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Apiculture

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The Diverse Roles of Honeybees in Agriculture

Honeybees have a part to play in several branches of agriculture. It is usually a part that does not easily fit into the mainstream of the husbandry in question, so they are often forgotten or ignored. For instance, they seem to have been overlooked when the Imperial Agricultural Bureaux were founded: entomology was concerned with pest insects, not with beneficial ones; veterinary medicine was considered in terms of mammalian and avian—but not insect—pathology; horticulture and field crops dealt with harvests of fruit, seeds and green fodder, not of nectar, honeydew and pollen. And pollination was dealt with from the standpoint of the plant, rather than that of the agent that accomplished the transfer of pollen.

From very early times, man has felt a special affinity with bees, first as the producer of the honey that he regarded as a gift from heaven, and later as providing an example of a well ordered society which seemed to mirror the sort of society he himself sought, whether in the political sphere or in the Christian church. As a consequence, many savants have pondered about the ordering of the colony, and in the last few centuries there has been much scientific enquiry about bee behaviour in general. Moreover honeybees can be maintained in almost any climate and with minimal attention, since they forage for their own food. For these reasons they are the most studied social insect — possibly the most studied insect — and they have been used for many investigations: on sense physiology, metabolism, caste differentiation, flight mechanisms, atmospheric pollution, and so on. Some of these studies have provided new knowledge that could be applied in apiculture, and others have not. In the last 30 years the choice of the honeybee as an experimental animal has also been influenced by the comparative ease with which scientific information could be obtained about it, through the work of the International Bee Research Association, and especially the publication of *Apicultural Abstracts*.

Jan Swammerdam (1637–1680) wrote in *Libre naturae:* "Among the wonders in the real economy of bees, nothing more deserves our attention than the certain presage they have of rain". This statement is hardly acceptable nowadays, but interest is again focused on bees as environmental indicators of chemical and electromagnetic pollution. Many contaminants are accumulated in or on plants (directly or from the soil), and thence in honeybees via pollen and nectar. They include industrial effluents such as fluorine, cyanide, sulphur dioxide, phenol compounds and hydrocarbons; metals such as lead and arsenic; and radioactive elements. A comprehensive study has been published (Greenberg et al 1978) on the effects of high-voltage transmission lines on honeybee colonies. In the USA, honeybees are being used to study effects on insects of microwaves such as would be generated in the NASA project to transmit solar energy to the earth via giant satellites.

Apiculture or beekeeping is in principle the maintenance of strong healthy colonies of honeybees in hives designed for the convenience of the operator, and the removal from the hives (and subsequent processing) of the products for which the colonies are kept. The products comprise (roughly in decreasing order of economic importance):

honey, beeswax, young queens, package bees (queen plus 1 or 2 kg of worker bees), pollen, royal jelly, propolis, bee venom, bee brood used as food. Colonies of bees may be maintained, alternatively or additionally, for pollination.

Honey is derived from the plant materials nectar and honeydew collected by bees, and indeed it is illegal to sell any other product as "honey". The use of bees as micromanipulators to harvest food from plants perhaps has its nearest parallel in the use of cormorants (on a neck-line which prevents swallowing) to catch fish. The beekeeper has an advantage over the fisherman in that the bees convert the nectar into honey, a very high-energy food, before he takes his harvest.

Bees collect pollen (proteins) from flowers as well as nectar and honeydew (carbohydrates). The dry pollen from anemophilous plants can be harvested without the agency of bees, but not the pollen of entomophilous plants, which is somewhat sticky; thus it adheres to the body of a honeybee visiting the flower and can be harvested by inserting a "pollen trap" across the entrances of hives in which the honeybees are kept. Bees collect propolis from sticky buds and twigs of certain trees; they use it, often mixed with beeswax, in repairing their nest or the combs in it.

Crop pollination is the most important economic outcome of honeybees' activities. Fruits, vegetables and nuts are mostly dependent on insect pollination. More than half the world's diet of fats and oils comes from oilseeds, many of which depend on, or benefit by, insect pollination. About half the beef and dairy products we consume are derived in one way or another from insect-pollinated plants. And honeybees are the most effective and the most easily provided pollinator for the majority of these crops (McGregor 1976), whose annual consumption in the USA was valued at nearly \$40 000M in 1970. Planned honeybee pollination is also used widely to ensure maximal *high quality* crop yields.

The Development of Apiculture 1929–1979

Background

During the 50–60 years under consideration here, apiculture has evolved from a craft into a science.* Some of the underlying reasons are common to many branches of agriculture; some more specific reasons are listed below.

1. A great increase in knowledge about the honeybee has made the evolution possible.
2. Continued increases in labour costs, and consequently in the mechanisation of handling operations, coupled with a reduction in bee forage in many regions, have led to a much larger scale of beekeeping operations than previously. This has necessitated effective disease control programmes, studies of nectar and pollen sources, and so on.
3. Development of irrigation methods has enabled crops to be grown on large tracts of land reclaimed from desert, which have no resident pollinating insects. Moving in hives of honeybees (up to 20 000 or more on to one crop) has proved the simplest way to ensure pollination, but requires appropriate technical knowledge.
4. The honeybee is an inefficient pollinator of a few important crops, for example lucerne (alfalfa, *Medicago sativa*) and red clover (*Trifolium pratense*). Large scale rearing of other bees has become possible by the use of precise methods that have been developed after experimental studies (see e.g. Bohart 1972).

Since the 1920s the study of the honeybee *Apis mellifera* (Fig. 1) has been greatly enriched by the study of social insects as a group (Michener 1974, Wilson 1971), and

*Using craft to mean an occupation needing high manual skill, and McKellar's (1957) statement that the purpose of any science is to provide within its given field of natural phenomena a realistic understanding, compatible with the explanations of other branches of science. Too often in the past, beekeepers have had insufficient knowledge of entomology in general, and of aspects of botany, chemistry and physics that are also highly relevant to apiculture.

"Apiculture" by Eva Crane (1980) Erratum

On p. 280, Fig. 4 shows the mite *Tropilaelaps clareae*, not *Varroa jacobnsoni* as stated. Delete "(Fig. 4)" on page 280, 7 lines above Fig. 4; *T. clareae* is referred to on page 281, 3 lines above the end of the section.

by the study of other Apoidea. Most of the 20 000 or more species are not social but solitary; nevertheless a number of them are candidates for new forms of apiculture for pollinating a specific crop.

Fig. 1. Clustered honeybee swarm (*Apis mellifera*).
A. M. Millington-Ward, Netherlands

Comparisons between the four *Apis* species, and detailed studies of the three Asiatic species (*cerana, dorsata, florea*), are only now getting under way (Crane 1980), and we must look to the next half-century for their fulfilment.

Of the many new biological and chemical techniques developed since the 1920s, and especially since the 1940s, a considerable number have been applied to problems concerning honeybees, a side interest in honeybees being widespread among scientists of different disciplines.

Bee management and equipment

During the period under review, large scale bee management has developed into a highly mechanised industry, with specialisation to serve one or several of the following markets: honey production; crop pollination; production of queens; production of package bees; production of a minor bee product (pollen, royal jelly, propolis, bee venom, beeswax, bee brood). Colony management procedures, and optimal colony composition, differ according to the product worked for.

Honey-producing establishments with hundreds or even thousands of hives were in operation well before the 1920s, in North America, the USSR, Australia, and some other countries. The last 50 years have been marked by a steady decline in bee forage in many of the temperate regions of the world, often because of the replacement of high-yielding natural vegetation by crops less useful to bees. Improved agricultural practices have also involved the destruction of weeds and hedgerows that used to provide bee forage. Land has been taken for buildings, roads, and other non-productive purposes. A series of daily records of the weight of a hive on the same site at Street, Somerset, England, for the years 1917 to 1936, shows a marked decline in the honey harvest, as the orchard trees that flowered in May were grubbed out to make way for houses; effective weed killing cleaned up the charlock that gave a June flow, and the July flow from the hedgerow brambles largely disappeared with the hedges themselves (Crane 1975). Statistics over several decades in the USA and Canada seem to show a drop in the honey yield per colony between 1930 and 1950, but thereafter modest increases, obtained by improved management. This includes migratory beekeeping, i.e. moving colonies to additional crops and, especially, learning to work on the basis that the unit of commercial operation is no longer a colony, but an apiary of 50–100 clone-like colonies, which can all be given the same treatment at the same time (Jay 1979).

There have been concomitant problems with labour (scarcity and increasing cost), and with poisoning of bees by pesticides. Beekeepers have reacted positively to the situation in various ways. They have mechanised their operations, especially lifting and transport, so that one man (with his truck and other mechanical devices) can manage several hundred, or in western USA up to 1000 or more, colonies. They migrate their colonies to a succession of whatever honey flows are accessible by road, and within an economic driving distance. Beekeepers have also learned more about bee behaviour and genetics, and methods of controlling diseases and enemies, and they have come to terms as best they can with the pest control programmes of the neighbouring farmers; policies of co-operation and education have been of vital importance. Where possible, beekeepers have also diversified their interests, the most common combination being honey production with some crop pollination.

Multiple-queen colonies and hyper hives

In the active season a normal honeybee colony consists of say 50 000 adult workers, 30 000 immature workers, a few hundred drones, and a single queen that is the female parent of all the rest. The idea of "breaking" this natural unit has attracted attention during the past 50 years, in the interests of higher productivity, and also in some countries on ideological grounds.

Usually a colony rears new queens only if the queen heading the colony is defective in some way, and produces insufficient pheromone(s) to inhibit the workers from queen rearing. But polygyny is not unusual in some races of honeybees, and the mother and one or more daughters may co-exist in different parts of the same brood nest, for a time. In practical beekeeping, a multiple-queen colony usually means one in which two (or more) queens are maintained in separate brood nests in the same hive, divided off from each other by two layers of queen excluder; these are slotted metal sheets through which workers can pass, but not the larger mated queens.

Dugat's book "La Ruche Gratte-Ciel à Plusieurs Reines" caused quite a stir when it was published in 1946 (and an English translation "The Skyscraper Hive" in 1948). Dr. C. L. Farrar in Wisconsin, who was highly successful in applying scientific principles to beekeeping practice, published an account of two-queen colony management (1946, updated 1955, 1958).

The benefit of two-queen units is that their large populations enable them to store more honey than their separate component parts each with one queen. Working them is a skilled operation not suited to all areas (or to all beekeepers, or to very large enterprises). Robert Banker, who uses the system successfully in south-east Minnesota, USA, finds serious problems even with 1500 two-queen units. His system is described by Dadant & Sons (1975).

I saw multiple-queen hives in commercial use in Western Australia in 1967, that extended horizontally, instead of vertically as skyscrapers do; they were called coffin hives. The unit consisted of a row of six 8-frame Langstroth brood boxes, separated by dividers, their flight entrances facing alternately to either side of the row. A single super (honey-storage chamber), holding 50 frames, extended across all six brood boxes, each of which had its own queen excluder. Alternatively a three-decker outfit was used, with a row of six separate honey supers below the 50-frame super. All lifting was mechanical, by gantry or by a mobile mini-gantry. I have not heard of such units in use in any other country.

Package-bee apiculture

Many methods used in modern large scale beekeeping were developed in the USA and Canada, through a range of latitude from 25°N in Florida to 55°N in Alberta. In the southern parts of the region, the mass production of queens in the relatively early spring was extended in a practical and imaginative way to the production of a "package" of newly reared worker bees with a young mated queen. The package usually contained 2 lb (1 kg) of bees, but larger and smaller packages have been used. The bees were shaken into a box with two opposite sides of wire mesh, to provide ventilation; the queen was in a small cage, and about 1 kg of sugar syrup was supplied in a safe feeder.

The packages were shipped to northern areas where spring came late — by train, by truck (600 per vehicle), and later by plane. An ancillary development was the use of package bees in the summer in regions farther north than bees could be overwintered. Large honey crops could be harvested there, from legumes grown for seed in newly cleared land; the high summer insolation, and consequent rapid plant development, led to copious nectar secretion. As soon as the honey had been taken from the hives, the bees were killed with cyanide. Recently, in the interests of safety, other chemicals have been tested, such as the insecticide resmethrin, and acrylonitrile mixtures. Markets were explored for the unwanted brood.

Package bee production has been developed in some other countries, but only the USSR encompasses a latitude span similar to that of the USA and Canada. A load of packages of bees needs closely controlled conditions of temperature and humidity, and the bees can be killed by delays at frontier posts between countries; by insecticide spraying in aircraft; and by many other hazards. Partly for this reason, no equivalent industry has been developed between, for instance, Mediterranean countries and northern Europe.

