot for three years. The blackberry variety "*Thornless Evergreen*" is self-fertile. Nevertheless the introduction of honeybees for (auto)pollination results in a more profitable growing system. The fruit develops earlier in the year and consequently, the crop is earlier marketable.

The figure 1 compares cropping behaviour of the branches in flight cages. It shows fruit on plants visited by bees ripen earlier in the year. Days indicated are days of the year, 230 being august 18th. Times of harvest, at wich the differences were significant are marked on the curve representing the bee pollinated plants, on the other curve all times of harvest are marked.

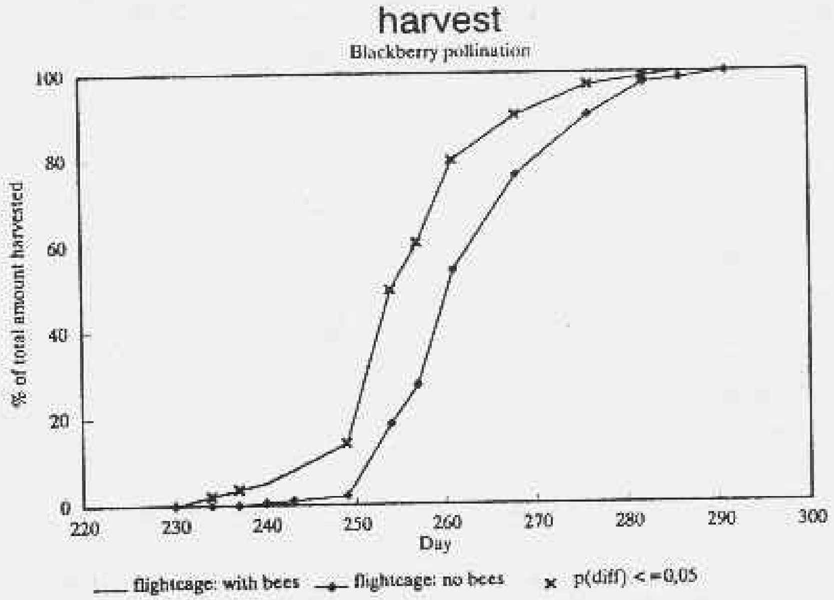

Figure 1.

The number of flowers to set fruit is independent of the presence of a pollinator, but about 10% more fruit by weight is to be expected if honeybee colonies are involved. Nevertheless, the variety has disappeared from the market, due to lacking of frostresistance. The area may have nightfrosts late in spring, as well as early in autumn, so also the harvest was in danger year after year.

II. THE FRUITGROWER, A THIRD PARTY

A. Agrochemicals

Modern fruit grower use smaller trees, and must use fungicides even during the blooming period. How these changes in the landuse have influenced the pollination activity of the honeybees has hardly been studied. In a very simple way we have tested the influence of the standard formulation impregnated in filterpaper. The amount impregnated was double the amount to be expected on the surface after the application of the agrochemical. As the table shows, nearly all the commercial formulations tested repell honeybees. We tested the bees in the open air, when no honeyflow was going on. So the bees accepted our feeding-dishes without any scent in the trainingphase easily.

ACTIVE INGREDIENT	HONEYBEES ATTRACTED %	+/- S
Control	*49,7*	*9,4*
Vinchlozolin	37,2	10,1
Thiophanate-methyl	36,6	12,7
Endosulfan	36,6	16,5
Sulfur	35,2	13,5
Cyhexatin	33,4	11,9
Fenarimol	26,6	12,9
Nitrothal-isopropoly+S	26,5	5,4
Captan+mancozeb	24,4	10,6
Dicofol	22,6	7,6
Captan	14,1	7,4

Table 1. This table 1 lists a number of pesticides used in an orchard during bloom. The substances are tabulated in a decreasing order of attractivity. None of the substances is more attractiv then the non-odourous control, offered in the test-situation at the same time.

Table 2 shows, that, if necessary, compounds can be found to disguise the bad odour for the honeybee. Hildanus, used to cover/mask the repellent odour of captan, appears in the fresh preparation to be able to attract more bees as the nonsenting control. This makes clear, that in our testsystem the behaviour of the bees as reported in table 1 can only be explained as the result of a repellency. The work described here is, to our knowledge, not done with other pollinators. Although the agrochemical market is changing rapidly and the fruitgrowers asked to continue to publish the actual data on new formulations, we had to refuse doing so.

ACTIVE INGREDIENT		**HONEYBEES ATTRACTED**	**+/- s**
Control	*No odour*	*32,6*	*5*
Control	*No odour*	*34,1*	*2,5*
Control	*No odour*	*31,6*	*6,9*
Captan	Fresh/dry	24,4	4,2
Captan + Hildanus	Fresh/dry	45,3	8
Control	*Fresh/dry*	*30,5*	*6*
Captan	3 days old	33,3	5
Captan + Hildanus	3 days old	35,1	2,5
Control	*3 days old*	*31,6*	*6,9*

Table 2.

