BEEKEEPING IN THE UNITED STATES

Agriculture Handbook No. 335

Agricultural Research Service

UNITED STATES DEPARTMENT OF AGRICULTURE

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Washington, D.C.

Issued August 1967

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price $1

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INTRODUCTION

By S. E. McGREGOR, *Chief, Apiculture Research Branch, Entomology Research Division, Agricultural Research Service*

Requests are frequently received by the U.S. Department of Agriculture for "all available information on honey bees." Such requests usually indicate the writer is unaware that several thousand books are written on bees, over a hundred bee magazines are issued regularly, and hundreds of technical articles on bees are published annually in every major language of the world.

What is really wanted and is supplied is a pamphlet, ARS 33-10-4, Information About Bee Culture. This pamphlet gives basic information about a hive of bees and where other bee information and supplies can be obtained.

This handbook on beekeeping is for the established beekeeper, the extension specialist, teachers, and those who desire to know more about bees. It includes information about the colony and its activity as affected by external environment or beekeeper manipulations, the makeup of the beehive, bee behavior, honey production, honey plants, use of bees in pollinating crops, and bee diseases.

Extreme variations in climate and flora affect bees. For example, a beekeeper in the extreme Northern States places his colonies where they will obtain maximum sunlight, whereas a beekeeper in the arid Southwest will supply them with shade. Bees may be storing nectar in the fall in the Deep South when colonies in the North are buried by snow. After a mild winter in the South, bees may again be storing a crop of honey from orange blossoms, while those in the Far North are still in their winter cluster. In general, however, basic information applies to the bee colony wherever it is located, cold or hot, wet or dry. This information is included in this handbook.

This publication has been prepared by U.S. Department of Agriculture specialists in beekeeping or bee products. Like other groups, these specialists do not agree on all details in every phase of apiculture. An attempt has been made here to give basic information without personal bias.

HISTORY OF BEEKEEPING IN THE UNITED STATES

By Eric V. Nelson, *apiculturist, Entomology Research Division, Agricultural Research Service* [1]

Beekeeping was unknown in the Western Hemisphere until after the first European settlers arrived. The natives of the West Indies used honey and waxes, which probably came from the native stingless bees (Meliponinae). Wax may also have been obtained as a plant derivative. The Indians of North America referred to honey bees as the "the white man's fly," and regarded their presence as indicating the coming of white settlers.

The actual date of importation of the first colonies of honey bees (*Apis mellifera* L.) to North America is unknown. It was during early colonization, since bees were important in the rural European economy. In 1622, bees were in Virginia; by 1648, beeswax and honey were abundant. In 1640, the town of Newbury, Mass., established a municipal apiary. (The expert put in charge became the town's first pauper.) In 1641, bee colonies in New England were sold for 5 pounds apiece, the equivalent of 15 days of labor by a skilled craftsman.

In 1763, the English introduced colonies of bees into Florida, although they may have been brought earlier to St. Augustine by the Spanish. In 1773, a single colony was taken from Florida to Mobile, Ala. By the end of the 18th century, bees were fairly common throughout the eastern half of the continent.

Bees reached the West from two very diverse sources. In 1809, bees were imported to Alaska from Russia by a Russian monk. In 1830, they were carried to California from Alaska. There is no record to indicate that these colonies survived. However, in 1856, gray-banded bees were found in the wild in California. These may have been descendants of the original Alaskan imports. In 1853, the first importations to California from the Eastern United States occurred, followed by extensive importations beginning in 1856. California soon became one of the most important beekeeping areas in the country.

The Golden Age of Beekeeping

Beekeeping in the American colonies declined rapidly after 1670, probably because of the disease now known as American foulbrood. The primitive beekeeping practices of the day made proper care and inspection of bees impossible. This situation continued for another century and a half. Not until the middle of the 19th century did a significant advance in beekeeping methods occur.

In 1828, Moses Quinby took up beekeeping in New York; in 1837, the Reverend Lorenzo Langstroth acquired two hives in Andover, Mass. These two men revolutionized the bee industry in the United States. Publication of their books in about 1852 signaled the advance to begin.

From then to the beginning of World War I, virtually every modern beekeeping method and much of the modern equipment were devised. It was truly "The Golden Age of Beekeeping."

Movable-Frame Hive and Bee Space

Prior to the time of Langstroth, bees were kept in a section of hollow log, a wooden box, or a straw skep, in which they were allowed to build comb in any way that instinct indicated. Inspection of the combs and removal of honey could only be accomplished by seriously disrupting or destroying the colony. In a few instances a honey "super" (a second box placed over the first and the two connected by a bee passageway) was employed. The beekeeper could remove honey from the super without destroying the colony, but could not inspect or manipulate the makeup of the colony.

For centuries the Greeks had used beehives, in which the combs were suspended from bars of wood placed across the top that permitted removal of individual combs. This method apparently made little impact on the rest of Europe until Dzierzon, a German clergyman, improved and used it in Germany during the early 19th century. Huber, a blind Swiss naturalist, then designed a hive, in which frames supported the comb on all four sides and were hinged to spread apart like pages of a book. Langstroth's discovery of "bee space" was the one feature needed to unite the hive designs of Dzierzon and Huber into a successful hive. Previous to Langstroth's discovery, practical use of a four-sided frame failed because it was designed to fit closely to the sides and top of the hive. Langstroth found that bees preferred a passageway of about three-eighths inch. A narrower space was sealed with propolis, which made removal of combs difficult. The bees were inclined to build comb in wider spaces.

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[1] In cooperation with Louisiana Agricultural Experiment Station.

Development of Modern Equipment

Langstroth's discovery of bee space led directly to the development of the modern hive. With the publication of his results, the U.S. Government Patent Office was deluged with designs for new hives. Every imaginable variation of Langstroth's design was attempted, many to avoid infringement on his patent. The fact that the patented feature was bee space, and not the frame itself, was ignored. Although Langstroth's patent was clearly valid, he had neither financial nor physical resources for the long court battles that followed, and he soon gave up the struggle to protect his patent. The deluge of hive designs ended; only a few sizes of hives are still in use today.