Wintering in a controlled environment

In temperate regions with an open winter, such as Mediterranean countries and southern states of the USA, adverse weather does not usually confine bees to the hive for more than a few days at a time. In England they may be prevented from flying for several weeks or longer at a time. In northern regions with a continental climate, low temperatures may prevent flight for several months, and the clustered bees may starve because the bees are too cold to move to food available elsewhere in the hive. The period under review has seen various ways of dealing with this problem. Hives have been wintered in "cellars" (half-underground shelters, dark and insulated against temperature changes); they have been wintered in the open, covered (singly or in fours) with insulating material protected with tarred paper; they have been wintered unpacked, but provided with an additional entrance high above the normal one at the bottom, which can get blocked with dead bees.

The beekeepers in the parts of Canada that relied on package bees had developed no expertise on wintering, but in the 1960s and 1970s they became increasingly dissatisfied with their dependence on imported bees. Some of these were infected with *Nosema apis*, a protozoan that can cause failure in an infected queen, and reduce the colony's efficiency as a honey-producing unit. Apart from this, the genetic stock was generally controlled by the package producers in USA. A vigorous effort was therefore made to winter colonies in maritime western Canada, round Vancouver and elsewhere. Also, more sophisticated versions of the earlier bee cellars were used; these were above-ground buildings in which the temperature (and sometimes also the humidity) were controlled by equipment that was then readily available. Such experiments will certainly be a feature of research in forthcoming years, and further progress may perhaps be made in wintering queens in incubators, each with a small number of workers. This has been tried in Romania, Canada and other countries, but success rates have not yet been satisfactory. It may be that the method would be economically sensible only for maintenance of special breeding stock.

Queen rearing and two-hemisphere operations

At latitudes higher than 35–40°, depending on climatic conditions, the beekeeper is fully occupied with his bees for only part of the year, which may be as little as 4 months at high latitudes. The beekeeper can use the winter period to make and maintain equipment, and deal with the honey harvested, but not much else. The idea of a dual-hemisphere operation, with two active seasons for producing honey, has been an attractive one. It is the ultimate extension of the concept of prolonging the period of honey flow by moving bees to different altitudes or latitudes within the same hemisphere.

Intercontinental transport is much more cost-effective for queens than for honey. The late Everett Hastings bred queens (originally of Caucasian origin) at Candle Lake north of Peace River in Alberta, Canada. In later years he used the Canadian winter to work with New Zealand bee breeders. Some of the queens reared there were sent by airmail to Canada, and seemed to survive the six-month switch in seasonal cycle.

Bee breeding and instrumental insemination

Large scale rearing of queens for sale pre-dated the period under review, but bee breeding proper is a comparatively late development. Honeybees mate in flight, and until 1963 knowledge about the event was limited to verbal descriptions of a few chance observations. However, from 1954 onwards evidence had been accumulating that queens do not mate with a single drone, but with a number of them (commonly 6–10), on a single flight.

Gary (1963) obtained direct evidence by observing, and taking motion pictures, from a television mast. Virgin queens were attached by thin nylon lines to a thicker line suspended over two pulleys, so that they could be hoisted up or lowered. Only a few seconds are required for mating, and other matings can follow in quick succession.

One discovery was that drones were not attracted to the queens until these had been elevated above a critical distance above the ground, which could vary from about 5 to 40 m, for reasons still not fully understood. The workers' flight space is below that of the reproductives.

Drones are likely to fly more than 5 km from their colonies, and queens nearly as far. Tests with genetically marked bees (cordovan, in which black coloration is replaced by brown) showed that 3 of 12 queens mated with drones from 16 km away. So, however carefully the genetic make-up of a queen is controlled, the genetic make-up of her worker offspring cannot be assured so long as there are any adventitious colonies containing drones within say 15 km of her own colony (*Bee World* 1971). The area of a circle of 15 km radius is about 700 km^2 (70 000 ha). Sites used for mating stations in different countries are: desert oases (excellent); small islands (often windy, but satisfactory if 15 km off shore); deep valleys with high mountains on either side to give protection there (but very few such bee-free valleys are available).

The difficulties in ensuring "pure" mating were appreciated long before details of the mating itself had been elucidated. An inviting approach to the problem was instrumental insemination of the queen. A technique was first devised in the USA by Watson (1927), and has been improved by many others since, in the USA and elsewhere. For some years now the procedure has been a routine one, and many thousands of queens are inseminated by technicians in bee-breeding programmes. Up-to-date descriptive and illustrated textbooks have been written by Laidlaw in the USA (1977) and edited by Ruttner in the German Federal Republic (1975).

In principle the queen, anaesthetised with carbon dioxide, is immobilized in a tube from which the tip of her abdomen protrudes, in the field of a binocular microscope. A specially designed syringe is mounted appropriately, and is charged with semen from several drones, which is then injected into the queen's vagina, beyond the valvefold which is held out of the way by a hook.

Many beekeepers practise a form of bee breeding, to the extent that they rear daughter queens from those heading their best-performing colonies, without much (or any) control over the drones that mate with the new queens. In some countries in continental Europe there have been schemes whereby beekeepers send their own selected daughter queens to an isolated mating apiary where selected drone-producing colonies are provided.

Particularly in the USA, there has been bee breeding for such specific characters as resistance to American foul brood caused by *Bacillus larvae*, and the rate of egg laying by the queen, as well as for honey production. Starline and Midnite hybrids, which show notable heterotic effects, are available commercially, but of course they cannot be used by the purchaser for further breeding.

One factor is not always taken note of: in the Old World there is a wealth of genetic material, still with some populations of relatively pure ancestry in isolated areas, whereas in the New World this situation does not exist, since all honeybees were introduced. It is, perhaps, a pity that the American initiatives in bee breeding could not benefit more from the richness of Old World material. Restrictions in importing foreign stock have become progressively more severe, in view of the danger of importing new pathogens with the bees.

Flight rooms

One of the hindrances to advances in both the science and practice of apiculture is the complexity of factors that are of specific or economic interest. For instance the beekeeper's honey yield is the difference between honey stored by the colony and the honey consumed by it. The population build-up of a colony depends on its genetic background, on external conditions, and on nectar and pollen sources (which again depend, although in different ways, on external conditions). Among components of the external conditions, temperature, insolation and day length may all affect the bees differently, and through different mechanisms, so they are very difficult to separate out. Moreover the food supplies of a free-flying colony cannot be accurately identified.

Since the 1950s, a useful technique has been developed for resolving some of the problems. Colonies are kept under controlled experimental conditions in an enclosed flight room. In the early days flight rooms seemed to pose more problems than they solved, but they have now been developed into a routine facility which enables active free-flying colonies to be maintained at any time of year, under controlled conditions of diet and foraging, photoperiod, ambient temperature and humidity, and so on. Discussions are given by van Praagh (1974) and in Symposium Proceedings edited by Ruttner & Koeniger (1977).

Diversification of Hive Products 1929–1979

Through history, and whether bees were hunted or kept in hives, honey has usually been the primary harvest. (In the mediaeval Christian church, however, beeswax was the more important: Vernon 1979). Modern technologies have created possibilities for collecting and exploiting other hive products as well, and in a period when honey prices are low there may be sufficient incentive to do this.

Royal jelly, pollen, propolis and bee venom can now all be produced commercially, and markets have been found or created for them. Meanwhile the honey industry has had to keep pace with changes in demand that come from selling outlets and from the retail consumer-purchaser.

Continuous-flow honey processing

Modern honey processing had its origins in the use of sweet clover (*Melilotus*) as a forage crop in the 1920s, especially in the USA and Canada. This plant gave large honey surpluses, and there was much spoilage through fermentation when honey was kept from one year to another because prices were low. The fermentation was initiated because glucose (the least soluble sugar in honey) crystallised out, leaving a liquid phase with an increased water content. The story has been told by Dyce (1975), who succeeded in overcoming the problem in 1931. The honey is first warmed to 49°C, strained to remove any wax particles, then flash-heated to 66°C in a heat-exchanger to kill any yeasts present. The honey is cooled rapidly, and finely strained or pressure-filtered to remove potential nuclei for adventitious crystal formation. Controlled crystallization (granulation) can be induced by adding a "starter" to the honey: a certain percentage of very finely granulated honey, obtained by crushing the crystals in it. With suitable temperature regulation, smooth, fine and soft granulation is achieved within a few days. The product is safe from fermentation.

The batch processing used initially was superseded by continuous-flow installations, and most of the supply of honey appearing on the world market is treated in this way. Where clear (i.e. liquid) honey is to be sold, no starter is added; if it is stored at 0°C for 5 weeks, granulation is sufficiently delayed to give the liquid honey an adequate shelf-life (Townsend 1975).

The 1970s have seen an ironic twist to this story. In the affluent societies of North America (and in Europe where there was always resistance to pressure-filtering of honey), the increasing demand for natural unprocessed foods has put a premium on honeys that have not been through the Dyce process, or indeed heated at all, and many small producers have done very well as a result.

Royal jelly

Royal jelly is the popular name for the secretion of the hypopharyngeal glands of young worker honeybees, fed to female larvae that develop into queens, and in smaller amounts to female larvae that develop into workers. It is also fed to egg-laying queens. Royal jelly looks very much like the sweetened condensed milk that can be purchased in tins.

The history of the commercial production of royal jelly has been published by Inoue & Inoue (1964). The first attempts were made in the early 1950s; France, Italy and Mexico were especially active in promoting it as a health improver — and more — and the announcement of a miraculous recovery by Pope Pius XII in 1958 after treatment with royal jelly gave a great boost to its sale and production. The UK remained more aloof than most countries, but useful reviews on royal jelly were published in *Bee World* (Johansson 1955, Johansson & Johansson 1958).

In the USA the production of royal jelly blossomed for a period, and more was imported from Mexico. By then Japan was producing 1.5 tonnes a year. Subsequently the interest seemed to shift to the Soviet Union and neighbouring countries, where clinical and cosmetic uses of royal jelly still create great interest and are the subject of many publications. Taiwan produced the astonishing total of 120 tonnes of royal jelly in 1976, and 80% of the beekeepers' income is said to come from its production and sale. Meanwhile in western Europe the spotlight had shifted to pollen during the 1960s; it is a nutritious substance that can also be harvested from hives, but with far less trouble and expense. Royal jelly is extracted, in minute quantites, from individual queen cells, whereas pollen can be trapped in bulk.

Pollen trapping

A populous colony of bees collects and uses around 35 kg of pollen a year, food that provides the proteins, vitamins and other substances needed in rearing new generations of bees, perhaps a quarter of a million individuals annually. In the hive, pollen foragers remove the pollen loads from their hind legs, and pack them into storage cells. A pollen trap is a device with a double grid, placed across the hive entrance, so designed that a fair proportion of incoming foragers, in manoeuvering their bodies through it, are parted from their pollen loads which fall into a collecting tray.