B. Treephysiology and the effects on pollination

The Corbet, Williams & Osborne (1991) schedules to analyse the plant-pollinator-pollen situation in the field are based on the presumption that handpollination provides the utmost quality of pollination. Optimal insectpollination should reach the same level. This approach seems to make sense. As the revenues from agriculture for the growers decrease, the growth-conditions must be improved. In modern apple plantings the shoots of young trees are bent to increase the flowering. The grower expects that the more labour invested in bending, the better the cropping results of those young trees will be.

The fruitgrower who pays for the pollinationservice offered by the beekeeper has an interest to know what pollinator density is needed for an optimal cropping of each plantation. So we looked for a method to be used as a means to get differentgrades of pollination intensity in the same area. In order to help the grower to make up his mind about which means to reach the most profitable growing system, including pollination as one important means, we used three grades of pollination intensity.

Grade I : As we know about the effects of captan on bee behaviour and pollengermination, we use captan every second day as a repellent to suppress fruitbearing in a plot.

Grade II : We introduce a surplus of honeybees in the field when 10% of the flowers are open. The theoretical density being app. 10 beecolonies / ha.

Grade III : Crosspollination by hand is done to reach "maximum pollination".

This system works, as we showed at the Tilburg meeting (van Praagh, Hauschild 1990). The average fruitset-relationship Grade I : Grade II : Grade III obtained was approximately 1,5 : 2,5 : 3,6.
At the end of the four year period, we did not grade the pollination intensity, but let the bees (2 colonies /ha) do their job.

The pollinationgrading was done in a growth experiment, where shoot-bending and pruning were to be compared. We used a row of 144 young Cox orange pepin trees; 12 per treatment and 2 replicates. Due to the differences in crop per flower in the blocks, the flowering in the next year was different. We were surprised to see, that under the normal pollinator-plant-crosspollen situation in the total area the flowers of pruned trees once again had a significantly better chance to become a fruit, then a flower on a bent tree.

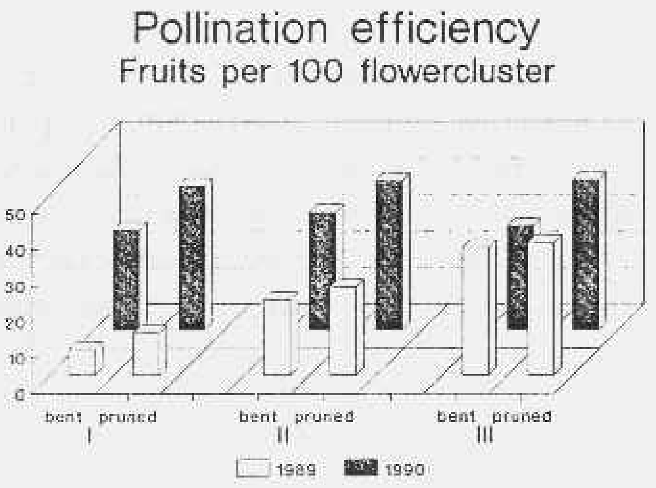

Figure 2. Number of fruits per 100 buds 1989 3 grades of pollination

That difference is independ from the number of flowers per tree. The density of flowers mainly depends on the pollinationgrade from the preceding year, as cropping and fruitbud formation are known to be negatively correlated in one vegetation period. This result makes clear that not only the density of pollinators and crosspollen, or climate etc. are to be considered when one looks for an advice concerning the number of colonies to be used, but the cultivation method (not only soil, agrochemicals) has to be taken into account too. The differences in the cropping ability appear to be independent of last years crop. Here the plantphysiologist is asked to give the management the right support.

III. INTEGRATED PEST MANAGEMENT AND THE POLLINATOR AT RISK

The modern insect growth regulators (IGR) are non-toxic to adult insects. There is a growing market for these pesticides, as they can better be targeted towards the damaging species by leaving their predators undamaged.

Prior to registration in Germany a pre-registration test on honeybee toxicity can be applied for. How to run these tests is described. This official German way of testing the risks for the honeybee cannot detect the hazards of IGRÔs, as the experiments have to be done with adult bees. The "Insegar story" (Gerig 1990, de Ruijter & v.d. Steen 1987), demonstrates how difficult it can be to judge the possibilities of adverse effects of substances which are tested. We are trying to develop a screening system, hoping that it may provide the possibility to judge the impact on the brood of a colony.