During this period the industrial revolution affected beekeeping, resulting in machine production of standard-sized interchangeable frame and hive. Two inventions, the wax comb foundation and the centrifugal honey extractor, completed the evolution of beekeeping from a tiny farming sideline to its present commercial status. Wax comb foundation is simply a sheet of wax impressed with the shape of worker cell bases and placed in the frame. The first foundation was produced by a German, Johannes Mehring, in 1857. A roller press to produce foundation commercially was developed in 1876 by A. I. Root. Finally the use of wire bracing in the foundation was developed by J. E. Hetherington. Further development of the wax foundation has been a process of refinement rather than innovation.

The idea of a centrifugal honey extractor came from an Austrian, Major Hrushka. Prior to his invention, honey could only be removed by cutting the comb from the frames, crushing it, and straining the honey from the wax. This was both time consuming and costly. Until the development of the extractor, the biggest seasonal honey crop for one beekeeper was obtained by Quinby and amounted to only 10 tons. Hrushka's extractor was modified by Langstroth, Dadant, Quinby, and many others. The first commercial extractor was marketed in 1870 by H. O. Peabody. The extractor made liquid honey available on a commercial scale previously unknown. However, many people refused to believe that it was pure honey, and several years passed before it was accepted by the public. Once public acceptance was won, extracted honey became the principal product of the American beekeeping industry.

Another equally indispensable development of the period included the bee smoker. The Porter bee escape and metal queen excluders were also developed. All are used by beekeepers today and have changed only slightly since their original development.

New Strains or Races of Bees

The bees in North America until the middle of the 19th century were descended from the British and German stocks brought over by the early colonists. They were highly susceptible to European foulbrood, swarmed excessively, and were difficult to handle. The renewal of beekeeping stimulated a worldwide search for new and more satisfactory strains or races of bees. Langstroth, Dadant, Frank Benton, and others led the way in this search.

After many disappointments, three significantly superior races were established and accepted in the United States. These were the Italian, the Caucasian, and the Carniolan races.

It is unlikely that any of the strains or races brought from Europe were pure when they arrived, and less likely that they remained pure after arrival in the United States. Only since the development of techniques for controlled mating has maintenance of pure strains or races of bees become possible.

The new stock of bees arrived at a time when great strides were being made in forcing colonies to rear queens. This development, combined with the discovery that queens could be shipped through the mail, made the purchase of queens by every beekeeper an easy matter. The new stock spread rapidly across the country; the Italian race soon became the most popular.

The Modern Era

At the beginning of World War I, the "Golden Age of Beekeeping" drew to a close. Interest in bees became increasingly commercialized and small farm apiaries declined. Beekeeping as a hobby was increasing.

The 20th century has been one of rapid technological achievement in beekeeping as in other industries. Apiculture research facilities have been established. The honey bee has become important not only as a producer of honey and wax and as a pollinator but also as a research animal in biological studies.

The package bee industry, by which bees raised in the Southern States and California are sent all over the United States and to other countries, was started just prior to World War I. It has been of great value to beekeepers in the Northern States and Canada, where cold weather makes successful wintering of colonies difficult. Many beekeepers in these areas kill their bees in the fall, then restock with a young queen and bees in the spring.

With controlled mating of bees now a refined and dependable method, at least two strains of hybrid bees have been made available to the beekeeper; more are certain to follow. In the future most of the queens used by beekeepers will probably be artificially inseminated, and the modern beekeeper will use different strains of bees for different areas and purposes.

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SEASONAL COLONY ACTIVITY AND INDIVIDUAL BEE DEVELOPMENT

By Norbert M. Kauffeld, *apiculturist, Entomology Research Division, Agricultural Research Service* [1]

Seasonal Colony Activity

Basically a colony of honey bees comprises a cluster of several thousand workers (sexually immature females), a queen (a sexually developed female), and, depending on the colony population, an undeterminate number of drones (sexually developed males) (fig. 1). A colony normally has only one queen, whose sole function is egg laying and not colony government. The bees cluster loosely over several wax combs, the cells of which are used for the storage of honey (carbohydrate food) and pollen (protein food) and for the rearing of young bees to replace old adults.

The activities of a colony vary with the seasons. The period from September to December might be considered the beginning of a new year for a colony of honey bees. The condition and activity of the colony at this time of year to a great degree affect its prosperity for the next year. In the fall the night temperatures decrease and the days shorten. Plant growth, nectar secretion, and flower characteristics respond in various ways that affect the activity of the bee colony.

Reduced incoming food causes reduced brood rearing and diminishing population. The proportion of old bees in the colony will begin to increase, since young bees emerging in the fall live longer. Many of the fall bees survive the winter. Propolis collected from the buds of trees is used to seal all cracks and reduce the entrance to keep out cold air.

When nectar supplies in the field become scarce, the workers drag the drones out of the nest and do not let them return, causing death by starvation. This elimination of drones reduces the consumption of winter honey stores. If the queen is old, she may be killed by the workers during late summer and replaced by a young mated one before the drones disappear.

When the temperature drops into the 50's, the bees begin to form a tight cluster. Within this cluster the brood (consisting of eggs, larvae, and pupae) is kept warm, with heat generated by the activity of the bees feeding on the stored honey. The egg laying of the queen bee tapers off