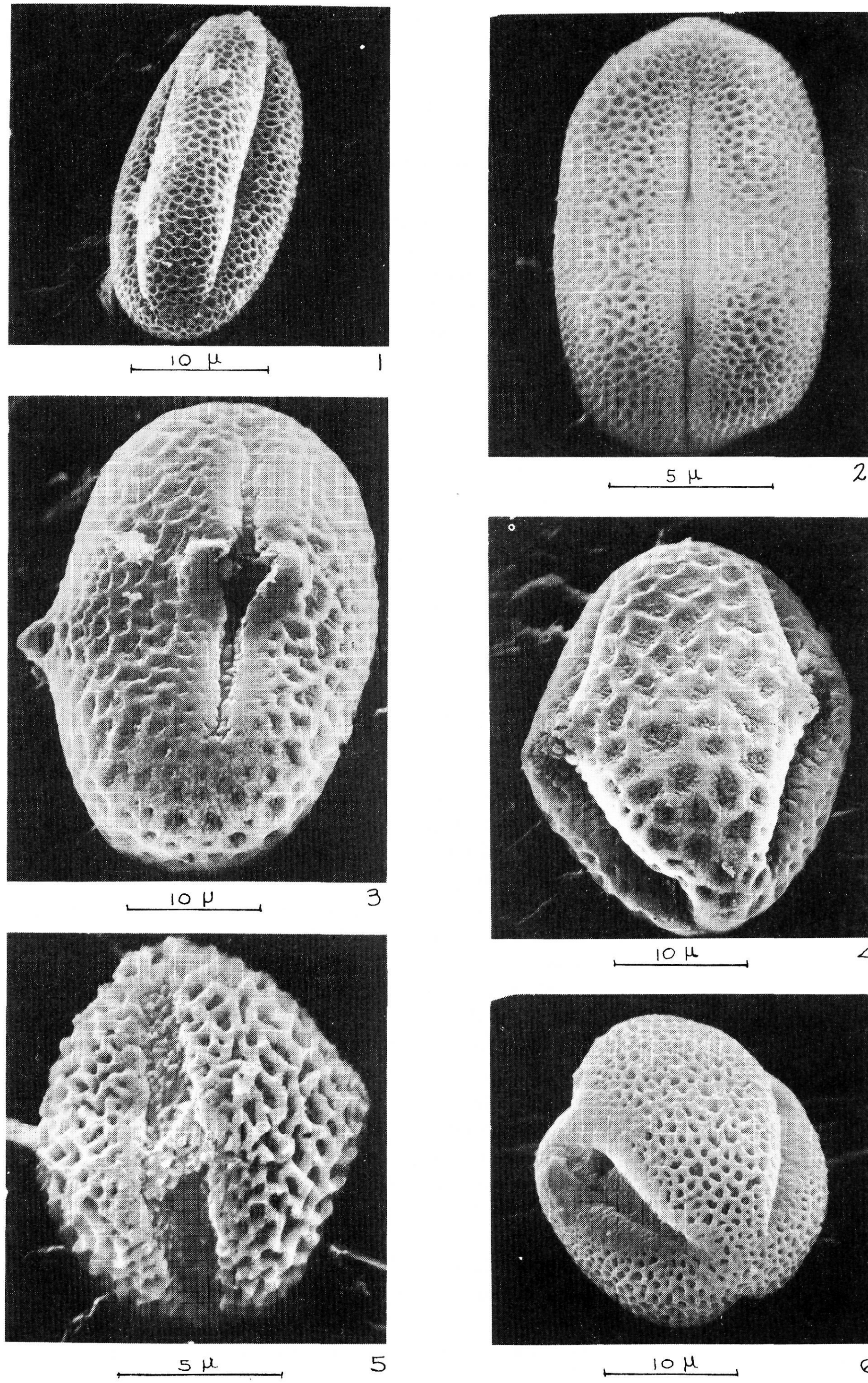
Pollen traps were first developed for experimental purposes in the 1950s or earlier. The yield can be as high as 1 kg per hive per day during a prolific flow, but the annual yield is not likely to be much above 10 kg. A reprint from *Bee World* (1975/76) describes various well designed traps, and also summarises the composition of pollen, which is discussed in much more detail by Stanley & Linskens (1974).

One of the most important uses of bee-collected pollen is in a dietary supplement for honeybee colonies when pollen forage is lacking, whether or not nectar is available. Some *Eucalyptus* species provide copious nectar flows, but no (or inadequate) pollen, so colonies can no longer rear brood, and would die out unless their diet was supplemented. Pollen has been incorporated in food for various young mammals, and also used for adult human consumption. The prices charged are high, and the same nutrients can normally be obtained more cheaply from other foods. In countries where undernutrition is common, and pollen could be collected cheaply, the situation might be different.

Bee-collected pollen is also used in studying and treating allergic conditions such as hay fever. In general, pollen collected for plant breeding and for pollinating certain varieties of fruit must be obtained directly from the flowers, since processing by bees inhibits its germination. The individual pollen grains of some plants are quite beautiful (Fig. 2).

Uses of propolis

Propolis created interest in the Ancient World, but it has become a commercial hive product only since the late 1950s. Propolis is a resinous plant secretion that honeybees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collect, usually from branches, leaves and buds of such temperate-zone trees as *Populus* and *Alnus*, and in Australia possibly from *Xanthorrhoea*. The bees use it, sometimes mixed with wax but otherwise possibly unaltered, for caulking cracks in their hive or other nest, for repairing and strengthening comb edges, and for the hygienic encasement ("embalming") of invaders too large to be removed, such as mice. The situation in the tropics is not fully known: it has been variously reported that the three tropical *Apis* species do not use it; that none is produced in Hawaii; that in Wake Island bees search for it avidly; that *A.m. adansonii* bees use it to varying degrees. Some European honeybee races (notably those from the Caucasus mountains) collect unusually large amounts of propolis; others collect little. It is not a food, and cannot be essential to a colony as nectar and pollen are.

Ghisalberti (1979) has published a comprehensive review on the composition and properties of propolis, and an annotated bibliography is also available (Walker 1976). About 20 flavonoids have been identified so far, as well as various acids and alcohols; many other components await identification. Propolis shows antibiotic activity against many organisms; Ghisalberti gives a three-page list. The identity of the component(s) responsible, however, is often not yet known. Propolis also shows anaesthetic, phytoinhibitory and pharmacological properties, including promotion of wound healing and tissue regeneration. Unfortunately much less attention has been paid to identifying and studying the source of the many effects observed, than to describing clinical effects after the use of propolis. Most of this case work is reported from eastern Europe. Propolis would seem to be well worth further basic studies, and it is to be hoped that Ghisa!berti's paper will stimulate such work. Experience in the last few years has shown that honeybee colonies can be worked to provide a propolis harvest, providing the financial return is adequate. If hive-parts are frozen, propolis adhering to them becomes brittle and can be removed by fracture.

Bee venom collection

Bee venom is used commercially in preparations for desensitising allergic patients, and in some countries also for treating certain types of rheumatism. There is currently extensive pharmacological research work on its components already identified, and on the identification of other active components. Some of this may well come to fruition in the next few decades; bee venom shares many characteristics with snake venom, and is not too difficult to harvest; some of the problems are mentioned below.

Like beeswax and royal jelly, venom is a secretion of worker honeybees; queens also produce venom, but it has been rather little studied. Firma Mack at Illertissen in southern Germany was producing venom commercially long before the 1950s when I visited the company. I was not shown the procedure, but it probably consisted of a slow and tedious method of inducing individual bees to sting into some material (absorbent paper?). In 1960, at the State Bee Venom Apiary at Radosina in Czechoslovakia, I saw a procedure that gave a more rapid harvest. Bees are stimulated to sting by an electric shock, administered by a bare wire stretched to and fro across a membrane mounted in front of a hive entrance. Bees leaving the hive are shocked, sting through the membrane (which is so thin that they can withdraw their stings through it, and are unharmed). Drops of venom remain on the underside of the membrane; they dry, and are scraped off.

Fig. 2. (opposite) Photographs of pollen grains of six plants used by honeybees, taken with a scanning electron microscope.

1. *Onobrychis viciifolia*
2. *Hedysarum alpinum*
3 *Trifolium incarnatum*
4. *Trifolium pratense*
5. *Hippocrepis comosa*
6. *Gleditsia triacanthos*

R. J. Adams and M. V. Smith, Canada

In the USA Morse & Benton (1964) developed this method to the stage where 1 g of venom could be collected from about 20 hives on a normal summer day. The procedure is not a pleasant one for the operator, or for people in the vicinity of the apiary, since many thousands of bees are alerted by alarm odour pheromone released at the site of stinging, and sting without further provocation. In 1968, when a UK government agency required 1 kg of bee venom for research purposes, beekeepers in five countries had to be approached before the total amount could be obtained.

The world shortage of beeswax

Until the 1850s, when Langstroth's movable-frame hive was devised and began to be adopted round the world, the bees attached their combs to the hive walls. Honey was harvested by cutting out the combs, and the honey was separated from the wax by pressing or crushing them, and straining out the honey. The beeswax yield was about 8% of the honey yield. With movable-frame hives, the combs (supported by the wooden frames round them) are spun in a centrifuge after the cell-cappings have been removed with a hot knife or a mechanically vibrated cutter. The only wax harvest is the cappings from which the adhering honey has been removed, together with any discarded combs, because the framed combs are reused. The wax yield amounts to 1½–2% of the honey yield; this is highly satisfactory to the honey producer, but as movable-frame beekeeping spread to one country after another, the average beeswax production per colony of bees dropped. Meanwhile many traditional uses for beeswax have become obsolete, partly because of world shortages and consequent high prices. At the same time an important new demand for beeswax was created: sheets of beeswax embossed with hexagonal cells of the appropriate size can be manufactured and fitted into the wooden frames, as a foundation for comb building by the bees. Substitutes have been sought, and are to some extent now used, for comb foundation and even for comb itself (Johansson & Johansson 1971).

By the start of the period being surveyed, beeswax was exported by tropical countries, especially in Africa, where there was a long tradition of beekeeping and where fixed-comb hives were still used. As each of the countries concerned has become more "developed", beekeeping has either declined or been encouraged by domestic or foreign development programmes in a more rationalised form, that yields more honey but less wax.

In 1965 Morse showed that comb building by a cluster of bees (a natural or artificial swarm) is not initiated until the bees are subjected to a period of comparative darkness, as they would be once they had settled in a cavity. Continuation of comb building does not require darkness, only its initiation. Morse explored the possibility of harvesting the tiny wax scales that form when the secreted wax hardens on contact with cooler air, by keeping swarms clustered (providing each with a caged queen) in full daylight, so that comb building was inhibited. This has not so far been developed commercially.

Development of Pollination Techniques Using Bees 1929–1979

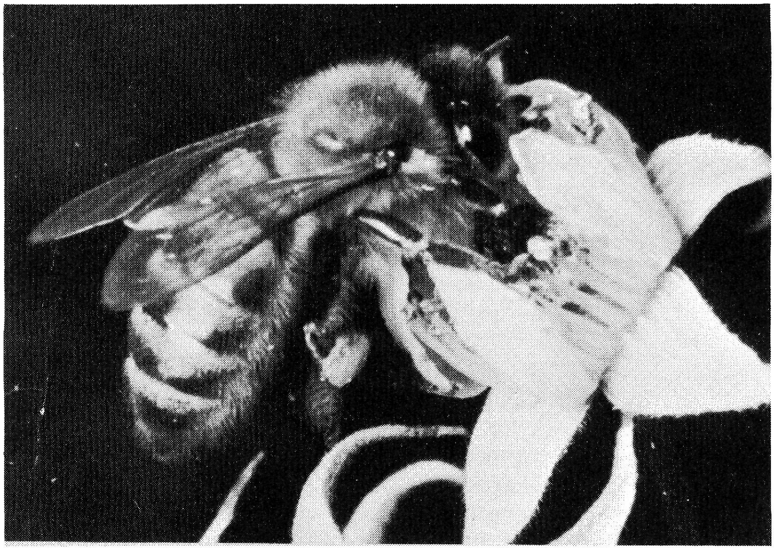
Two comprehensive books provide recent syntheses of knowledge on insect pollination of crop plants (Free 1970, McGregor 1976). The topics involved are dealt with rather briefly here, since further details can be found in one or other of the books. Attention is focused on problems whose full solution lies in the future, rather than on achievements about which information is easily available.

Moving hives of honeybees to the crop

This practice started well before the 1920s. In the 1890s, the USDA sent M. B. Waite to find out why an orchard of 22 000 Bartlett pear trees in Virginia failed to bear fruit. He established that cross-pollination was necessary, but that pear pollen was too heavy and sticky for wind pollination; however, honeybees could transfer it, and he recommended that colonies should be within at most three miles of the orchard (1895). With the increasing development of roads and road transport, moving honeybees to crops for pollination (Fig. 3) has become standard practice in all developed countries, and much research has been done on the requirements of the plants and the capabilities of the bees.

Fig. 3. The honeybee (*Apis mellifera*) is an excellent pollinator of raspberry (*Rubus idaeus*).

H. A. N. Dellow, UK



The scale of the operation may range from a truck load of 50–80 hives, or even fewer, taken to a fruit orchard, to 20 or 30 thousand hives moved on to alfalfa seed plots, as in California. Detailed timetables have to be set up: so that the bees do not unnecessarily suffer from insecticide applications; so that they first encounter the crop to be pollinated at the stage in its flowering cycle that will lead to maximal visitation by bees; and so that the beekeeper's pollination contract fits in as far as possible within his programme of migration to successive honey flows.

The times at which the hives are moved on and off the crop are very important. Foraging honeybees moved to a new area tend to seek the plant species they were visiting before the move. Apart from this, they will seek the most attractive crop within foraging range, and if the bees arrive before the crop to be pollinated is in bloom, they work other plants and may continue to do so even when the crop flowers. So while it is essential that the crop to be pollinated has a sufficient percentage of flowers open, the surrounding forage (past and present) can also affect the issue. Flight distance, concentration of sugars in the nectar, the amount of nectar that a bee can extract from one flower, and the speed of the operation, are all relevant factors. In broad terms the bees prefer to work whatever crop gives the colony the greatest net energy income.