We have to realise that substances which should influence on non- adult stages can only reach the larvae, if these larvae come into contact with contaminated honey; pollen; or larval food, synthesised by the nurse bees. Our schedule is based on three different tests:

1. **Flightcages**
   Small colonies gather pollen and nectar from contaminated plants in flight cages. We control the development of the broodnest. That gives a first insight of possible damages, probably caused by the substances in question. From these colonies we collect pollen, from the combs as well as from the returning

foragers. An analysis of the amount of substance in the pollen and bee brood is needed for the tests to be run in the laboratory.

2. Liebefeldercages

Small groups (200) of bees are kept in an incubator. They are fed a pollen paste *at libitum* (Pollen, icing sugar, water (6 : 40 : 10) according to Velthuis, 1970). They are kept queenless. The second week we offer each population three queen cups from a starter colony. The larvae being at the L2 stage. The cells are left in the Liebefelder cages till closure. We compare the rearing of control groups with groups that are fed with the pollenpaste contaminated with IGR. We use concentrations of IGR as they are found in 1.

3. Invitro-rearing

Young worker larvae (L1,L2) are reared on a semi-artificial diet according to Czoppelt & Rembold (1981). The diet is contaminated with IGR, in order to find a LD 50%, LC 50% for the substances in the test. It is our experience that the number of young larvae reaching the adult stage strongly depends on the quality of the royal jelly used in the semi-artificial diet. Thus making this way of screening very laborious. It must be realised that in this test we will only find the LD/LC 50 % of the formulation under test for young larvae. As we do not know the precise moment when an IGR might disturb the development of the larvae, we feel it necessary to work with the youngest possible larvae in this test. The use of L3 or L4 gives a more acceptable survival rate in the controls, but cannot be that representative.

As the testing system under development should be "transferable" to other institutions we are looking for "stable" simulating systems. We doubt that the third method alone - growing larvae on a contaminated semi-artificial diet- is the solution to screen IGR's. The knowledge of the LD/LC 50% of a substance, without knowing anything about its fate in the colony, nor anything about its fate from the application on the crop untill the reaching of the hive does not provide adequate information of the risks for bees. As far as the possible contamination of pollen is concerned we have the first indications that the amount of active ingredient introduced into the colony depends on the formulation, and on additives etc. in the commercial product. In order to be able to estimate the risks for honeybees and other pollen-gathering insects because of any substances to be used on flowering plants, we must realise that the contamination also depends on the species of the plant that is sprayed.

The transfer of possible risks from contaminated bee bread through the nursebee to the larvae, as realised under 2 does give the most direct answer towards the question -"how can we judge the impact of an IGR on a colony". So we simulate the effects of substances as they are transferred by means of the nursebee as carrier, so coming close to the natural situation in the colony. But at the same moment we are not that much influenced by any antifagant qualitity of the contaminated pollen or nectar, as it appears to happen inside the colony (Gerig 1990).

Although the IGR can only influence the broodcycle of a colony for a short period, leaving enough time for the colony to survive, other pollinators,- with a short activ phase -are much more at risk. The question has to be answered, if the honeybee can be used as an "indicator" for those other bees/pollinators at risk. Other bees are known to use orchards and other flowering crops as basis for the nourishment of their progeny as well (Klug 1984).

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ACCELERATED FRUIT SETTING OF TOMATOES BY INSECT POLLINATION

D. HOUBAERT & F.J. JACOBS
CBLT - IWON,
Laboratory of Zoophysiology,
University of Gent
Belgium

ABSTRACT

Honeybees and bumblebees can both adequately replace manual vibration of the tomato flowers, but bumblebees seem to accomplish the most complete pollination. With respect to hand pollination, insect pollination can further improve the total tomato production, lessen the occurrence of small tomatoes, and accelerate fruit setting and harvest.

INTRODUCTION

In early heated tomato crop in greenhouses of Northwestern Europe it was, up to recently, a common and necessary practice to vibrate the flower trusses mechanically, in order to improve pollination (PICKEN, 1984). This manual vibration was a time-consuming and expensive labour, putting one man to work per hectare.The idea of using honeybees for the pollination of tomatoes occurred already in 1895, to BAILEY and LODEMAN. They concluded that honeybees were useless for the pollination of tomatoes. Three years later, FINK (1898) disputed this; and several authors after him, who all demonstrated that honeybees can be valuable pollinators of tomato (in McGREGOR, 1976; SPANGLER & MOFFETT, 1977; DE RUIJTER et al., 1987).

The idea of using bumblebees for the pollination of greenhouse tomatoes originated in Belgium, prompted by the success of private bumblebee management. In 1987-88, bumblebees started to be utilized for pollination in tomato greenhouses. Theystraightaway convinced the growers of their pollinating value (demonstrated by VAN RAVERTIJN & VAN DER SANDE, 1991), resulting in a precipitated expansion of bumblebee management in different countries, and in an almost complete conversion of manual vibration to bumblebee pollination in 1991.