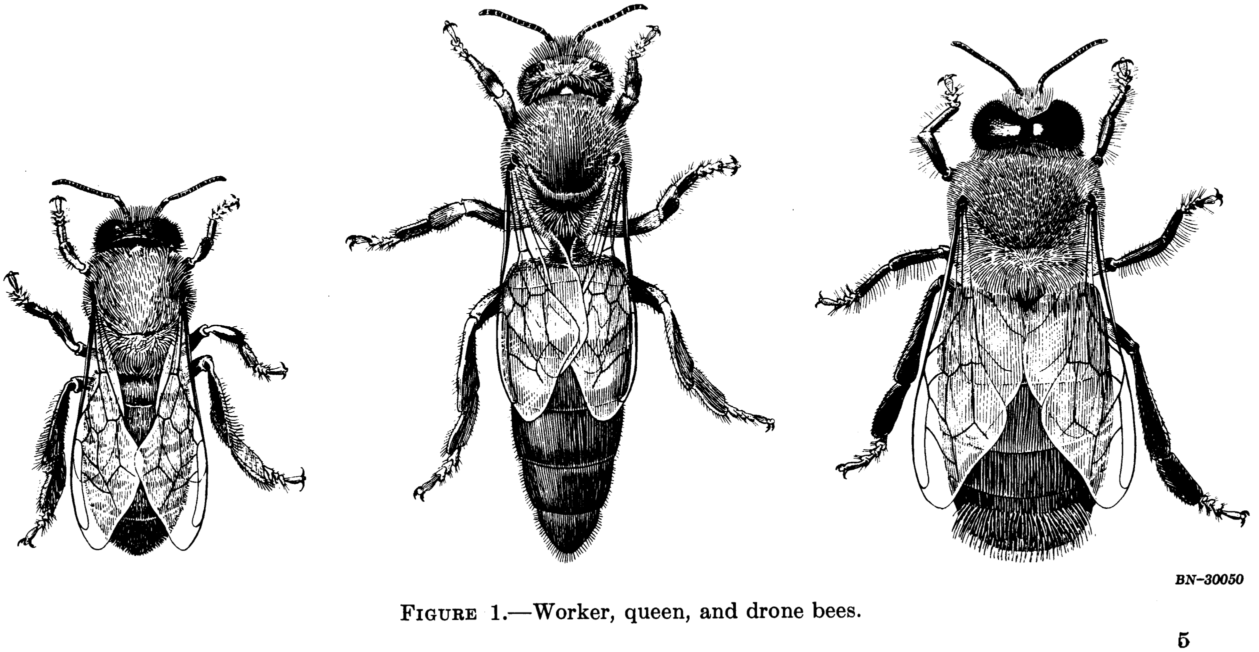

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Figure 1.—Worker, queen, and drone bees.

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[1] In cooperation with Wisconsin Agricultural Experiment Station.

and may stop completely during October or November, even if pollen is stored in the combs. During the winter the colony is put to its severest test of endurance.

As temperatures drop, the bees draw closer together to conserve heat. The outer layer of bees is tightly compressed, insulating the bees within the cluster. As temperatures rise and fall, the cluster expands and contracts. The bees within the cluster have access to the food stores. During warm periods, the cluster shifts its position to cover new areas of comb containing food. An extremely prolonged cold spell can prohibit cluster movement, and the bees may starve to death only inches away from food.

The queen stays within the cluster and moves with it as it shifts position. About mid-January to early February if the colony is well supplied with honey and pollen, it will begin to stimulatively feed the queen and she begins egg laying. This new brood aids in replenishing the number of bees that have died during the winter. The extent of this early brood rearing is determined by pollen stores gathered during the previous fall. A lack of pollen delays brood rearing until more is collected from spring flowers, and the colony emerges from winter in a weakened condition.

The colony population during the winter decreases because few young bees emerge to replace those dying. Colonies with plenty of young bees during the fall and an ample supply of pollen and honey for winter usually have a strong population in the spring.

During early spring the lengthening days and new sources of pollen and nectar stimulate brood rearing. The bees also gather water to liquefy thick or granulated honey in the preparation of brood food. Rarely will there be any drones within the colony at this time of the year.

Later in the spring the population of the colony expands rapidly and the proportion of young bees increases. As the population increases, the field-worker force also increases. It may collect nectar and pollen in greater amounts than is needed to maintain brood rearing, and surpluses of honey or pollen may accumulate. This, of course, will depend upon the availability of plants that produce pollen and nectar.

As the days lengthen and the temperature continues to increase, the cluster expands further and drones are produced. With increase in brood rearing and the accompanying increase in adult bees, the nest area of the colony becomes crowded. More bees will be evident at the entrance of the nest. A telltale sign of overcrowding is to see the bees crawl out and hang in a cluster around the entrance on a warm afternoon.

Combined with crowded conditions, the queen also increases drone egg laying in preparing for the natural division of the colony population by swarming. In addition to rearing workers and drones, the bees also prepare to rear a new queen. A few larvae that would normally develop into worker bees are fed a special food called royal jelly, their cells are altered to handle the larger queen, and her rate of development is speeded up. The number of queen cells produced will vary with races and strains of bees as well as individual colonies.

Regardless of its crowded condition, the colony will try to expand by building new combs if food and room are available. These new combs are generally used for the storage of honey, whereas the older combs are used for pollen storage and brood rearing.

When the first virgin queen is about ready to emerge and prior to the main nectar flow, the colony will swarm during the warmer hours of the day. The old queen and about half of the bees will rush en masse out the entrance hole. After flying around in the air for several minutes, they will cluster on a limb of a tree or similar object. This cluster usually remains an hour or so, depending on the time taken to find a new home by scouting bees. When it is found, the cluster breaks up and flies to it. On reaching the new location, combs are quickly constructed, brood rearing starts, and nectar and pollen are gathered. Swarming generally occurs in the Central States during May or June, although it can occur at almost any time from April to October.

After the swarm departs, the remaining bees in the parent colony continue their field work of collecting nectar, pollen, propolis, and water. They also care for the eggs, larvae, and food, guard the entrance, and build combs. Emerging drones are nurtured so that there will be a male population for mating the virgin queen. When she emerges from her cell, she eats honey, grooms herself for a short time, and then proceeds to look for rival queens within the colony. Mortal combat eliminates all queens except one. When the survivor is about a week old, she flies out to mate with one or more drones in the air. The drones die after mating, but the mated queen returns to the nest as the new queen mother. Nurse bees care for her, whereas prior to mating she was ignored. Within 3 or 4 days the mated queen begins egg laying.

During hot summer days the colony temperature must be held down to 93° F. The bees do this by gathering water and causing it to evaporate within the cluster by its exposure to air circulation.

During the early summer the colony reaches its peak population necessary for the collection of the greatest amount of nectar and the storage of honey for the coming winter. After reproduction, all colony activity is geared toward winter survival.

Summer is the most favorable time for the storage of food supplies. More food is available and warm weather permits free flight. The daylight period is the longest then, permitting maximum foraging, although rain or drought may reduce flight and the supply of nectar and pollen available in flowers. It is during the summer that stores are accumulated for winter. At times enough is stored that man can remove a portion and still leave ample for colony survival.

Individual Bee Development

The queen lays small, elongated, white eggs, one attached to the base of each cell. The egg remains in an upright position for 3 days, then a larva hatches.