A further factor is that bees newly on a site, searching for forage but without fixed patterns of flight and flower visitation, can often give more widespread pollination than bees whose foraging patterns are already fixed. A procedure of "switching" colonies from one site to another, even interchanging them if necessary every few days, can sometimes prove beneficial. Weaver (1979) has produced some persuasive evidence that foragers can recruit others to a specific area of an apparently uniform crop, on a day when for some reason it is yielding better than other areas.

The bees convert nectar into honey, of which colonies can store large amounts, irrespective of their requirements at the time or during the next dearth period: it is for this reason that beekeepers can use them as honey-producing units. The collection of pollen, on the other hand, is rather closely linked with the colony's immediate needs for the nutrients it contains, which are required for rearing brood. When Free (1967) removed brood from colonies, there was a rapid decrease in foraging in general, and of pollen collection in particular, whereas the addition of brood rapidly increased pollen collection. Pollen is deposited into store by the foragers themselves, in cells immediately around the brood nest, and direct contact with brood seems to stimulate pollen foraging. With many crops, bees collecting pollen may be more efficient pollinators than those collecting nectar. The above considerations show that colonies required for pollination should have a large amount of brood to feed; for honey production the number of adult bees is much more important.

Since the 1920s there have been many demonstrations that bees will not range far from the hive if acceptable forage is available nearby. The old rule of one colony per acre (2/ha) is no longer regarded as providing optimal coverage; moreover spacing hives out singly or in small groups is more effective than larger groups at greater intervals. Waite's 1895 recommendation of having hives within three miles of a pear orchard seems extraordinary now: we would put them within the orchard, and also take into account that if the trees are in well separated rows, bees will tend to work within a single row, and thus not to cross-pollinate between rows.

Two types of site present special problems: bogs and enclosed spaces. With bogs, where cranberries and other *Vaccinium* crops need pollination but access is difficult, disposable packages containing bees with or without a queen (but no frames), have been dropped from aircraft and left on the site. Disposable units have also been tried for almond pollination.

Where hives are sited within enclosures of transparent glass or plastic, problems are encountered because bees fly against the surface, and may cluster there or become disoriented. This is partly prevented if bees are used which have not flown before they are taken into the enclosure. Colonies can maintain their populations better if the hives are placed just outside it, with a flight entrance into the enclosure and another to the open air. Free (1970) gives a good discussion of the subject.

Pollen dispensers

Since the early 1930s methods have been developed and improved for controlling the plant source of the pollen carried by bees to flowers, especially in orchards where the planting plan was fixed before pollination requirements were fully understood. A device known as a pollen dispenser or pollen insert is fitted to the hive entrance, by means of which the outgoing foragers are dusted with a metered amount of the pollen selected, which is of a variety that will cross-pollinate flowers of trees (usually apple or pear) under treatment.

Experiments in which the pollen was marked with a fluorescent dye have shown the distribution of the "loaded" bees, and the effectiveness of the method has been demonstrated by large increases in both quantity and uniformity of the fruit produced; other methods of distributing specific pollen, such as blowing, have not proved as effective.

Scent-training bees

One method tried for persuading honeybees to visit and pollinate flowers that are not sufficiently attractive to them has been to "train" the bees in the hive to the flower scent. This has usually been done by feeding the colony with sugar syrup containing an infusion of the flowers. Many reports have been published, and considerable success claimed for the method, especially in the USSR, but the concensus of opinion in most countries now is that such feeding will not "train" bees to visit flowers unless these are inherently attractive to them. (Feeding syrup without flower scent brings about an increase in pollen foraging, because it increases brood rearing.) Stapel (1961) discusses the various factors involved.

An earlier method of attracting bees to specific trees or areas of ground crops was to spray them with sugar syrup. This can result in bees visiting the sprayed leaves and flowers to collect the syrup, but it does not increase pollen or nectar collection from the flowers, that would lead to greater pollination.

Breeding honeybees

During the period under review many observations have been made about the preferences of honeybees for specific crops, and variations in such preferences between races of bees and even between colonies (e.g. Åkerberg & Lesins 1949). In the USA line-breeding was used to produce bees that foraged preferentially on alfalfa (Nye & Mackensen 1970).

In Europe, attention has been focused on red clover (*Trifolium pratense*), which has flowers with too long a corolla for most honeybees to penetrate, except flowers formed after a first cutting. In general the length of the corolla tube decreases, and the proboscis length in native worker honeybees increases, from north to south in Europe; Åkerberg & Stapel (1966) give diagrams. In southern Europe, therefore, the gap between the proboscis and the nectar is smallest, and selective breeding from honeybee races that have a long proboscis has met with considerable success. In northern Europe the disparity is greater, and tetraploid red clover, with an even longer corolla, is increasingly grown; this presents severe pollination problems. Much can be done by using high densities of honeybee colonies, and by inducing honeybees to collect pollen from red clover, even if the nectar is inaccessible to them. But another solution has also been found: the use of long-tongued bumble bees (*Bombus*) for pollination work.

Rearing non-*Apis* bees

Beekeeping, or apiculture, is not confined to *Apis mellifera*, or indeed to *Apis* species. In the past, *Apis cerana* was the hive bee in all Asia from the Indian subcontinent eastward, although it has now been replaced in some areas by *A. mellifera*. *Apis dorsata* and *A. florea* also inhabit tropical Asia. Various species of Meliponini have been kept in primitive hives in the American tropics since prehistoric times, and to a lesser extent in tropical Africa. All these bees were reared because they produced honey and wax, but they are also effective pollinators.

Bumble bees have only rarely been kept in hives for their honey (see Crane 1975), but in the last few decades certain species have increasingly been reared, and their colonies established and maintained, specifically for pollination, especially in Europe. Populations of suitable species of *Bombus* in the wild can also be increased by locating red clover seed plots near land with many suitable nesting sites, and by leaving uncultivated land round the plots; this has proved very effective in Finland, for example.

In North America, work has been concentrated on the search, and then the development of rearing methods, for other species of Apoidea that were efficient pollinators of alfalfa. Indications of the change in emphasis are apparent from the published Proceedings (1962, 1966, 1975, 1979) of the first four International Symposia on Pollination, sponsored by the IUBS International Commission for Bee Botany and (except for the first) by the International Bee Research Association.

Year and venue of Symposium	1960 Copenhagen	1964 London	1974 Prague	1978 Maryland, USA
Total no. pollinator species discussed	3	4	6	13
Papers on bumble bees	54%	56%	42%	8%
Papers on (red) clover	57%	33%	10%	3%

Since 1950, two species have been extensively studied and commercially reared for alfalfa pollination in north-west North America: an alkali bee *Nomia melanderi* and a leafcutter bee *Megachile rotundata*. The pioneers in this work have included: *Nomia*, Dr. G. E. Bohart (1972) and Dr. W. P. Stephen (1965); *Megachile*, Dr. G. A. Hobbs (1972). The dates quoted relate to the most recent descriptive publications of these authors.

Nomia melanderi is an American highly gregarious solitary bee that nests in large numbers in fine soils with a silt loam or a fine sandy loam texture. Dependable methods have been developed for preparing and stocking new nesting sites or "bee beds" near alfalfa fields, provided the necessary conditions of soil and drainage can be achieved; salts can be added as necessary. Other prepared bee beds within 1½ km may be colonised by migration; at further distances the bees must be brought in, in blocks of undisturbed soil from established beds, containing pupae. Numerous diseases and enemies must be kept under control, but where populous bee beds can be created, the bees pollinate alfalfa most efficiently and very high seed yields can be produced. A bee bed 250 m^2 in area is sufficient for about 30 ha of seed alfalfa.

There are many native leafcutter bees in North America, but *Megachile rotundata* is an adventitious introduction, which spread rapidly from the east coast (where it arrived perhaps about 1930); in 1972 Bohart reported that it occupied "roughly the northern three-fourths of the contiguous United States". The American success with this bee has led to a new appreciation of its worth in eastern Europe and western Asia where it is indigenous.

M. rotundata is another highly gregarious solitary bee. It uses circular sections from leaves, usually alfalfa, to line its nest in a hollow tube above ground, such as a plant stem. Nests can be simulated by 4-mm straws, or grooves in wooden or plastic boards, and thousands of such nests can be set up in a block. The pupae are wintered in dry cool storage at 0–4°C; in spring, about three weeks before flowering is expected, they are incubated at about 29°C and 50–70% RH. Shelters containing batteries of new horizontal "stems" are meanwhile set up in the fields, and trays of pupae are taken to them when the bees start to emerge. Diseases and enemies must of course be controlled, and much research has been done on them. It is estimated that one shelter containing about 10 000 nesting females of *M. rotundata* will pollinate 2 ha of alfalfa.

Success with these two bees has been spectacular enough to generate searches in all continents for bees of special value as pollinators, that could be reared commercially. *Xylocopa, Osmia, Anthophora*, and other *Megachile*, are of special interest at present. One obvious place to search is the point of origin of the crop to be pollinated; the wisdom of importing any foreign bee species must, however, always be considered with great care.

Pollination agreements and contracts

The idea that the beekeeper will receive an adequate reward for the pollination services of his bees, from whatever honey he gets, was shown to be erroneous long ago. His colonies have to be built up for effective pollination, not for honey production; also he often runs the risk of losing his colonies through pesticide poisoning, or through damage to the queens during transport. In those socialist countries where beekeeping and crop production are both parts of an integrated agricultural programme, no specific contract may be necessary between the beekeeper providing colonies of bees for pollination and the grower of the crop to be pollinated. In some other countries where the need for insect pollination is still not understood by farmers, beekeepers may be unable to get a contract — or indeed payment — from the farmer for taking colonies to his crop. But in many countries suitable agreements have been devised.

The following rubric has been developed during the past 50 years in the USA, where there has been most experience, and other developed countries follow somewhat similar lines. The contract or agreement covers the following: identification of participants; rental price (and time and method of payment) and statement as to who pays any special costs incurred; date of delivery of the colonies (or arrangement for fixing this nearer the time); penalty for late delivery, which could result in crop failure; number of colonies per acre or ha and the area to be served; strength of colonies; their precise siting (colonies are usually delivered at night); their operation, maintenance and removal; provision of uncontaminated water by the grower; protection of bees against pesticides and other farming hazards; protection of personnel against stings, and associated liabilities. A statement of penalties for not adhering to the contracts is necessary, and the incorporation of rewards (e.g. for prompt payment, or extra-high crop yields) can be beneficial. In 1976 McGregor quoted a proposed fee of \$10.50 per 10-frame colony $\pm$\$2.50 for every two frames more or less. Colonies were assumed to have brood in half the frames, and brood areas are laid down since the presence of brood induces pollen foraging. In practice, the fee is often set as so much per colony; McGregor favours the use of "colony equivalents", so that 90 populous or 110 smaller colonies could be supplied to an area for which 100 had been designated.

In practice, much depends on mutual co-operation and concern between beekeeper and grower: the beekeeper could swindle the grower by providing hives containing few bees, and the grower can kill all the bees by improper pesticide applications. In providing colonies, the beekeeper is placing his stock in the hands of the grower; in hiring them, the size of the grower's potential harvest may be in the hands of the beekeeper.

Cataclysmic Events 1929–1979

Many hives and colonies were destroyed in the general devastations of the Second World War, but this section refers to three specifically apicultural traumas: the poisoning of bees by pesticides; the introduction of tropical African honeybees to tropical America; and the spread round the world of the mite *Varroa jacobsoni*, with *Tropilaelaps clareae* perhaps to follow.

Poisoning of bees by pesticides

Poisoning of bees has occurred ever since insecticides have been applied to crops. It has been reported and discussed in *Bee World* from the first volume (1919) onwards; the early poisons were few, arsenic being one of the most troublesome. Developments brought about by the needs of the Second World War and by the subsequent reconstruction of agriculture, with the creation of large scale mechanised operations, faced beekeepers in many countries with a crisis, and many felt that beekeeping was doomed. The situation in successive decades has been usefully set out by Hocking (1950) and Johansen (1966 1979). Education and public relations have achieved much in converting the crisis into a hazard amenable to improvement by co-operation. As a result of much persuasion, producers of pesticides now label their materials according to degree of toxicity to bees; in some countries legislators have banned some of the most toxic materials; growers accept, and often act upon, the concept that since live bees are needed to pollinate their crops, it is counterproductive to kill these bees; and beekeepers have accepted the fact that crop yields are being increased through the operation of pesticide programmes.