In modern pollination studies, more and more attention is given to the concrete pollination value of different cropvisiting, manageable insects. In this contribution, the pollinating value of both honeybees and bumblebees for greenhouse tomato production is thoroughly compared, and the advantages of insect pollination, with respect to manual vibration, are investigated. In addition, the effect of variable bumblebee pollination activity on resulting tomato production is dis cussed.

MATERIAL AND METHODS

All experiments were undertaken at the experimental station "Noorderkempen", in Hoogstraten near Antwerpen, Belgium.

Honeybee pollination

1) In February-March 1988, the pollinating capacity of honeybees was studied on tomatoes in a Hortiplus-covered heated glasshouse compartment of 800 m^2. The tomato plants (cultivar VDB977) were sown on 27 October 1987, and planted on 21 November 1987 on rockwool substrate (Grodan), at 2.5 plants / m^2, for early culture.

   Two honeybee colonies (Apis mellifera L.) from the laboratory apiary in Gent were moved to the tomato greenhouse on 22 February 1988.

   Four plots of 20 plants each, were demarcated in the same part of the compartment, and the production of three subsequent flower trusses (between truss 4 and 8) was examined.

   The flower trusses of two plots were denied honeybee pollination by shielding them within a gauze bag (20 x 20cm; 1g; 0.8mm meshes). The bags were adjusted over the trusses just before the flowers opened, taking care that the bags did not touch any part of the flowers except the stem.

   Two plots were manually vibrated twice a week with a vibration stick, one plot with screened trusses and one with exposed, bee-pollinated trusses. The two remaining plots (also with screened and exposed trusses) were not vibrated.

   When brown spots were observed on the outside of the stamina of some tomato flowers, following high honeybee activity, an amount of such flowers was individually tagged in the greenhouse, and the resulting tomatoes were additionally examined.

Fruit setting of the trusses in the plots was calculated as percentage of set flowers. The tomatoes were harvested twice a week, weighed and sorted by tomato class according to the auction quality classes. Only the most common classes are mentioned in this paper ("Bonk", small "Bonk", "A+70", "A" and "B"). So called "Bonk" tomatoes are broad tomatoes, more or less elongated in the width; "A"and "B" tomatoes are perfectly round tomatoes. Broad and round tomatoes are further subdivided according to their dimensions (e.g. "A+70" > "A" > "B"; "A+70" having a width of 7cm or more). Eventually, the seeds of examined tomatoes were counted.

The activity of the pollinating bees was measured by means of census. An observer walked hereby slowly between two rows of 100 tomato plants, through a path from the middle of the greenhouse to the end of it, returning through the next adjacent path. The circuit was subsequently walked five times, at 10 minutes per circuit. All bees observed on walked-by tomato flowers were tallied. In order to avoid bias by differences in flower amount in separate circuits, the total number of bees per census were recalculated to the relative amount of bees per 100 flowers. All the well-open, bright yellow tomato flowers of the circuit were therefore counted each census-day.

2) In February-March 1989, a duplicate pollination experimen with honeybees and tomatoes was repeated in the same greenhouse as described above, with analogue culture circumstances. The experiment aborted because no one of the introduced honeybee colonies was willing to visit the tomato flowers.

BUMBLEBEE POLLINATION

1) During February-September 1990, the impact of bumblebee pollination on the fruitbearing of tomato flowers was measured in two identical and adjacent glass-covered heated greenhouse compartments of about 1,000m2 each. The tomato plants (cultivar Capello) were sown on 27 October 1989, and planted on 23

November 1989 on rockwool substrate (Grodan), at 2.5 plants / m^2, for long culture.

One of the compartments was supplied with bumblebees, four plots of eight plants were demarcated in the right half of this compartment. The other compartment was not supplied with bumblebees, and the flower trusses were manually vibrated twice a week. Here again four plots were demarcated in the right half of the compartment.

Tomato flowers, second on the flower truss of two subsequent trusses, were individually tagged in the plots, and theirresulting tomatoes examined as described above. Such sample was repeated at the beginning, the middle and the end of thetomato culture. The total tomato production in the plots of both compartments was continuously recorded, from May till October.

The flowering period of the tagged flowers was registered in the plots of both compartments.

The pollinating activity of the bumblebees was measured by means of censi as described above; the amount of flowers was counted each observation day, discriminating between flowers with and without brown spots on their stamina, resulting from bumblebee visits.

2) During February-September 1991 the differences in bumblebee pollination were studied in a glass-covered heated greenhouse compartment of about 1,000m^2. The tomato plants (cultivars Dombito, Capello and Trend) were sown on 25 October 1990, and planted on 19 November 1990 on rockwool substrate (Grodan), at 2.5 plants / m^2, for long culture.

Four neighbouring plots of 45 plants were demarcated in the greenhouse, one for Dombito and Capello, two for Trend. One plot of Trend plants was given additional manual vibration on of the usual bumblebee pollination.