The larva, a small white grub, is mass fed royal jelly by nurse bees for the first 2 days to such an extent that it literally floats in this food. For the next 4 days the worker larva is fed a less nutritious food at regular intervals (progressive feeding) by a different group of nurse bees. During these feeding periods it grows rapidly to several times its size at hatching, and soon occupies the greater part of its cell. Its cell is capped on the ninth day after hatching. No feeding occurs after the cell is capped.

The next 12 days are spent in the capped cell in prepupal and pupal stages. Following the fifth or last larval molt, which occurs 2 or 3 days after the cell is capped, the distinct adult body parts appear, such as legs, antennae, wings, mouth parts, head, thorax, abdomen, and eyes. Initially the pupa is white and extremely soft textured, but as it grows, to emerge from the cell as an adult, it changes from white to a darker gray and finally to its adult color. Hair develops on the various body areas, and on the day before emergence it completes its sixth and final molt. On the 21st day the young worker bee cuts its way through the capping and crawls out of the cell as a physically adult honey bee.

The activity of a honey bee within the colony varies according to its age and the development of its internal glands. During the first 3 days following emergence, it aids in cleaning the nest area. From the fourth to seventh day after emergence, it feeds older larvae with mixtures of honey and pollen. About the seventh day after emergence its pharyngeal glands become developed and it produces royal jelly. As such a nurse bee, it mass feeds the young larvae or queen until it is 10 to 13 days old.

About the 12th day of its life the wax glands, located between the fourth and seventh segments on the undersurface of the bee's abdomen, develop. Through some still unknown body process honey is eaten and converted into beeswax, which is secreted as small scales between these segments. The flakes of wax are kneaded by mandibular action into cell walls in the construction of combs. When the bee is about a week old, it takes short orientation flights during the afternoon to memorize its home location. Various activities such as the conversion of nectar into honey, packing pollen pellets in the cells, handling water brought in for air-conditioning, fanning for ventilation, and guarding the entrance are performed until about the 21st day, after which it begins foraging for food.

Adult honey bee workers live about 6 weeks during the peak activity periods of late spring, summer, and early fall. Most of them die in the field. Those that die in the nest are carried out some distance from the entrance and dropped to the ground.

The development period of drones from egg stage to adult is 24 days compared with 21 days for workers and 16 for queens. They are larger than workers, do not have stings, and are generally fed by the workers. Their activity consists merely in eating honey and making flights from the nest for possible mating with a virgin queen bee. They live about 8 weeks during the active season but are killed off in the fall at any age.

The queen bee, which is longer than the worker or drone (fig. 1), has the shortest period of development from egg stage to adult. Her diet from the larval stage throughout her entire life seemingly is royal jelly, although she can eat honey herself. The nurse bees groom and care for her bodily needs from feeding to removal of feces. Her sole function within the colony is to lay eggs for the production of the necessary bee population needed to store sufficient food supplies for survival. Her life expectancy is about a year, but some queens have been reported to live up to 6 years. She gives off a substance that has a stabilizing effect on the colony.

The coloration of honey bees varies with the races and strains. Usually the more distinctive patterns separate one species from another.

For additional information about colony activity and bee development, see pages 23–30.

DEVELOPMENT OF AMERICAN BEEHIVE

By Spencer M. Riedel, Jr., *apiculturist, Entomology Research Division, Agricultural Research Service*[1]

The modern American beehive (fig. 1), commonly called the Langstroth hive, permits development of a strong colony and production of a large honey crop. With it the beekeeper has control over the bees. It is simple in design, mobile, light, durable, and economical. Its components are interchangeable with those of other hives.

The dimensions for a Langstroth 10-frame hive are given in figure 2. Basically the queen and her brood are confined in the brood chamber. The worker bees can pass through the queen excluder and store honey in the super. Since one shallow super is not enough space for a populous colony, beekeepers often use several supers. The brood chambers and supers are used interchangeably. If the combs contain brood, the section is referred to as a brood chamber; if no brood is present, it is called a super.

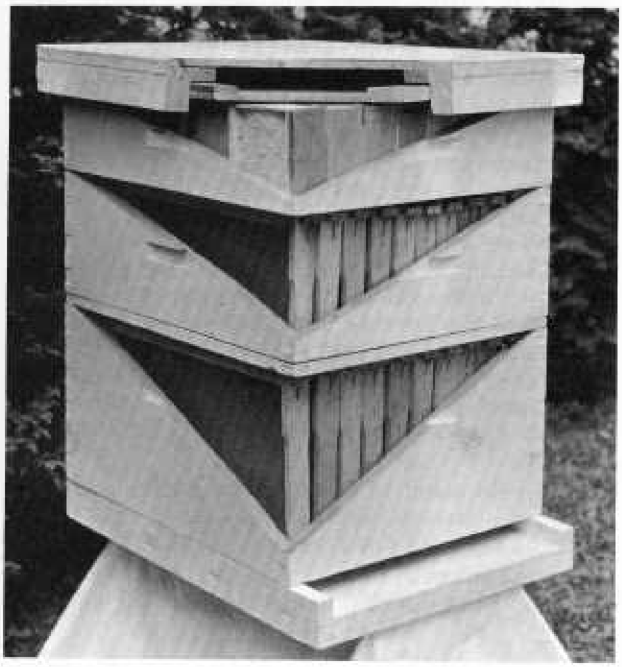

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Figure 1.—Modern beehive cut away to show interior and placement of movable frames: Bottom, full-depth hive body; middle and top, shallow hive bodies.

The shallow super is frequently used in production of liquid or extracted honey, when honeycomb is to be cut from the frame, or when special comb sections are to be filled with honey and then individually removed.

Several variations of the Langstroth hive are used to a limited extent. They include the 8-frame Langstroth, the modified Dadant that holds 11 frames, the 12-frame Langstroth, and a square hive that holds 13 frames but is only 6½ inches deep. The most popular is the full-depth 10-frame Langstroth for both brood nest and honey storage.

Early-American beekeepers kept colonies of bees in hollow tree trunks, which for convenience and safety were gathered together in an apiary, or a "bee yard." Since many of these logs came from gum trees, the log hive became a "bee gum." This term is rapidly disappearing, but the terms "hive" and "colony" remain synonymous.