Among advanced countries, the Pacific states of the USA have included some of the hardest hit areas. The number of colonies killed completely by pesticides in California was reduced from 82 000 per annum to 36 000 between 1962 and 1973, from about 17% to 7% of the total. Many other colonies lost their foraging bees several times during the season. In August 1979, on cane-fruit farms in the Columbia River valley in Oregon, I found that beekeepers expected their field force of bees to be killed at each insecticide application. One application is on the day before harvesting, although many flowers are still open, because the presence of any insect parts with the harvested fruit disqualifies the crop, on the grounds that they make it unacceptable to the consumer. In the Williamette valley nearby, one beekeeper had lost his livelihood in 1978, when two thirds of his 1500 colonies had been killed by insecticide spraying.

Encapsulated insecticides are now presenting a special hazard; methyl parathion in this form is collected by bees like pollen and persists in the hive from one season to the next. Granular formulations, on the other hand, cause much less bee mortality than powders or sprays.

The changing pattern of bee poisoning in Britain since 1948 has been described by Stevenson et al (1978); they, as well as Johansen in the USA (1979), make a series of useful recommendations. Honeybees are at very high risk in some developing countries, where agricultural programmes often include applications of insecticide carried out in ignorance of or indifference to the indispensability of bees. In Egypt in 1978 I found that beekeepers no longer dared to take their bees to the cotton, which used to give their main honey crop (30 kg or more a year). The cotton is sprayed from the air five times in all, at intervais of two weeks, too short a period to allow the forager population to build up again, since the adult worker honeybee does not emerge until three weeks after the egg is laid.

Sometimes, if they know when insecticides will be applied, beekeepers can remove their hives beforehand. Populations of wild bees have no such means of escape, and consequently their losses are, in proportion, more severe.

Transport of tropical African honeybees to tropical America

This event, its aftermath so far, and further consequences predicted for the future, have been much discussed in scientific circles and have also received much sensational and nonsensical publicity. Briefly, the facts are these.

Honeybees are not indigenous to the Americas. European *Apis mellifera* was introduced to Latin America in the last century, and — thanks to the abundance of bee forage — Argentina and Mexico, and some smaller countries and islands outside the full tropics, have become important honey-exporting countries (Crane 1975). Nearer the Equator the European bees did less well. As part of an attempt to improve productivity, in 1956 Professor W. E. Kerr imported queens from the Pretoria region of South Africa to São Paulo in Brazil for breeding experiments. These are among the honeybees of the African tropics referred to as *Apis mellifera adansonii*, although investigations now under way are likely to show a much more complex taxonomic situation. Through a mischance 26 absconding swarms headed by African queens escaped, and "Africanised" bees have by now replaced the European races in most of tropical South America, as far as Colombia and Venezuela. This has been due to their evolution in tropical conditions (in foraging behaviour and in other ways), their very rapid swarming cycle, their acceptance of smaller nesting sites, and the dominance of their drones in mating. Under favourable conditions a 1 kg swarm can produce another swarm in 48–50 days, and swarming can occur in nearly all months of the year. Also, the swarms probably make several temporary stops before they finally occupy a nesting site where they build combs and rear brood, many kilometres from the parent colony.

Almost all areas in South America where the Africanised bees have advanced strongly seem to be rather dry, with less than about 1000 – 1500 mm rainfall a year. In Africa *A. m. adansonii* occurs in a wide range of habitats but seems to be most abundant in Central African plateaux at 1000 – 15 000 m, with an annual rainfall of 500–1500 mm. From the bee's distribution in South Africa Taylor (1977) estimated that its probable tolerance to cold would enable it to resist short intervals with temperatures as low as −10°C, 6–8 weeks with mean temperature of +10°C and mean maxima and minima of 17° and 4°; up to (perhaps more than) 60 days a year with temperatures below 0°, and up to (perhaps more than) 150 days between the first and last frosts, i.e. with a 215 day growing season. Certainly the bee's spread southwards into Argentina has been slower, and it seems to have got no further south and west than around the 10°C mean isotherm in the coldest month of the year. Farther north, the whole of Central America and Mexico, and adjoining regions of the USA together with its west and south coasts, come within the limits quoted.

There is plenty of evidence that in areas of Brazil where beekeepers have adopted new and satisfactory methods of managing Africanised bees, honey yields are higher, and in some areas surplus honey has been produced for export for the first time. But there can be great difficulties when the bees first arrive in an area, because the bees can easily become alerted to sting en masse and this affects more people than just the beekeepers.

Varroa jacobsoni

This mite, the only species in the genus, has caused great concern to the beekeeping industry during the late 1970s. It was first reported in 1904, on *Apis cerana* in Malaya, and later on *A. mellifera* in Hong Kong. By 1968 it had been recorded on *A. cerana* in India, the USSR Far East (on the Pacific coast), and possibly in mainland China. It had also parasitised *A. mellifera* in the Philippines, Japan, Vietnam, and the USSR Far East. The mites had been causing heavy colony losses in these areas. Then they were found in European USSR, and 1975 *Bee World* carried a note of warning that *Varroa jacobsoni* was a prospective pest of honeybees in many parts of the world. The mite has now spread as a parasite of *A. mellifera* to many European countries via European USSR, and to South America from Japan.

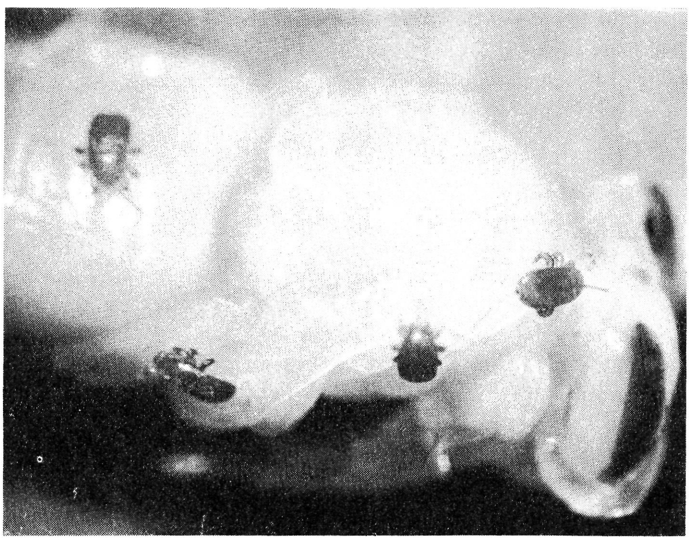
The spread of the mite seems to be due to the following events. *Apis cerana* bees were indigenous in the USSR Far East, living wild in the forests of Ussuriysk. Peasants who migrated there from European Russia in the last century tried to keep them in log hives, but they had difficulties and lost many colonies through swarming. These bees, like *A. cerana* in much of its habitat, were parasitised by *Varroa*. Later, peasants from the Ukraine settled in the area, taking with them their own Ukrainian bees (*A. mellifera*), which in due course became infested with *Varroa*. This is a likely fate for any European bees taken into *cerana* territory.

In more recent years, there have been many reports of high honey yields in the USSR Far East, which led some beekeepers in European USSR to believe that the bees there must be of a very good strain, although the high yields are in fact due to excellent flows from limes (*Tilia*) and other plants. Queens of these "honey-getting" strains were purchased from the Far East for apiaries in European USSR, and with these queens came *Varroa* as well. The next European country to find the mites, presumably introduced with queens imported from USSR, was Bulgaria. Other countries, too, imported foreign queens and *Varroa* with them. There has also been a direct importation of *Varroa* into Germany on *A. cerana*, brought from Asia for experimental purposes, but this infestation may have been contained.

As far as can be ascertained, in early 1980 *Varroa* occurs throughout Asia as a parasite of *Apis cerana*, and also as a parasite of *Apis mellifera* where both bees are present; it is also in Iran and Turkey. In Europe it already parasitises *A. mellifera* in parts of Bulgaria, Hungary, Czechoslovakia, Romania, USSR, Yugoslavia and Greece. In South America it is in Argentina, Paraguay and Brazil; in Africa, in Libya and Tunisia. The following countries are believed to be free from *Varroa*: in Europe, Austria, Finland, Ireland, UK; in America, all countries except the three mentioned; also Africa south of the Sahara, Australia, New Zealand, the Pacific Islands, and some countries of the Middle East.

Colonies are damaged by the mite as follows. The female lays up to 12 eggs in a single brood cell, just before it is capped. The nymphal stages feed on the haemolymph of the immature honeybee, and can kill it (Fig. 4). They also attach themselves to emerging adult bees, and gain access to the haemolymph through the less chitinous parts of the exoskeleton. Mites overwinter in the colony, and readily move from one bee to another, inside or outside the hive. So they spread easily within an apiary — and to the other side of the world if infested bees are sent by airmail. Infestation makes adult bees restless; they try to rid themselves of the mites, and have been observed carrying them away in their mandibles.

Fig. 4. Honeybee pupa parasitized by *Varroa jacobsoni*.
Pongthrep Akratanakul, Thailand



Individual infested bees may appear to have deformed wings, and colonies may be killed within a few years or less. There have been many local reports in recent years of losses of thousands of colonies, but substantive evidence is often lacking that *Varroa* is the cause. No very satisfactory cure has yet been found, although many acaricides have been tried. The most effective so far is a Japanese fumigant Varrostan-Bayer, but this is also quite toxic to bees.

Governments of many countries are hastily introducing legislation in an attempt to prevent the importation of *Varroa* into their own countries. An urgent job for the future is to obtain basic information on the mite, for instance by artificial infestation of colonies, and on its effects on colonies of *Apis cerana* and *A. mellifera* in different climatic zones. In some countries *Varroa* is blamed for much colony mortality in *A. cerana*, whereas in others it is regarded as having little more than a nuisance value. It is likely that *Varroa* has been blamed for the deaths of many more *A. mellifera* colonies than it has caused. Without adequate observations at the time, it is impossible to apportion blame correctly for colony depopulation, and there are various candidates: viral or other infections, inbreeding, poisoning, and a number of parasites. Often the most recently known cause of damage is used as a scapegoat for many others.

The above information is taken from Crane (1978c) and the references given there. A bibliography listing 299 publications on three Asiatic mites, *Varroa jacobsoni*, *Tropilaelaps clareae* and *Euvarroa sinhai*, is just published (De Jong & Morse 1979). *T. clareae* can certainly parasitise *A. mellifera*, but we do not yet know about *E. sinhai*; both these mites have a similar life cycle to *Varroa*, and it seems possible that one or other will expand its territory as *Varroa* has done, and cause similar concern.

The Significance of the Tropics for Apiculture in the Future

The unique circumstances of each continent

There are four tropical regions: the three separate land masses in Africa, Asia and America, and the Pacific islands; each has its own distinct characteristics with regard to honey-producing bees.

Africa, with its offshore islands, is the only region with native tropical subspecies of *Apis mellifera*, which include the group known as *A. m. adansonii*, also in the south *A. m. unicolor* and *A. m. capensis*, and in the Nile Valley *A. m. lamarckii*. Asia, with its offshore islands, has three native *Apis* species, all tropical: *cerana, dorsata* and *florea. Apis cerana* (Fig. 5), the only one that can be kept in hives, extends as far north as Japan and Pacific USSR; the other two build a single-comb nest in the open air. Honey hunting provides small harvests from *A. florea* and substantial yields from *A. dorsata* (Fig. 6); open-sided hives for *A. dorsata* are now being used experimentally (Fig. 7). In the Americas and the Caribbean islands native tropical stingless bees (Meliponini) have been kept in hives since prehistoric times, but there are no native *Apis* and beekeeping there is now based on *Apis mellifera* from Europe and Africa.

Finally, the comparatively recently formed Pacific islands have no native honey-storing bees at all, except stingless bees in one small area. European *Apis mellifera* have been taken to most of the groups of islands in the last 100 years or so, and the remainder are still without them.

At various times European *Apis mellifera* have been introduced by man into all four of the tropical regions. The bees often thrive in subtropical climates, or where there are no native *Apis* species (as in Pacific islands), but not in general where these are present. With modern methods of management, new honey industries have been developed: Mexico, Israel and the People's Republic of China provide examples. But transferring temperate zone management methods to tropical bees, or transferring both methods and bees to the full tropics, is often quite unsuccessful, for biological

Fig. 5. Honeybee (*Apis cerana*) foraging on cotton (*Gossypium arboreum*).

A. S. Tanda and N. P. Goyal, India

Fig. 6. Single-comb nests of honeybees (*Apis dorsata*) in a tree.