The flowers in each cultivar plot were counted each observation day, discriminating between flowers with none, some and many brown spots on their stamina, resulting from a variable amount of bumblebee visits.

Tomato flowers, second on the flower truss from two subsequent trusses, were again individually tagged and followed as described above, at the beginning and middle of the tomato culture.

RESULTS AND DISCUSSION

Honeybee and bumblebee pollination of tomatoes

Table 1 shows that honeybee as well as bumblebee pollination of tomato flowers can replace manual vibration. Fruit setting was always slightly though not significantly better with insect pollination. The mean fruitweigth was similar with honeybee pollination, and slightly though not significantly higher with bumblebee pollination.

TOMATO TRAITS	POLLINATION TYPE			
	Manual vibration	Honeybees	Manual vibration	Bumblebees
Fruit set (%)	84±9a (31)	87±8a (36)	81±10a (73)*	88±9a (61)*
Fruit weight (g)	204±58a (270)	20564a (269)	149±37a (126)	16247a (124)
Seeds (n)	133±18a (24)	203±15b (19)	149±61a (124)	203±64b (123)
Flowering period (days)			4.2±0.9a (129)	2.6±0.6b (102)
Pollination rate	8 honneybees/100 flowers		11 bumblebees/100 flowers	
Brown flowertips (%)	2 % (at 12 bees/100 flowers)		80 % (at 12 bees/100 flowers)	

Table 1. Flower and tomato characteristics for different pollination types [average ± standard deviation (amount)]. Values followed by a different letter in a same compartment are significantly different (P<.05; LSD test after Anova).

* = at mid-culture

Additional manual vibration of the honeybe-visited flowers further improved the fruitweight up to 223 g, although without accelerating harvest (cumulative harvest : 14.0 %, 27.6 %, 55.6 %, 89.7 %, 100 %; see Table 3). However, DE RUIJTER et al. (1987) did not acquire a higher production withe the combination of manual vibration and honeybee pollination.

Additional manual vibration of bumblebee-visited flowers in the third experiment of 1991, with the cultivar Trend, showed no further improvement of the fruitweight. On the contrary, additional vibration resulted in a significantly lessened fruitweight (157g ± 31, against 178g ± 44).

The amount of seeds (Table 1) was always and significantly higher in insect-pollinated tomatoes, but this did not necessarily result in a higher fruitweight, as shown for honeybees.

The flowering period (Table 1) of bumblebee-pollinated tomato flowers was definitely shorter than of vibrated flowers. This is probably the result of a more rapid fertilization of the flowers.

The pollination rate (Table 1) of the tomato flowers by honeybees and bumblebees was quite similar, but high pollination rates by honeybees were not always observed. In other pollination experiments the rate was much lower (e.g. 1 bee / 100flowers in a summer culture) or even non-existing (in the 1989 experiment). It appears that quite often, honeybee colonies can not be motivated to forage on the poorly rewarding tomato flowers (the flowers probably do not produce nectar at all,and the honeybees only succeed in collecting part of theenclosed pollen).

This very variable pollination rate of honeybees, and the fact that honeybees leave the greenhouse and the tomato flowers from April on, prefering outside flowers (VAN RAVENSTIJN & VAN DER SANDE, 1991), are both a disadvantage in choosing honeybees for the pollination of tomato flowers. Therefore, we conclude with SPANGLER & MOFFETT (1977), that honeybees can be valuable pollinators of tomato, as long as they actively visit the flowers.

Table 1 shows that the pollinating visits of honeybees do not result as readily in brown spots on the outside of the stamina as happens with bumblebee visits. For an identical pollination rate of 12 bees / 100 flowers, only 2% of the honeybee-pollinated flowers showed brown spots on their extremity, whereas as much as 80%

of the bumblebee-pollinated flowers showed brown spots, 40% of which already on the first flowering day. This could be due to the greater body weight of the bumblebees and to the fact that bumblebees much more actively shake the tomato flowers through wing-muscle vibrations.

Table 2 demonstrate that insect pollination results in a lower occurrence of small "B" tomatoes, to the benefit of the bigger "A" tomatoes. The effect on class distribution by bumblebeepollination was variable in the progression (begin, middle, end) of the long tomato culture; the only one constant was a consistently higher percentage of broad "Bonk" tomatoes.