In 1921, Dadant & Sons perfected a method of inserting vertical wires into the foundation. This extra support of the comb was beneficial when beekeepers began using high-speed extractors. An aluminum comb was developed but was unacceptable to the bees. Both aluminum and plastic foundations have also been developed. They are embossed with the cells and coated on each side with beeswax. Since aluminum is a good conductor of heat, it is not satisfactory in brood rearing areas of the hive. Neither of these permanent base materials is readily accepted by the bees unless properly installed in the frames and supplied to the bees during a heavy honey flow.

The best foundation is still beeswax held firmly in the frame with embedded wires. The best type of hive under most conditions is the Langstroth 10-frame hive.

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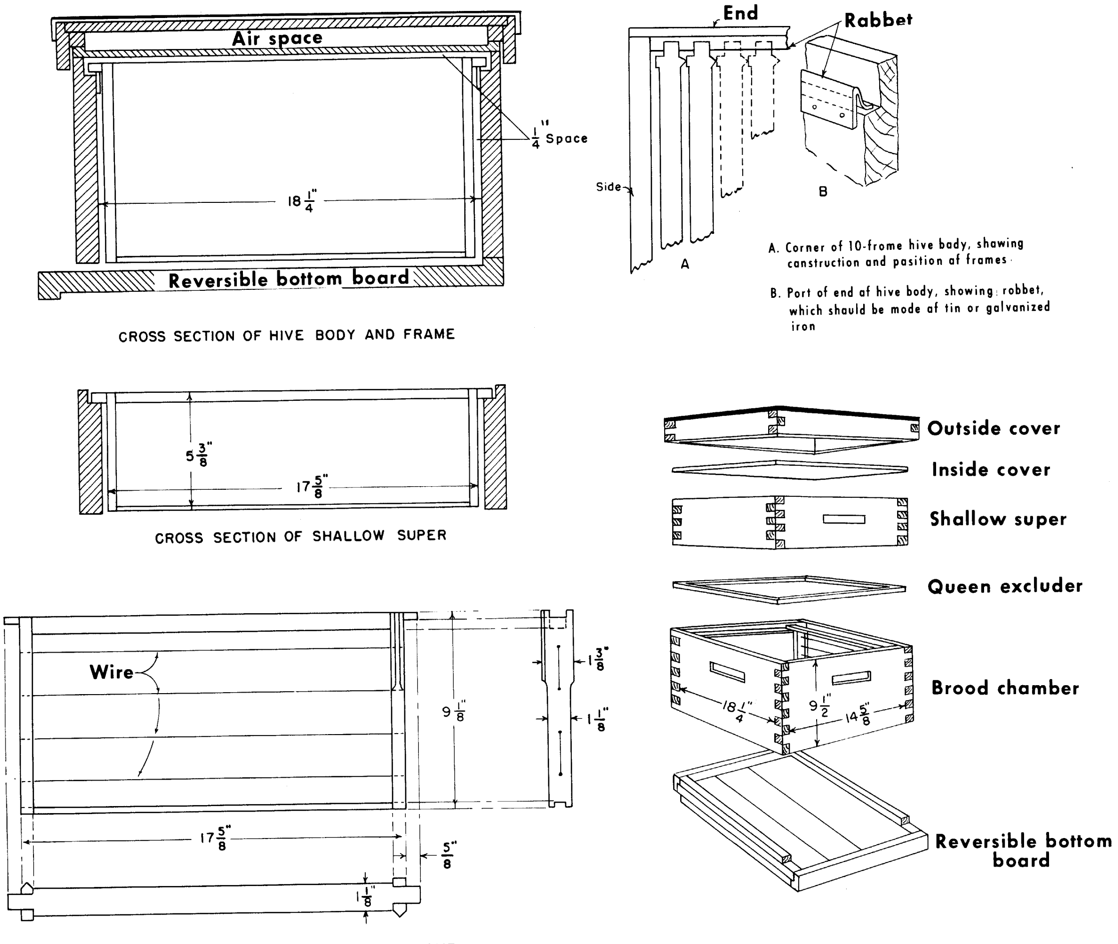

CROSS SECTION OF HIVE BODY AND FRAME

A. Corner of 10-frame hive body, showing construction and position of frames.

B. Part of end of hive body, showing rabbet, which should be made of tin or galvanized iron

CROSS SECTION OF SHALLOW SUPER

SIDE, END, AND TOP ELEVATION OF FRAME

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FIGURE 2.—Plans and dimensions for Langstroth 10-frame beehive.

NECTAR AND POLLEN PLANTS

By E. OERTEL, *apiculturist, Entomology Research Division, Agricultural Research Service*[1]

In order to manage bee colonies for successful honey production, a beekeeper must have available data on the nectar and pollen plants in the vicinity of his apiary. Such information enables him to calculate when he should install package bees, divide colonies, put on supers, use swarm-control measures, remove honey, requeen, prepare colonies for winter, and locate profitable apiary sites.

Vansell[2] listed 150 species of nectar and pollen plants in California, but only six are principal sources for commercial honey production. He[3] listed about 90 species of nectar and pollen plants in Utah, but noted that the main sources of commercial honey are alfalfa and sweetclover. Wilson et al.[4] observed honey bees visiting the blossoms or extrafloral nectaries of 110 species of plants in Colorado, of which the most important honey sources are alfalfa, yellow sweetclover, and dandelion.

Beekeepers are advised to record the blossoming period for the nectar and pollen plants in their vicinity. Most State agricultural extension services have bulletins available on beekeeping. These usually contain a list of the important nectar and pollen plants. Unknown plants can be sent to the botany department of the State university or agricultural college for identification.

Beekeeping Locations

Beekeepers, especially commercial operators, have learned that the nectar- and pollen-producing plants may change considerably over the years. Variations may be caused by droughts, changes in agricultural crops and practices, irrigation projects, and subdivision development. Changes have been particularly rapid since World War II and are likely to continue.

Acreages planted to buckwheat, alsike clover, and cotton have decreased, whereas those with alfalfa hay, mustard, safflower, and soybeans have increased. Soybean crops increased from 12 million acres in 1949 to about 32 million in 1964. In some States certain soybean varieties are reported to be valuable sources of nectar. However, because of contradictory reports, the beekeeper should test an area for several years to determine whether the soybean produces nectar in amounts adequate for his purpose.