C. V. Thakar, India

Fig. 7. Experimental open-sided hives for *Apis dorsata*.
C. V. Thakar, India

reasons that have not so far been overcome, or indeed completely understood. This is one of the important problems for the future. The tropical bees may migrate, or be quite unamenable to handling, or fail to amass large honey stores. Imported temperate zone bees may die out because of pests and enemies they cannot combat, or because their foraging behaviour is out of phase with the food available — they may fly in the mid-day heat instead of early and late when the flowers produce nectar and pollen. Or there may be mating competition from drones of other species, because the sex attractant is the same for all *Apis* species. On the other hand if the imported bees are successful, they may compete with local bees until these are exterminated.

Developments 1929–1979

The period from 1929 to 1949 was uneventful enough, but the general political and economic changes in the last 30 years have been accompanied by important beekeeping developments. Initially the impetus came from more advanced countries: beekeepers and honey traders saw large areas of unexploited nectar-producing land, thanks to the expansion of air travel; in African countries especially they saw many hives, but enquiry showed that their yields were very low; in some regions they met beekeepers who were distraught because some unknown disease had killed most of their colonies.

Knowledge of the tropical species and races of honeybees was scanty, and unorganized, but in the 1950s a new feature started to dominate developments in tropical apiculture: aid programmes. Apiculture is not a major branch of agriculture, and many apicultural programmes have been planned and implemented in relative ignorance of what has been done elsewhere, and many mistakes have been unnecessarily repeated, some programmes being devised by personnel with very little knowledge of bees and honey production.

It has often not been easy for an aid agency to decide wisely between basic methods of procedure. It is possible to improve management (and hence production) with existing fixed-comb hives; or to teach existing beekeepers how to use movable-frame hives; alternatively to teach this skill to young non-beekeepers who have nothing to unlearn; or to use intermediate hives in which there are movable combs but no frames.

In a fixed-comb hive (log, basket, pot, etc.) the bees attach their combs to the structure of the hive, and the combs cannot be removed for management or disease inspection; honey combs are harvested by cutting them out. These hives are, however, made by the beekeeper from local materials, at no cost. In movable-frame hives, every part must be precision made, and a "bee-space", usually 6 mm, left all round each frame (except its two points of support); also the equivalent parts of individual hives must be exactly interchangeable. The financial investment in this precision is worth while only if full advantage is taken of it in operation, as it is with educated beekeepers of advanced countries. In the intermediate hives, suspended top-bars are used instead of four-sided frames, and the only precision measurement is the width of the top-bars, which are placed in contact with each other.

The continued and extended use of fixed-comb hives is not often promoted; since the combs cannot normally be inspected, detection and control of brood diseases are virtually impossible. Nevertheless diseases are in general less significant in the tropics than in the temperate zones, and they are less easily spread with fixed-comb than with movable-frame hives.

Movable-frame hives have been the norm for beekeeping developments in tropical regions with no native *Apis* (South and Central America and the Pacific islands) and in parts of tropical Asia, where there was more traditional honey hunting than traditional beekeeping.

Intermediate hives have been used very successfully in Africa; they have certain similarities with the cylindrical traditional hives there, and like them can be suspended from trees or other supports to prevent access by animal enemies. The most extensive development with these hives has been in Kenya (Townsend 1976), and they or similar hives have been used in other parts of both East and West Africa (Crane 1978a). As far as I know intermediate hives have not yet been tried for *A. cerana*, but a book just received from Nepal (Saubolle & Bachmann 1979) describes and illustrates them.

The development of beekeeping in the tropics has provided honey for home consumption, for local barter, and for sale to town markets via co-operative processing centres. It also yields beeswax for a world market where it is in short supply (International Trade Centre 1978). A most important factor is that it can provide populations of honeybees for use in pollinating appropriate crops and increasing the yield of many foodstuffs. Exporting honey can come only at a more advanced stage (International Trade Centre 1977).

The First Conference on Apiculture in Tropical Climates, held in London in 1976, generated many seminal ideas that have already been acted on, and the Proceedings (Crane 1976) provided an organised survey of the subject. This was followed by Apimondia Symposia in South Africa (on African bees, Fletcher 1977), and in Brazil in 1978. IBRA has accepted the invitation of the Indian Council of Agricultural Research and the Government of India to hold the Second Conference on Apiculture in Tropical Climates in New Delhi in March 1980. Meanwhile the Commonwealth Secretariat and International Bee Research Association have jointly published a collection of articles under the title "Unexploited Beekeeping Potential in the Tropics" (1979).

One of the greatest hindrances to useful developments has been the lack of knowledge available to beekeeping leaders in developing countries and to planners and operators of development programmes. There are some, although far too few, scientific studies. There is also much information scattered in publications that are outside the catchment of abstracting systems.

In 1977 the International Development Research Centre in Canada provided funds to IBRA to prepare, publish, and distribute a "Bibliography of Tropical Apiculture" in 24 subject Parts. The Bibliography (Crane 1978a) has information on 145 out of 184 countries. So far it has been requested by 276 institutions in 94 developing countries. The Bibliography, with 4045 entries, is supplemented by 14 Satellite Bibliographies (Crane 1978b) with a further 2395 entries. For the first time, information that exists on tropical apiculture has been made accessible to those who want it.

The future

In the next few decades the most significant developments in apiculture, and possibly also in apicultural research, are likely to occur in the tropics. The type of movable-frame hive used today was first developed and promulgated in 1851. We ourselves are therefore living too late to share in the stimulus and excitement of the intensely inventive phase of beekeeping in the 50 years that followed. But much of the tropics and subtropics, which together represent about half of the earth's land area where beekeeping would be viable, is just about as ready — or unready — for beekeeping development as an equivalent area in the temperate regions 130 years ago. I think that in the tropics beekeeping is now at the threshold of a similar phase of innovation and expansion. This will be helped by the fact that now, for the first time, there is an organized and comprehensive information basis for such developments.

The German government aid agency Gesellschaft für Technische Zusammenarbeit (GTZ) is providing funds to IBRA for the preparation of a directory of apicultural aid programmes past and present. The work done so far on this has brought to light a complex tangle of feasibility studies and programmes, many carried out in ignorance of others in neighbouring (or even in the same) countries. It has also led to an assemblage of detailed reports, with permission for access to them by other workers in the field.

Beekeeping can add substantially to the income of peasant farmers in many of the poorest countries in the world; there is much good will to help to bring about this improvement, and it must be hoped that such an improvement can be achieved quite widely. There are reports from various countries that some peasants have tripled their whole income by keeping a few hives of bees.

Scientific Information Services on Apiculture

1919–1949: The Apis Club and *The Bee World*

The story opens after the end of the First World War, 10 years or so before the foundation of the Imperial Agricultural Bureaux. Many people at that time felt impelled to break down international barriers, and to work with specialists in other countries, for the common good in their own chosen sphere. One such person was an Egyptian physician living in England, Dr. Ahmed Zaky Abushady, who formed an association of beekeepers called the Apis Club. In June 1919 the Club published the first number of *The Bee World*; it was a monthly journal costing its subscribers 2s. 6d. per annum. Payment of 7s. 6d. entitled them to membership of the Club with attendant advantages, which included demonstrations at an experimental apiary at Benson, participation in conferences, and the use of a library. The various other ramifications and rather grandiose aims need not concern us here. There were two Directors besides Dr. Abushady: Robert Lee, Chairman of James Lee and Son Ltd of Uxbridge (predecessors of the present firm Robert Lee (Bee Supplies) Limited) and William Johnson Law, Solicitor's Managing Clerk.

In his first editorial for *The Bee World*, Abushady wrote: "Science and education have no geographical boundaries", and he looked to "the establishment of the international spirit in every branch of culture". Similar sentiments were expressed throughout the early numbers of *The Bee World*, and they are indeed very much in line with the spirit of the International Bee Research Association today. In a later issue he said that Britain had been chosen for this international experiment as being "the most democratic country".

Dr. Abushady edited *The Bee World* until 1926, by which time he had returned to Egypt; 1923–1926 were very difficult years but the Apis Club survived, although the company Bee World Ltd was voluntarily wound up in 1928 and its large debit balance written off. A new company, Apis Ltd, was formed with a working capital of £500. Before this decision was taken, some drastic changes had been effected, which put the Company's finances on a much sounder footing. During this difficult period the international character of the enterprise — which had been the primary aim of the founders — became much more marked. Extracts from journals of many countries continued to appear regularly in the feature The Press Mirror.

In January 1928 *The Bee World* was again issued on a monthly basis, edited by Captain J. P. Morgan. The no-man's land between bee farming and scientific research was by then on the way to being bridged, and in the last Editorial before his death in 1929, Morgan said: "The Apis Club is thus, inevitably, bound to become a scientific society — though one in which the practical applications of science are always kept in view. Its policy is to leave the national Beekeepers' Associations of each country to perform their obvious function — to provide practical guidance, commercial and social organisation for their members; matters in which the Club cannot intervene with profit or success, even if it were justified in making the attempt. Its function is other: to be a sort of 'Clearing House' for ideas and results of research which, by reason of language or other limitations, might not become part of the general stock of knowledge without the aid of the Club and its organ, *The Bee World*; and to provide a common arena of discussion for students of the bee of all nations."

Miss A. D. Betts, BSc, succeeded Captain Morgan, both as Managing Director and as Editor of *The Bee World*. During the war she had been engaged on aeronautical research, but she had been associated with the Apis Club since its inception in 1919, and had become expert on subjects relating to bees; she was also a most remarkable linguist. It was she who selected and translated most of the excerpts from foreign-language journals which appeared regularly in The Press Mirror, and many articles and letters had already appeared above her name. Unfortunately she was very deaf, and this made her unwilling to attend meetings; she preferred to settle problems by post. When, after 20 years, she decided to retire, she cited her (by then total) deafness as "the best of the reasons why I am not going on as Editor". Her statement included the words: "Writing the whole of each number is a thing I abhor, but during the war (1939–1945) I often had to do so". She had also written much of every issue since then, reporting on beekeeping literature that came to her, and it is therefore not surprising that there was great difficulty in finding a successor.

1949: Foundation of the Bee Research Association

After the Second World War, in 1946, there was again a resurgence of the desire to work together across national frontiers, but no new initiative seems to have arisen within the Apis Club, either in England or elsewhere. Of the Members who had been active before the War, Miss Betts was living as a recluse on account of her deafness, and Mr. L. Illingworth (Secretary since 1936) suffered from ill health. In England the forum for discussions about research had moved to a Research Committee which the British Beekeepers' Association had set up in 1945. Its members included Mr. E. G. Burtt, head of the hive manufacturers Burtt & Son in Gloucester; Major A. R. Cormack, an accountant; myself, then on the staff of the University of Sheffield; Dr. A. L. Gregg, an ophthalmologist; and Mr. E. B. Wedmore, CBE, formerly Director of the Electrical Research Association. It seemed to this eager group of people that so much needed doing, and that with the willingness to co-operate so much could be done. But funds would be needed, and the Research Committee had none except what little could be allocated from the BBKA Council. To remove this hindrance, the Committee decided that a separate research organisation, the Bee Research Trust, should be set up as a Company Limited by Guarantee, and an appeal made for funds for research and for the dissemination of information about research, through an abstract journal containing summaries of scientific papers published all over the world. This move had the full support of the BBKA, of which the new body immediately became a Specialist Member. It was incorporated on 24 January 1949, but under the name Bee Research Association (BRA): the Board of Trade had objected to the word Trust because of possible confusion with the Lawes Agricultural Trust which provided some of the funds of Rothamsted Experimental Station, where there was an important Bee Department.

At the time the BRA was formed I was in a position to undertake voluntary work, and I was appointed its Director. In the summer of the same year, 1949, I was invited by the Apis Club to succeed Miss Betts as Editor of *The Bee World*, but I was unwilling to dissipate my energies by undertaking this, unless the avowed aims of the BRA could thereby be promoted — and *The Bee World* was definitely not an abstract journal.

In August 1949 the 13th International Beekeeping Congress was held in Amsterdam. One scheduled speaker failed to arrive, and to fill the gap Mr. Burtt and I were invited to give an account of the developments mentioned above. This had the most fortunate result of enlisting co-operation from the scientists present from other European countries and from the USA: they also needed what the BRA was setting out to do. Strengthened especially by the advice of Dr. O. Morgenthaler, Head of the Bienenabteilung at Liebefeld-Bern in Switzerland, and Mr. J. I. Hambleton, Head of the USDA Bee Research Section (both long-standing supporters of the Apis Club and *The Bee World*), I gave my reply to the Apis Club. I agreed to edit *The Bee World* (another honorary job) if, and only if, the existing discursive reporting of the literature were replaced by abstracts in the style used in scientific disciplines. It was the right decision from the standpoint of BRA, but a very hard one one for the Apis Club to accept. However, it did so, and from January 1950 *Apicultural Abstracts* appeared monthly as part of *The Bee World* and was also reprinted separately. The title was proposed by Dr. C. L. Whittles of the West of Scotland Agricultural College at Auchincruive.