	POLLINATION TYPE			
QUALITY CLASS	**Manual vibration**	**Honeybees**	**Manual vibration**	**Bumblebees**
"Bonk"	41.5 % (112)	36.1 % (97)	13.5 % (17)	22.1% (27)
small "Bonk"	-	-	6.3% (8)	1.6% (2)
"A + 70"	14.4 % (39)	13.0 % (35)	21.4 % (27)	22.1 % (27)
"A"	27.4 % (74)	38.7 % (104)	246 % (31)	31.1 % (38)
"B"	7.4 % (20)	2.6 % (7)	29.4 % (37)	19.7 % (24)

Table 2. Procentual distribution of the tomatoes in auction quality classes

POLLINATION TYPE	HARVEST DAY					
	1	2	3	4	5	(N)
Vibration	11.9 %	23.3 %	57.4 %	91.9 %	100 %	270
Honeybees	13.4 %	24.9 %	53.5 %	86.6 %	100 %	269
Honeybees*	33.3 %	70.4 %	96.3 %	100 %		27
	HARVEST WEEK (mid-culture)					
	1	2	3	4	5	(N)
Vibration	10.4 %	60.4 %	93.7 %	100 %		48
Bumblebes	9.8 %	95.2 %	100 %			41

* = honeybee-pollinated flowers with brown spots on their stamina

Table 3. Cumulative percentage of the total harvest of tomatoes from concurrently tagged flowers.

Table 3 demonstrates that the harvest of tomatoes from concurrently tagged flowers is earlier when honeybees and bumblebees have markedly visited the flowers. The event is common for bumblebee-visited flowers, but is only partial for honeybee-visited flowers, since it is restricted to flowers with brown spots on their stamina.

Figure 1 demonstrates that also the total harvest of tomatoes started earlier in the greenhouse compartment containing bumblebees, than in the neighboring compartment where the flowers were manually vibrated twice a week. The usually higher auction prices at the start of an early crop, thus provide the bumblebee-using grower with an additional bonus. The total average tomato production per plant, was slightly higher with bumblebees (12.4 Kg / plant) than without (12.1 Kg / plant).

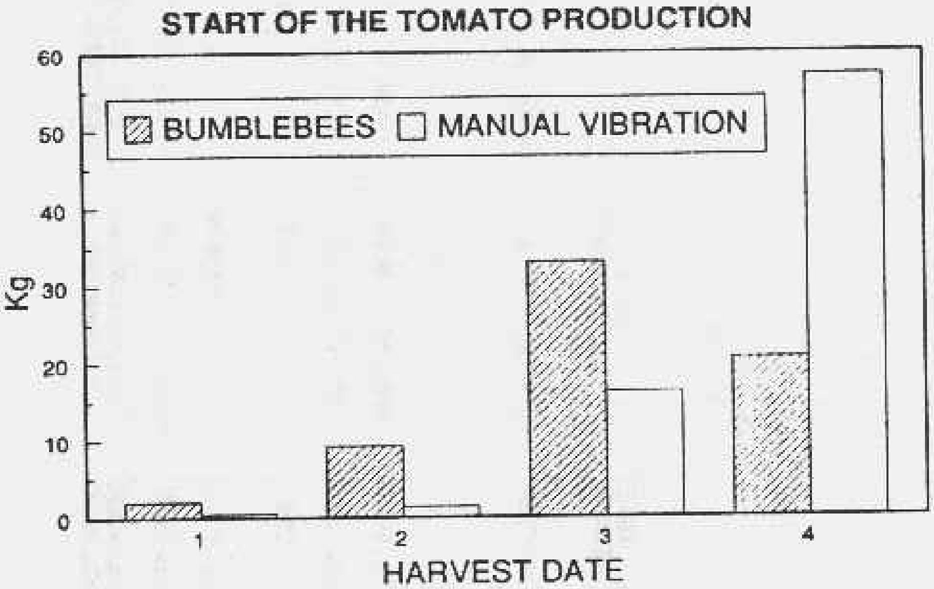

Figure 1. Start of the tomato production, in a compartment with, and a compartment without bumblebees

The above observations imply that honeybee pollination of tomato flowers is usually not as complete as bumblebee pollination. Only honeybee-visited flowers with brown spots on their stamina provided heavier (215g ± 67) and earlier (Table 3) tomatoes than the manually vibrated flowers.

The effect of variable bumblebee pollination

Figure 2 shows that there can occur a variable amount of brown-staining on the flowers, depending on the foraging activity of the bumblebees.