Introducing a new crop into a locality can benefit beekeepers if the plant provides nectar or pollen. Land in the Soil Bank reserve, 28 million acres in 1957, may benefit beekeepers, depending on what plant species are growing on the land. Beekeepers should survey areas taken out of cultivation, because they may be suitable for apiary locations.

Other changes in agricultural practices include the use of herbicides and power mowing machines. They reduce or eliminate plants that are important sources of nectar or pollen. Farmers are depending less on legumes to add nitrogen to the soil and are using more liquid ammonia fertilizer.

Pests, such as insects or nematodes, may cause so much damage to some plant species that farmers change to other crops. In Ohio in 1966 the alfalfa weevil (*Hypera postica* (Gyllenhal)) became so destructive that there was serious concern farmers would stop growing alfalfa, an important nectar source. The sweetclover weevil (*Sitona cylindricollis* Fåhraeus) has destroyed much of the sweetclover that formerly was grown in the Midwest. The acreage planted for seed has decreased over 50 percent since 1950. Plant breeders have introduced a nectarless cotton so that destructive insects will not be attracted to the plant.

There is no information concerning the effects of air pollution caused by factories, motor vehicles, radioactivity, and major metropolitan areas on nectar and pollen plants except in limited areas.

Productive locations for the commercial beekeeper will become more difficult to find. However, if a housing development or new subdivision forces a beekeeper to move his colonies from his home, he may have difficulty finding a desirable location nearby.

Poisonous Honey Plants

Fortunately the American beekeeper seldom needs to be concerned about plants that are poisonous to honey bees. Locations with abundant growth of California buckeye (*Aesculus* spp.), deathcamas (*Zigadenus venenosus* Wats.), loco-

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[1] In cooperation with Louisiana Agricultural Experiment Station.

[2] VANSELL, G. H. NECTAR AND POLLEN PLANTS OF CALIFORNIA. Calif. Agr. Expt. Sta. Bul. 517, 55 pp. 1931.

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weed (*Astragalus* or *Oxytropis* spp.), laurel (*Kalmia* sp.), or rhododendron (*Rhododendron* spp.) should be avoided, if possible, while these plants are in bloom. Damage to colonies from poisonous nectar or pollen may be severe in some years, but of small consequence in others.

Nectar Secretion

Beginners in beekeeping frequently ask: "Are there any plants that I can grow that will increase my yield of honey?" In general, it is not economically practical to grow a crop for the bees alone. Beekeepers are dependent on cultivated crops grown for other purposes or on plants growing wild. Certain nectar and pollen plants, such as alfalfa, the clovers, and sweetclover, are grown widely for agricultural purposes and they are wild to some extent. These plants, together with less important ones, such as citrus (orange, grapefruit, lemon, limes, tangelos), cotton, sage, and tupelo, furnish the greater part of the Nation's commercial honey.

Sometimes friendly farmers will seed small areas near an apiary with nectar-producing species if the beekeeper provides the seed and thus honey production increases. A few ornamental flowers or trees on a city lot are of small value to an apiary or a colony of bees. From one to several acres of abundant flowers are usually necessary to provide sufficient nectar for one colony.[5]

Nectar secretion or production is affected by such environmental factors as soil type, soil condition, altitude, latitude, length of day, light conditions, and weather. Such soil conditions as fertility, moisture, and acidity may affect not only the growth of the plant but also the secretion of nectar. Luxuriant plant growth does not necessarily imply that maximum nectar secretion will take place. In some instances limited growth results in increased nectar production. Clear, warm, windless days are likely to favor nectar secretion. Most of our information on nectar production is based on casual observation rather than on experimentation.

Nectar is secreted by an area of special cells in the flowers called a nectary. Certain species, such as vetch, cotton, partridgepea, and cowpeas, produce nectar from tiny specialized areas in the leaves or stems called extrafloral nectaries.

Honeydew

Honeydew is the sweet liquid secreted by certain insects, such as aphids or plant lice, scale insects, gall insects, and leafhoppers, and also by the leaves of certain plants. Honeydew honey differs chiefly from floral honey in its higher dextrin and mineral content. The quality of honeydew honey varies greatly. Some are fairly palatable, whereas others are undesirable for human food or for wintering bees in northern areas.

Pollen Plants

Pollen is an essential food used in the rearing of the honey bee larvae. It supplies the necessary protein. The adult honey bee can live on carbohydrates alone, but the developing larvae must have some protein. A good, strong colony of bees may collect and use 50 to 100 pounds of pollen during the season. Lack of pollen slows colony development in many localities in the spring and in some locations in the summer and fall. Pollen may be available in the field, but cold or rainy weather may prevent the bees from gathering it. Some beekeepers feed pollen supplements, alone or mixed with bee-gathered pollen, to their colonies. Pollen supplements are sold by bee-supply dealers.

Plants valuable only for the pollen that honey bees obtain from them include corn, oak, and ragweed. Examples of plants that produce nectar and pollen at a time when brood rearing is important are dandelion, maple, elm, willow, wild cherry, wild plum, boneset, goldenrod, and aster. The clovers produce large amounts of both nectar and pollen.

For information on the honey bee as a pollinating agent and the nutritional value of pollens, see pages 77 and 52, respectively.

Nectar and Pollen Plant Regions

In table 1 the nectar and pollen plants are listed by region (see fig. 1, p. 17). Some of the species are limited to a small area within a region; for example, thyme in New York, fireweed in the northern part of the north-central region and the West, gallberry in the Southeast, and citrus in the Southeast, Southwest, and West.

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[5] OERTEL, E. NECTAR YIELDS OF VARIOUS PLANT SPECIES AT BATON ROUGE IN 1955. 10th Internatl. Cong. Ent. Proc. 4, pp. 1027–1029. 1958.