One of the Founder Members of BRA was Dr. D. J. Campbell, a specialist in scientific documentation who was for some years Assistant Director of ASLIB. Dr. Campbell was (and is) also an amateur beekeeper, and he devoted much time and thought to the question of a subject classification that would suit the needs of BRA, for its proposed library and bibliography and — subsequently — for *Apicultural Abstracts*. The final choice was the Universal Decimal Classification (UDC). It offered an existing general subject classification in worldwide use and, being numerical, it was independent of language. The section for the honeybee and beekeeping, 638.1, was in a rather primitive condition, and Dr. Campbell took the initiative in working out a complete revision, in consultation with myself and with G. A. Lloyd, Secretary of the British Standards Institution UDC Committee, the UK agency for the Fédération Internationale de Documentation (FID). In due course the revised form of 638.1 was approved by FID and included in the published English and German UDC schedules. In 1949 computers hardly existed, and we could not know then that a numerical classification system would benefit us 20 years later because it simplified subject indexing by computer.

An alphabetical index to descriptors selected for all UDC numbers used was accumulated on cards. In response to requests from readers of *Apicultural Abstracts*, this was published in 1968 (with revised editions in 1971, 1975 and 1979) as EASI 1, 2 and 3: English Alphabetical Subject Index to UDC numbers used by IBRA in Apicultural Abstracts.

Cumulative card indexes, by author and by subject number, were built up to entries in *Apicultural Abstracts*, first by pasting on to cards and later by a diazo process from transparent masters. In due course these were sold as CASCIAA (Complete Author and Subject Card Index to *Apicultural Abstracts*). Until 1969, when we started computer operation, they provided a unique source of information, which then covered 20 years. They have been so much used since, that they are still produced in spite of the availability of computer printouts on paper and on COM.

All the above work was done by private enterprise and enthusiasm, with support and help (especially in providing abstracts) from beekeepers and scientific institutions in a number of countries but, in the early years, without any external funding whatsoever. No other insect — and not many mammals or birds — would inspire so much dedication.

It was perhaps inevitable that the Apis Club did not survive very much longer, and it was disbanded on 31 December 1951. BRA agreed to take over publication of *Bee World* (*The* was dropped) incorporating *Apicultural Abstracts* from January 1952, and the Apis Club Library — a very large part of which in fact belonged to Miss Annie Betts — was, with her agreement, also taken over by BRA. The tide had ebbed, but a new tide was flowing strongly.

1961: BRA supported by CAB

The voluntary work was continued and consolidated; the growth of the BRA Library — and of BRA's other enterprises — is described in "Bee Research Association 1949–1974: a history of the first 25 years". But the Association still had no grant-aid, and it nearly foundered in 1955. However, in July 1956 a grant from the Development Fund was agreed by the UK Treasury, up to a limit of £500 in 1956 and £1000 for the four following years. This grant was given to provide help for the Library, for publications, and for information services; it was continued, and increased from time to time, but the strictest economy had to be practised, and there was still no question of paying a Director's salary.

It seemed to those concerned with the well-being of BRA that, since *Apicultural Abstracts* was doing for apiculture what CAB journals did for other branches of agriculture, CAB might logically be asked to provide help towards the cost of producing *Apicultural Abstracts*. I went to see Sir Herbert Howard, then Secretary of CAB, and I can still remember how affronted he was at my request that CAB might consider giving grant-aid to an outside body. Others consulted also said that it would be out of the question. In January 1961 Mr A. E. Trotman succeeded Sir Herbert as Secretary of CAB, and he had a special interest in apiculture, through his contacts with it in Africa. But he died almost immediately he took office, and was succeeded by Sir Thomas Scrivenor, CMG. Later in 1961 CAB finally agreed to make a grant to BRA (£1500 in that year); and CAB support for *Apicultural Abstracts* has continued ever since.

Meanwhile BRA had moved to Chalfont St. Peter in Buckinghamshire in 1955, for the simple reason that my husband, J. A. Crane, MBE, started working in London that year. BRA was becoming more and more of an encumbrance in the Crane household, and in 1961 Sir David Bowes Lyon, KCVO, then President of the Association, inaugurated an International Appeal to enable the Association to acquire its own headquarters. At last, in 1966, it became financially possible for BRA to purchase Hill House, a Georgian building in the same area, and by chance within a few miles of Farnham House. We received much help and good advice from Sir

Thomas Scrivenor until his retirement in 1973, and he was elected President of the Association for the term 1974–1976. He has been a permanent Vice-President since then.

1969: Canadian partnership in computer and microfiche indexing

Ever since its foundation in 1949, the work and the membership of BRA had become steadily more international. The proportion of its subscription income from countries outside the UK had grown over the years from little more than a quarter in 1955 to three-quarters in 1979. As a result of requests from bee scientists from many countries, which reached a climax at the 18th International Beekeeping Congress in Madrid in 1961, the BRA journal system was reorganised. From 1962, instead of one monthly journal, three separate quarterlies were published: *Bee World*, *Apicultural Abstracts* and *Journal of Apicultural Research*, a primary journal for research papers. The third did not become quarterly until a few years later, but is now the leading primary journal for research papers on bees and apiculture.

The Association's only link with the Commonwealth as such had been through CAB, but Canada has played a special part in its development of computer services. The Apiculture Department at the University of Guelph, Ontario, Canada, had consistently been one of the most active users of *Apicultural Abstracts*, and its Head, Professor G. F. Townsend, had been a Member of BRA Council since 1958. In 1969 an Institute of Computer Science was established at the University. Initially — but never again — capacity exceeded input, and Professor Townsend was able to have basic data for each entry in *Apicultural Abstracts* (including UDC subject numbers) key punched and stored on magnetic tape, which became IBRA Tape 1. There were of course many setbacks, and many false starts; although only 10 years ago, none of us had had any experience in the requirements and capabilities of computer handling of information. However, as a small independent body, BRA had one advantage over more complex organisations in that decisions could be made, and acted upon, quickly. Thus BRA gained several years' lead over many other abstracting journals in the computer handling of journal entries.

The most important permanent outcome of this collaboration was the publication in 1976 of "Index to Apicultural Abstracts 1950–1972" by Eva Crane & Gordon F. Townsend, published by William Dawson and Sons Ltd. for Bee Research Association. As far as we know *Apicultural Abstracts* is the first, if not the only, abstract journal to which a computer-generated cumulative index has been published in book form. The unit entry of the Index gives: author(s), year, English title (sometimes shortened), language, whether summary in English (or full translation in IBRA Library), *Apicultural Abstracts* entry number, and whether IBRA holds the original publication. Unit entries are listed in the Author Index under each author, and in the Subject Index under each UDC number, these being arranged in numerical UDC order. Keys lead from alphabetical subject descriptors to UDC numbers (as in EASI), and from numerically arranged UDC numbers to subject descriptors. All sequences of unit entries start with the most recent year (of entry in *Apicultural Abstracts*) and continue backwards in time, on the grounds that the most recent publications are likely to be the most sought after.

The closing year for Tape 1 was set at 1972 because, at the request of BRA, *Apicultural Abstracts* was included in the CAB computer-aided system of production from 1973 onwards. Dr. G. A. Somerfield was most helpful in devising a method whereby a copy of the tape containing the contents of each issue of *Apicultural Abstracts* could be sent by CAB to Guelph, and could there be reprogrammed for IBRA Tape 3, which carries the cumulative indexes for 1973 onwards. Paper printouts of updates were supplied to BRA until 1979, when they became so bulky that it was decided to switch to 270-frame microfiches. At the end of 1979 the combined indexes for seven years since 1972 occupy only 25 fiches, in spite of the fact that each unit entry contains much more information than those in the 1950–1972 Index. This form of COM (computer output microfilm) is proving very satisfactory.

Another cumulative index to apicultural literature, covering the 30 years immediately preceding *Apicultural Abstracts*, was published in 1962: "The Bee World: Index to Volume 1–30, 1919–1949" by D. J. Campbell & G. P. Henderson. IBRA Tape 2, also maintained at Guelph, carries bibliographical details of apicultural publications not on Tapes 1 and 3, i.e. not reported in *Apicultural Abstracts*. Most of these are, of course, pre-1949. In theory, the three IBRA tapes should provide a complete catalogue of individual publications in the IBRA Library, since each publication held by the Library is so indicated on the IBRA Tapes. In practice, it has so far proved impossible to obtain funds to complete Tape 2, the British Library being interested but unable to provide grant-aid to an organisation receiving regular support from the Development Commission, and the Commission being unable to fund work of this nature. So the rest of the material remains inaccessible on a subject basis, which is a great pity.

The Development Commission was, however, able to provide grant-aid towards the publication of "British Bee Books: A Bibliography 1500–1976" (International Bee Research Association 1979). The publication of bibliographies had started in 1963, and in 1978 culminated in the "Bibliography of Tropical Apiculture" in 24 Parts, with 14 Satellite Bibliographies (see p. 285).

1976: International Bee Research Association

In 1975 an International Beekeeping Congress — the 25th at Grenoble in France — once again provided the impetus for specific action by the Association. At the BRA Members' Meeting customarily held during these Congresses, a Member asked the pertinent question: "Since our Association is international in its scope and work, why is it not called the International Bee Research Association?" After wide discussion among Members, by Council, and with the Board of Trade in England with which the Association is registered, the change in name was unanimously approved at a Members' Meeting on 27 March 1976.

1980: Forecast for the future

Any forecasts relating to information services may be brusquely set aside by new techniques, not yet envisaged, that supersede those now in use. With this proviso, the following points are worth making. Some were set out in "The Future of the Bee Research Association" (in Bee Research Association 1974), and some are of more recent origin.

From the outset BRA, like the Apis Club before it, set no barriers to an international scope of its work, and actively welcomed co-operation from any country. Relations with the USDA and with corresponding organisations in countries of western Europe have been very close, and all such institutions have contributed to IBRA's information services — in kind, although not in cash. Research workers throughout the world have come to depend on IBRA, and to recognize it as their centre for scientific information and services. Moreover, apiculture is a small enough subject to be dealt with almost on a personal footing, and is exempt from many troubles that beset larger disciplines. On the other hand it is correspondingly less important financially, with the result that IBRA, its accepted "centre of excellence" which provides information services and techniques well ahead of many fields, is working in a permanently impoverished situation. In the next phase, either more working funds — not only grants for specific projects — will be provided from some of the 105 countries served, or the services will atrophy, and the best scientific apicultural library in the world is likely to be submerged into that of some larger organisation in one country or another. If this happens, bee research workers and beekeepers will lose permanently the work of the past 60 years, and the development of services tailored to suit their needs.

IBRA in relation to CAB

On the basis of the number of abstracts published each year, research on apiculture represents only about 1% of that on all branches of agriculture. IBRA therefore gains greatly by the shelter provided by CAB against many hazards faced by scientific information services, owing to the rapid advances of technologies involved, and for various other reasons. We in IBRA hope that we can continue to receive these benefits, from the headquarters staff, from Systems Group, and from the Commonwealth Institute of Entomology through which the grant towards the cost of *Apicultural Abstracts* is administered. We hope that Dr. N. C. Pant, Director of the Institute, will continue his active and benevolent interest in our affairs, from which we have already gained much.

Voluntary services

Judging by the past 50 years, it may seem inevitable that in the next half-century voluntary work in translating, abstracting, and so on, will continue to decline; the reasons are general ones and need not be set out here. Nevertheless, there have been changes during the past decade that provide some hope for the future as far as apiculture is concerned. There has been a general resurgence of interest in beekeeping throughout the world, after a period of steady decline since the sugar shortages in the 1940s. This is partly because the use of bees for cropping harvests of nectar that would otherwise go to waste is now rewarded by high prices for honey and beeswax. It is supported by the widespread move from so-called artificial foods to so-called natural ones, and an increasing awareness of ecological and environmental issues, with a recognition of the appropriateness of the study of bees in these contexts.

All these factors are likely to remain with us, and to become more effective, in the foreseeable future. Such a situation carries with it a hope for support and help from the next generations of people interested in bees — who may have the leisure, the education, and the commitment to international undertakings, that would make them useful to a scientific information centre that can use them imaginatively.

Acknowledgment

In preparing this paper, I have benefited from discussions with David G. Lowe, Assistant Editor of *Apicultural Abstracts*, on many of the points covered. All illustrations are from the IBRA Picture Collection.