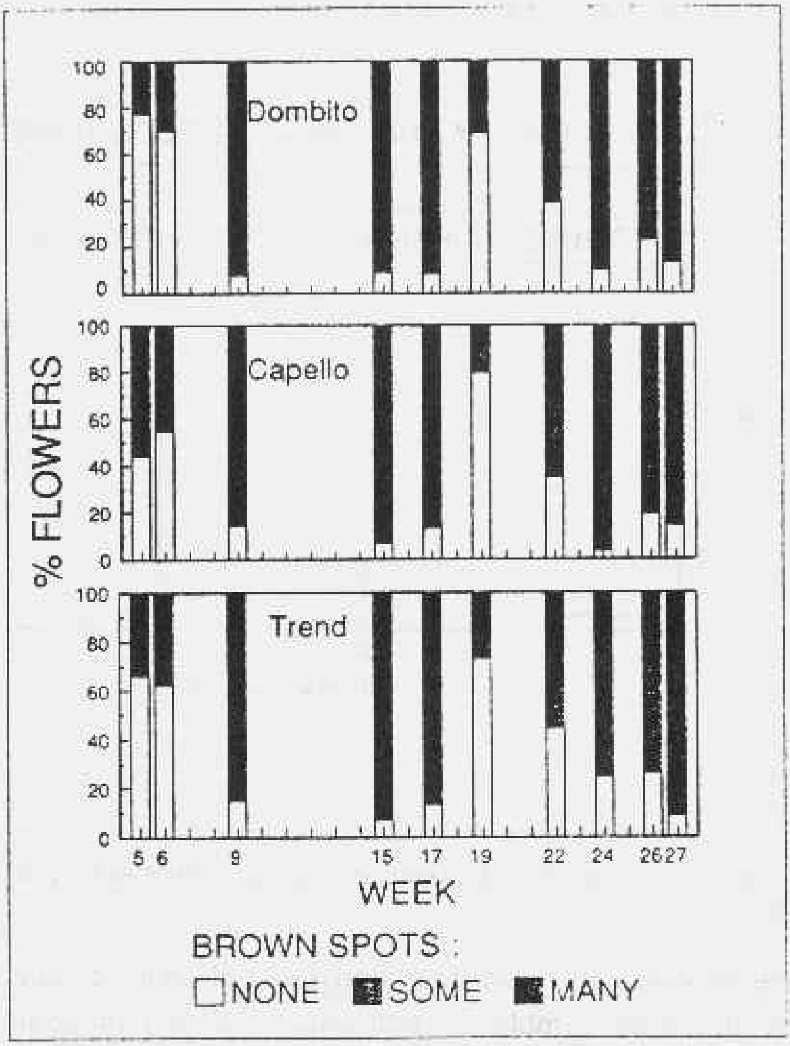

Figure 2. Procentual amount of tomato flowers, with none, some, and many brown spots on the outside of the stamina, during a tomato culture with three different cultivars.

Table 4 shows that there is a significant increase in fruit weight together with the increased occurrence of brown spots on the stamina of the tomato flower, as results of different three different tomato cultivars, all of them exhibiting parallel results.

TOMATO TRAITS	BROWN SPOTS ON VISITED FLOWERS		
	None	Some	Many
Fruitweight (g)	153 ± 34 a (111)	167 ± 42 b (251)	176 ± 47 c (122)
Seeds (n)	231 ± 80 a (111)	259 ± 84 b (251)	252 ± 88 b (122)
Quality Classes (%)			
"Bonk" (10)	9.0 % (41)	16.3 % (45)	36.9 %
small "Bonk"	1.8 % (2)	3.2 % (8)	5.7 % (7)
"A + 70"	37.8 % (42)	44.6 % (112)	27.0 % (33)
"A"	45.0 % (50)	32.3 % (81)	23.0 % (28)
"B"	5.4 % (6)	2.8 % (7)	7.4 % (9)

Table 4. Tomato traits resulting from variable bumblebee pollination activity [average Ò standard deviation (amount)]. Values followed by a different letter in the same row are significantly different (P<.05; LSD test after Anova)

It is interesting to note that additionally vibrated tomatoes (Trend cultivar) did not show any flowers with many brown spots, whereas the exclusively bumblebee-pollinated flowers showed up to 51% such flowers. The question is whether the additionally vibrated flowers loose a substantial part of their pollen by the heavy vibration, and thus become less attractive to bumblebees. The lower amount of bumblebee visits on additionally vibrated flowers could maybe explain why these flowers produced smaller tomatoes than exclusively bumblebee-pollinated flowers.

There was a significant difference in amount of seeds between "none" and "some" flowers (Table 4), but not between "some" and "many " flowers, as if pollination was already maximal in flowers with "some" brown spots. This evolution was identical for all three cultivars, except for the cultivar "Trend" which showed still some more seeds (not significant) for flowers with "many" brown spots. The procentual distribution of quality classes differed more or less between differently visited flowers. Together with increased staining from elevated bumblebee visits, there was a tendency towards more broad tomatoes ("Bonk"), and less round tomatoes ("A+70"; "A"). The same phenomenon was already observed in the 1990 experiment, comparing manual vibration with bumblebee pollination, the latter resulting in a higher occurrence of broad tomatoes. Half of the "Bonk" tomatoes from the heavily stained flowers in Table 4 showed a more or less angular and/or irregular shape.

It seems that an intensive pollination activity of the bumblebees on tomato flowers, resulting in heavily stained flower extremities, is beneficial for the global tomato production, unless perfectly round tomatoes are preferred by the consumer.