TABLE 1.—*Nectar and pollen plants by regions*

Plant	Northeast	North-central region	Southeast [1]	Plains region	Mountainous region [2]	Southwest	West [3]	Alaska [4]	Hawaii [5]
Alder (*Alnus* spp.)						X	X	X	
Alfalfa (*Medicago sativa* L.)	X	X		X	X	X	X	X	
Algaroba (*Prosopis chilensis* (Mol.) Stuntz)									X
Alkaliweed (*Hemizonia* spp.)							X		
Almond (*Prunus amygdalus* Batsch.)							X		
Amsinckia (*Amsinckia* spp.)							X		
Ash (*Fraxinus* spp.)					X	X			
Aster (*Aster* spp.)	X	X	X	X		X	X		
Baccharis (*Baccharis* spp.)						X			
Balsamroot (*Balsamorrhiza* spp.)					X				
Basswood (*Tilia americana* L.)	X	X	X	X	X				
Bermudagrass (*Cynodon dactylon* (L.) Pers.)						X	X		
Bindweed (*Convolvulus* spp.)					X	X			
Birdsfoot trefoil (*Lotus corniculatus* L.)	X						X		
Bitterweed (*Helenium amarum* (Raf.) Rock)			X						
Blackberry (*Rubus* spp.)	X		X				X		X
Black wattle (*Acacia* spp.)									X
Bladderpod (*Lesquerella gordonii* (Gray) Wats.)						X			
Blueberry (*Vaccinium* spp.)	X	X						X	
Bluecurls (*Trichostema* spp.)							X		
Blue thistle (*Echium vulgare* L.)	X		X						
Bluevine (*Gonolobus laevis* Michx.)		X							
Blueweed (*Cichorium intybus* L.)							X		
Boneset (*Eupatorium* spp.)			X	X				X	X
Boxelder (*Acer* spp.)					X				
Broomweed (*Gutierrezia texana* (DC.) T. & G.)				X	X	X			
Buckbrush (*Symphoricarpos* spp.)		X		X		X			
Buckeye (*Aesculus californica* (Spach) Nutt)							X		
Buckwheat (*Fagopyrum esculentum* Moench)		X	X						
Burroweed (*Haplopappus tenuisectus* (Greene) Blake ex Benson)					X	X			
Cacti (*Cactaceae* family)						X			X
Camphorweed (*Heterotheca subaxillaris* (Lam.) Britt. & Lusby)					X	X			
Cascara (*Rhamnus purshiana* DC.)							X		
Catclaw (*Acacia greggii* Gray)						X			
Ceanothus (*Ceanothus* spp.)					X	X			
Cedar elm (September elm) (*Ulmus serotina* Sarg.)				X					
Citrus (*Citrus* spp.)			X			X	X		X
Cleome (*Cleome serrulata* Pursh)					X	X	X		
Clethra (*Clethra alnifolia* L.)	X								
Clover:									
Alsike (*Trifolium hybridum* L.)	X	X			X		X	X	
Crimson (*Trifolium incarnatum* L.)			X						
Red (*Trifolium pratense* L.)	X	X		X	X		X	X	X
Sweetclover (*Melilotus* spp.)	X	X	X	X	X	X	X		X

See footnotes at end of table.

TABLE 1.—*Nectar and pollen plants by regions*—Continued

Plant	North-east	North-central region	South-east [1]	Plains region	Moun-tainous region [2]	South-west	West [3]	Alaska [4]	Hawaii [5]
Clover—Continued									
White (*Trifolium repens* L.)	X	X	X	X	X		X	X	X
Coffee (*Coffea arabica* L.)									X
Corn (*Zea mays* L.)		X	X	X	X	X	X		
Cotton (*Gossypium* spp.)			X	X		X	X		
Cottonwood (*Populus* spp.)			X		X	X	X		
Cowpea (*Vigna sinensis* (Torner) Savi)			X						
Cranberry (*Vaccinium macrocarpon* Ait.)	X	X					X		
Creosote bush (*Larrea tridentata* (DC.) Coville)						X	X		
Crownbeard (*Verbesina* spp.)			X	X		X			X
Cucurbits:									
Cantaloup (*Cucumis melo* L.)	X	X	X	X		X	X		
Cucumber (*Cucumis* spp.)	X	X	X	X	X	X	X		
Gourds (*Cucurbita* spp.)	X	X	X						
Melon (*Citrullus* spp.)	X	X	X			X	X		
Pumpkin (*Cucurbita* spp.)	X	X	X		X		X		
Squash (*Cucurbita* spp.)	X	X	X				X		
Dandelion (*Taraxacum* spp.)	X	X			X		X	X	X
Eardropvine (*Brunnichia cirrhosa* Gaertn.)			X						
Elm (*Ulmus* spp.)	X	X	X	X	X	X			
Eucalyptus (*Eucalyptus* spp.)						X	X		X
Filaree (*Erodium* spp.)						X	X		
Fireweed (*Epilobium angustifolium* L.)		X					X		
Fruit bloom:									
Apple (*Malus* spp.)	X	X	X	X	X		X	X	
Apricot (*Prunus* spp.)					X	X	X		
Cherry (*Prunus* spp.)	X	X			X		X		
Citrus (*Citrus* spp.)			X			X	X		X
Peach (*Prunus* spp.)	X	X	X	X	X	X	X		
Pear (*Pyrus* spp.)	X	X	X	X	X		X		
Plum (*Prunus* spp.)	X	X	X	X	X		X		
Gallberry (*Ilex glabra* (L.) Gray)			X						
Goldenrod (*Solidago* spp.)	X	X	X	X	X	X			X
Grape (*Vitis* spp.)			X						
Greasewood (*Sarcobatus vermiculatus* (Hook.) Torr.)					X				
Guajillo (*Acacia berlandieri* Benth.)						X			
Guava (*Psidium guajava* L.)									X
Gumweed (*Grindelia* spp.)				X	X	X			
Hemp (*Cannabis sativa* L.)							X		
Holly (*Ilex opaca* Ait.)			X						
Horsemint (*Monarda* spp.)				X		X			
Huckleberry (*Gaylussacia* spp.)			X						
Hue (*Lagenaria siceraria* (Mol.) Standley)									X
Ilima (*Sida* spp.)									X
Johnsongrass (*Sorghum halepense* (L.) Pers.)						X	X		
Kly (*Acacia* spp.)									X
Knopweed (*Centaurea repens* L.)					X				
Koa haole (*Acacia* spp.)									X
Lantana (*Lantana* spp.)									X
Lima beans (*Phaseolus limensis* Macf.)			X				X		
Locoweed (*Oxytropis* or *Astragalus* spp.)					X	X			

Footnotes at end of table.