References

All publications cited are in the IBRA Library, from which photocopies can be obtained in accordance with copyright regulations. The entry AA261/79 indicates an abstract in *Apicultural Abstracts* (no. 261 in the 1979 volume); AA261L/79 would indicate a listing by title only, or with a short note.

Åkerberg, E.; Lesins, K. (1949) Insects pollinating alfalfa in Central Sweden. *K. LantbrHögsk. Annlr* 16, 630–643

Åkerberg, E.; Stapel, C. (1966) A survey of pollination and seed growing of red clover in Europe. *Bee World* 47 Supplement, 15–42. AA197/67

Bee Research Association (*Ed*) (1974) Bee Research Association, 1949–1974: a history of the first 25 years. London, UK; Bee Research Association, 200 pp. ISBN 0 900149 51 5. AA388/76

Bee World (1971) The effectiveness of queen mating stations. *Bee World* 52, 8–10 *BRA Research News* No. 3

Bee World (1975/1976) Pollen and its harvesting. *Bee World* 56, 155–158; 57, 20–25 *IBRA Reprint* No. M86. ISBN 0 900149 80 9. AA588L/76

Bohart, G. E. (1972) Management of wild bees for the pollination of crops. *Annual Review of Entomology* 17, 287–312. AA277/73

Campbell, D. J.; Henderson, G. P. (1962) The Bee World: Index to the first thirty volumes, 1919–1949. London, UK; Bee Research Association, 139 pp. AA56/64

Commonwealth Secretariat; International Bee Research Association (*Eds*) (1979) Beekeeping in rural development. Unexploited beekeeping potential in the tropics, with special reference to the Commonwealth. London, UK; Commonwealth Secretariat, 200 pp. ISBN 0 85092 160 0

Crane, E. (*Ed*) (1975) Honey: a comprehensive survey. London, UK; Heinemann/International Bee Research Association, 608 pp. SBN 434 90270 5. AA 542/76

Crane, E. (*Ed*) (1976) Apiculture in tropical climates. London, UK; International Bee Research Association, x+208 pp. ISBN 0 900149 85 X. AA1155/77

Crane, E. (1978a) Bibliography of tropical apiculture. London, UK; International Bee Research Association, 380 pp. ISBN 0 86098 030 8

Crane, E. (1978b) Bibliography of tropical apiculture. Satellite bibliographies. London, UK; International Bee Research Association, 273 pp. ISBN 0 86098 076 6

Crane, E. (1978c) The Varroa mite. *Bee World* 59, 164–167 *IBRA Research News* No. 16. AA1040/79

Crane, E. (1980) The scope of tropical apiculture. *Bee World* 61, 19–28 *IBRA Reprint* No. M102. ISBN 0 86098 085 5

Crane, E.; Townsend, G. F. (1976) Index to Apicultural Abstracts 1950–1972. London, UK; Wm. Dawson for International Bee Research Association 1824 pp. ISBN 0 7129 0684 3. AA493/77

Dadant & Sons (*Eds*) (1975) The hive and the honey bee. Illinois, USA; Dadant & Sons, 740 pp. AA859/77

De Jong, D.; Morse, R. A. (1979) Annotated bibliography on *Varroa jacobsoni*, *Tropilaelaps clareae* and *Euvarroa Sinhai*. Bibliography, International Bee Research Association No. 15, 36 pp. ISBN 0 86098 084 7

Dugat, M. (1946) La ruche gratte-ciel à plusieurs reines. Marlieux, France; Abbaye de N.D. des Dombes, 54 pp.

Dugat, M. (1948) The skyscraper hive. London, UK; Faber and Faber, 78 pp.

Dyce, E. J. (1975) Producing finely granulated or creamed honey. In: Crane, E. (*Ed*) Honey: a comprehensive survey. London, UK; Heinemann/International Bee Research Association, p. 293–306. SBN 434 90270 5

Farrar, C. L. (1946) Two-queen colony management. *Publication, United States Bureau of Entomology* No. E-693, 14 pp.

Farrar, C. L. (1955) Two-queen colony management. *Bee World* 34, 189–194 *IBRA Reprint* No. M13. AA33/55

Farrar, C. L. (1958) Two-queen colony management for production of honey. *Publication, United States Department of Agriculture* No. ARS–33–48, 11 pp. AA96/61

Fletcher, D. J. C. (*Ed*) (1977) African bees: taxonomy, biology and economic use. Pretoria, South Africa; Apimondia, 207 pp. AA861/78

Free, J. B. (1967) Factors determining the collection of pollen by honeybee foragers. *Animal Behaviour* 15, 134–144

Free, J. B. (1970) Insect pollination of crops. London, UK; Academic Press, 544 pp. AA478/71 Reprinted 1979. SBN 12 266650 X

Gary, N. E. (1963) Observations of mating behaviour in the honeybee. *Journal of Apicultural Research* 2, 3–13. AA792/64

Ghisalberti, E. L. (1979) Propolis: a review. *Bee World* 60, 59–84 *IBRA Reprint* No. M99. ISBN 0 86098 078 2

Greenberg, B.; Kunich, J. C.; Bindokas, V. P. (1978) The effects of high voltage transmission lines on honey bees. Palo Alto, CA, USA; Electric Power Research Institute, 82 pp.

Hobbs, G. A. (1972) Beekeeeping with alfalfa leafcutter bees in Canada. *Bee World* 53, 167–173 *BRA Reprint* No. M66. AA984L/73

Hocking, B. (1950) The honeybee and agricultural chemicals. *Bee World* 31, 49–53. AA158/52

Inoue, T.; Inoue, A. (1964) The world royal jelly industry: present status and future prospects. *Bee World* 45, 59–67, 69. AA842/65

International Bee Research Association (1979) British bee books: a bibliography 1500–1976. London, UK; International Bee Research Association, 270 pp. ISBN 0 86098 077 4

International Bee Research Association (1979) EASI 3: English alphabetical subject index to Universal Decimal Classification numbers used by the International Bee Research Association in Apicultural Abstracts and in subject indexes. Third enlarged edition. London, UK; International Bee Research Association, 114 pp. ISBN 0 86098 057 X

International Symposium on Pollination, Proceedings: (1962) Stockholm; Swedish Seed Growers' Association, 224 pp. AA434/63

International Symposium on Pollination, Proceedings: (1966) *Bee World* 47 Supplement, 216 pp. AA191/67

International Symposium on Pollination, Proceedings: (1975) *Bulletin Technique Apicole* 2 Supplement, 331 pp. AA1197/76

International Symposium on Pollination, Proceedings: (1979) *Special Miscellaneous Publication, Maryland Agricultural Experiment Station* No. 1, viii+541 pp.

International Trade Centre, UNCTAD/GATT (1977) Major markets for honey: openings for quality supplies from developing countries. Geneva, Switzerland; International Trade Centre, UNCTAD/GATT, xiv+120 pp. AA590/78

International Trade Centre, UNCTAD/GATT (1978) World market for beeswax: a high-value product requiring little investment. Geneva, Switzerland; International Trade Centre, UNCTAD/GATT, viii+105 pp. AA 1348/78.

Jay, S. C. (1979) The essence of beekeeping. *Bee World* 60, 140–142

Johansen, C. A. (1966) Digest on bee poisoning, its effects and prevention, with an annotated list of 92 insecticides. *Bee World* 47, 9–25 *BRA Reprint* No. 28. AA544/66

Johansen, C. A. (1979) Honeybee poisoning by chemicals: signs, contributing factors, current problems and prevention. *Bee World* 60, 109–127 *IBRA Reprint* No. M100. ISBN 0 86098 080 4

Johansson, T. S. K. (1955) Royal jelly. *Bee World* 36, 3–13, 21–32. AA211/56

Johansson, T. S. K.; Johansson, M. P. (1958) Royal jelly. II. *Bee World* 39, 254–264, 277–286. AA227/59

Johansson, T. S. K.; Johansson, M. P. (1971) Substitutes for beeswax in comb and comb foundation. *Bee World* 52, 146–156. AA381/73

Laidlaw, H. H. (1977) Instrumental insemination of honey bee queens. Illinois, USA; Dadant & Sons, 144 pp. AA924/78

McGregor, S. E. (1973) Insect pollination — significance and research needs. *American Bee Journal* 113, 249; 294–295; 330–331. AA509L/74

McGregor, S. E. (1976) Insect pollination of cultivated crop plants. *Agricultural Handbook, United States Department of Agriculture* No. 496, 411 pp. AA1088/77

McKellar, P. (1957) Imagination and thinking: a psychological analysis. London, UK; Cohen & West.

Michener, C. D. (1974) The social behavior of the bees: a comparative study. Cambridge, MA, USA; Belknap Press, xii+404 pp. SBN 674 81175 5. AA579/75

Moeller, F. E. (1976) Two-queen system of honey bee colony management. *Production Research Report, United States Department of Agriculture* No. 161, 11 pp. AA1262/77

Morse, R. A. (1965) The effect of light on comb construction by honeybees. *Journal of Apicultural Research* 4, 23–29. AA112/66

Morse, R. A.; Benton, A. W. (1964) Notes on venom collection from honeybees. *Bee World* 45, 141–143. AA339/66

Morse, R. A. (*Ed*) (1978) Honey bee pests, predators, and diseases. Ithaca, USA; Cornell University Press, 430 pp. ISBN 0 8014 0975 6. AA1016/79

Nye, W. P.; Mackensen, O. (1970) Selective breeding of honeybees for alfalfa pollen collection: with tests in high and low alfalfa pollen collection regions. *Journal of Apicultural Research* 9, 61–64. AA153/72

Praagh, J. P. van (1974) De ontwikkeling van een klimaatkamer voor de honingbij (*Apis mellifera L.*) Doctor in de Wiskunde en de Natuurwetenschappen, Rijksuniversiteit te Utrecht, Netherlands, 17 pp. AA436/78

Ruttner, F. (*Ed*) (1975) The instrumental insemination of the queen honeybee, 2nd edn. Bucharest, Romania; Apimondia, 122 pp. AA822/76

Ruttner, F.; Koeniger, N. (*Eds*) (1977) Bienenhaltung in Flugräumen: Symposium über Flugraumtechnik. *Insectes Sociaux* 24, 279–302. AA827/78

Saubolle, B. R.; Bachmann, A. (1979) Beekeeping: an introduction to modern beekeeping in Nepal. Kathmandu, Nepal; Sahayogi Prakashan, 64 pp.

Stanley, R. G.; Linskens, H. F. (1974) Pollen: biology — biochemistry — management. Berlin; Springer-Verlag, ix+307 pp. ISBN 3 540 06827 9. AA585/76

Stapel, C. (1961) Undersøgelser over duftfodring af honningbier med henblik på rødkløverens bestøvning. *Tidsskrift for Planteavl* 65, 477–518. AA153/63

Stephen, W. P. (1965) Artificial beds for alkali bee propagation. *Station Bulletin, Oregon Agricultural Experiment Station* No. 598, 20 pp. AA586/69

Stevenson, J. H.; Needham, P. H.; Walker, J. (1978) Poisoning of honeybees by pesticides: investigations of the changing pattern in Britain over 20 years. *Rothamsted Report for 1977* Part II, 55–72

Taylor, O. R., Jr. (1977) The past and possible future spread of Africanized honeybees in the Americas. *Bee World* 58, 19–30 *IBRA Reprint* No. M89. AA926/77

Townsend, G. F. (1975) Processing and storing liquid honey. In: Crane, E. (*Ed*) Honey: a comprehensive survey. London, UK; Heinemann/International Bee Research Association, p. 269–292. SBN 434 90270 5

Vernon, F. G. (1979) Beekeeping in 1269–1270 at Beaulieu Abbey in England. *Bee World* 60, 170–175

Waite, M. B. (1895) The pollination of pear flowers. *Bulletin, Division of Vegetable Physiology and Pathology, United States Department of Agriculture* No. 5

Walker, A. P. (1976) Annotated bibliography on propolis, 1976. *Bibliography, International Bee Research Association* No. 16, 14 pp. ISBN 0 900149 82 5. AA670L/77

Watson, L. R. (1927) Controlled mating of queen bees. Hamilton, IL, USA; American Bee Journal, 50 pp.

Weaver, N. (1979) Possible recruitment of foraging honeybees to high-reward areas of the same plant species. *Journal of Apicultural Research* 18, 179–183

Wilson, E. O. (1971) The insect societies. Cambridge, Mass., USA; Harvard University Press, x+548 pp. SBN 67445901. AA15/73

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