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GROUP IV

CONCLUSIONS AND RECOMMANDATIONS

Chairman : A. DE RUIJTER

Reporter : VAN PRAAGH

CONCLUSIONS AND RECOMMENDATIONS OF THE E.C. WORKSHOP ON "BEES FOR POLLINATION" HELD IN BRUSSELS 1-2 MARCH 1992

Collated and compiled by Ingrid H; WILLIAMS
LACR, Rothamsted Experimental Staion,
Harpenden, Herts,
AL5 2JQ
UK

This workshop was held to discuss the present situation regarding bees as pollinators of crops and plants native in Europe and the future pollination needs of European agriculture. Twenty pollination scientists representing each E.C. member state presented contributions organised into three sessions (1) pollination and the plant-insect relationships, (2) present and future use of pollinating insects, and (3) agriculture and insect pollination. A discussion took place after each presentation and session and, in the last session, after a wide-ranging debate, the delegates agreed on the following conclusions and recommendations.

CONCLUSIONS

Agriculture in the E.C. needs bees to pollinate most of its crops and bees need food and nesting sites from the agricutural environment to thrive.

The majority of crop plants grown in the E.C. are insect pollinated. Of the 252 crops grown, little is know about the pollination requirements of about a third, but 84 % of the remaining 170 crops are dependent on or benefit from insect pollination for their insect pollinators becaue they have co-evolved a highly interdependent relationship with entomophilous plants.

The area of insect-pollinated crops is increasing while the numbers of wild and domesticated bees are decreasing; a general and widespread shortage of pollinators in Europe is therefore to be expected. A shortage of wild, (especially the long-tongued pollinators) and managed honey bees already exist in several regions of the E.C.. This situation threatens not only the quantity and quality of agricultural production and hence its competitiveness, but also the survival of native plant species and in turn many other herbivorous or seed-eating insects, birds and small mammals.

Different bee species excel at pollinating different plant species.
Recent research has led to the commercial rearing of bumblebees for pollination of some glasshouse crops and techniques are being developed for the rearing of several species of solitary bees for a variety of greenhouse as well as field crops. However, at present, for field crops and where local pollinators are insufficient, the managed honeybee remains the only available pollinator that can be readily transported to crops for supplementary pollination. Introduction of bees to new areas has associated risks, for example, the spread of diseases and the disruption of the ecological and genetic stability of indigenous populations of pollinators with unknown consequences.

Intensive agriculture has produced an inhospitable environment for bees.
Changes in land management and agricultural practices during recent decades have resulted in an overall decrease in the availability of natural forage and nesting sites for bees. Excessive use of herbicides and insecticides unnecessarilly kills bee forage and bees respectively. Integrated and biological pest management sympathetic to the needs of bees improves pollination and minimises harm to the environment.

RECOMMENDATIONS

To ensure the sustainability and continued competitiveness of European agriculture by improving the pollination of crop and wild plants, this workshop makes the following recommendations.

1. The importance of pollination

That research be encouraged to determine which crops and wild flowers are bee pollinated, which bee species pollinate them best, and what are the optimum pollinator densities. Economic evaluations of the benefits of bee pollination should be made for different crops in each region.

2. Diversity of pollinators

That relevant research and development and agricultural policies be adopted to ensure adequate populations of appropriate pollinators for different crops in different regions. Particular attention should be given to :

- the development and improvement of techniques for the rearing of solitary bees and bumblebees (particularly of the long-tongued species for pollination of flowers with deep corollas).

- the support of taxonomic research to develop techniques and keys for the identification of the numerous solitary bee species of potential value to agriculture and the environment.

- the promotion of a thriving beekeeping industry, the organization of beekeepers to provide efficient and specialist pollination services to growers and the establishment of expert pollination advisers in the different regions.

- the encouragement of the use of native rather than exotic bees for crop pollination to reduce the risk of disease spread and undesirable genetic and ecological disruption.

- the monitoring of the movement of commercially bred bees providing information on their origin, number and sanitary status, and of the impact of disease spread (e.g. of *Varroa*) on pollination where it has become established.

- the investigation of the impact of moving large numbers of managed honeybee colonies into an area on local populations of native bees.

3. Habitat management

That E.C. land use policies promote appropriate management of agricultural, forested, semi-natural, conservation and amenity areas to improve habitats for wild and managed bees, by increasing the availability of successional forage and nest sites.

Particular attention should be given to :

- conserving and restoring natural vegetation.

- minimising soil surfface disturbance which destroys established nest sites.

- promoting the growth of perennial herbaceous vegetation essential for bumblebees.

- developing appropriate seed mixtures of bee forage plants for set aside land.
- promoting the use of legumes in agriculture, to improve bee forage and reduce use of nitrates.

- developing pesticides safe for bees. Studies are needed not only into acute effects, but effects in the long term, synergism between pesticides such as insecticides and fungicides, and on immature stages of bees.