TABLE 1.—*Nectar and pollen plants by regions*—Continued

Plant	North-east	North-central region	South-east[1]	Plains region	Moun-tainous region[2]	South-west	West[3]	Alaska[4]	Hawaii[5]
Locust:									
Black (*Robinia pseudo-acacia* L.)	X	X	X	X	X	X			
Thorny (*Gleditsia triacanthos* L.)			X						
Water (*Gleditsia aquatica* Marsh)			X						
Loosestrife (*Lythrum* spp.)	X								
Lupine (*Lupinus* spp.)						X	X		
Macadamia (*Macadamia* spp.)									X
Mamane (*Sophora* spp.)									X
Mangrove:									
Black (*Avicennia nitida* Jacq.)			X						
Red (*Rhizophora mangle* L.)			X						
White (*Laguncularia racemosa* (L.) Gaertn. F.)			X						
Manzanita (*Arctostaphylos* spp.)					X	X	X		
Maple (*Acer* spp.)	X	X	X	X	X		X		
Matchweed (*Gutierrezia sarathrae* (Pursh) Britt. & Rusby)					X	X			
Mesquite (*Prosopsis juliflora* (SW.) DC.)						X	X		
Mexican clover (*Richardia scabra* L.)			X						
Milkvetch (*Astragalus* spp.)					X				
Milkweed (*Asclepias* spp.)	X	X		X	X				
Mint (*Mentha* spp.)							X		
Monkeypod (*Samanea* spp.)									X
Mountain apple (*Eugenia malaccensis* L.)									X
Mule ear (*Wyethia* spp.)					X				
Mustard (*Brassica* spp.)		X			X	X	X	X	
Nohu (*Tribulus cistoides* L.)									X
Oak (*Quercus* spp.)			X		X	X	X		
Ohia lenhua (*Metrosideros* spp.)									X
Oi (*Verbena* spp.)									X
Oregon grape (*Berberis nervosa* Pursh)							X		
Oregon maple (*Acer macrophyllum* Pursh)							X		
Paintbrush (*Castilleja* spp.)									X
Palmetto (*Sabal* spp.)			X						
Palmetto, saw (*Serenoa repens* (Bartr.) Small)			X						
Palm trees (*Palmaceae* family)									X
Partridgepea (*Chamaecrista* spp.)			X						
Peppervine (*Ampelopsis arborea* (L.) Koehne)			X	X					
Persimmon (*Diospyros virginiana* L.)			X	X					
Pili (*Heteropogon contortus* (L.) Beauv. ex Roem. & Schutt.)									X
Pine (*Pinus* spp.)							X		
Pluchea (*Pluchea* spp.)									X
Poplar (*Populus* spp.)								X	
Rabbitbrush (*Chrysothamnus* spp.)					X	X			
Ragweed (*Ambrosia* spp.)			X	X	X	X			
Rape (*Brassica napus* L.)				X					
Raspberry (*Rubus* spp.)	X	X					X	X	
Rattanvine (*Berchemia scandens* (Hill) K. Koch)			X	X					

Footnotes at end of table.

TABLE 1.—*Nectar and pollen plants by regions*—Continued

Plant	North-east	North-central region	South-east [1]	Plains region	Moun-tainous region [2]	South-west	West [3]	Alaska [4]	Hawaii [5]
Redbud (*Cercis canadensis* L.)			X	X					
Resinweed (*Grindelia* spp.)				X		X			
Russian-thistle (*Salsola* spp.)				X	X	X	X		
Safflower (*Carthamus tinctorius* L.)					X	X	X		
Sage (*Salvia* spp.)							X		
Saguaro (*Carnegiea gigantea* (Engelm.) Britt. & Rose)						X			
Sainfoin (*Onobrychis* spp.)					X				
Saltcedar (*Tamarix gallica* L.)					X	X			
Santa maria (*Parthenium hysterophorus* L.)			X						
Silky oak (see silver oak)									X
Silver oak (*Grevillea robusta* A. Cunn.)									X
Smartweed (*Polygonum* spp.)	X	X	X	X		X	X		
Snakeweed (see matchweed)					X	X			
Snowvine (*Mikania scandens* (L.) Willd.)			X						
Sorghum (*Sorghum* spp.)				X		X	X		
Sourwood (*Oxydendrum arboreum* (L.) DC.)		X	X						
Soybeans (*Glycine max* (L.) Merr.)		X	X						
Spanish-needles (*Bidens bipinnata* L.)		X	X	X					X
Sumac (*Rhus* spp.)	X	X		X					
Summer farewell (*Petalostemun* spp.)			X						
Sunflower (*Helianthus* spp.)			X	X		X			
Tamarix (*Tamarix aphylla* (L.) Karst.) (*Tamarix articulata* Vahl)						X	X		
Tarweed (*Hemizonia* spp.)							X		
Thistle (*Sonchus arvensis* L. and *Cirsium* spp.)					X				
Canadian (*Cirsium arvense* (L.) Scop.)							X		
Star (*Centaurea* spp.)							X		
Thyme (*Thymus* sp.)	X								
Tievine (*Convolvulus* or *Ipomoea* spp.)			X	X					
Titi:									
Black (*Cliftonia monophylla* (Lam.) Britton ex Sarg.)			X						
Spring (*Cyrilla racemiflora* L.)			X						
Summer (*Cyrilla* spp.)			X						
Toyon (*Photinia arbutifolia* Lindl.)							X		
Tulip poplar (*Liriodendron tulipifera* L.)	X	X	X						
Tupelo (*Nyssa* spp.)			X						
Vervain (*Verbena* spp.)			X						
Vetch (*Vicia* spp.)			X	X	X		X		X
Vine maple (*Acer circinatum* Pursh)							X		
Wild alfalfa (*Lotus* spp.)							X		
Wild buckwheat (*Eriogonum* spp.)					X	X	X		
Wild currants (*Ribes* spp.)					X				
Wild dandelion (*Hymenopappus arenosus* Heller)					X				

Footnotes at end of table.

Table 1.—*Nectar and pollen plants by regions*—Continued

Plant	Northeast	North-central region	Southeast[1]	Plains region	Mountainous region[2]	Southwest	West[3]	Alaska[4]	Hawaii[5]
Wild snowberry (*Symphoricarpos* spp.)					X				
Willow (*Salix* spp.)	X	X	X				X	X	
Wingstem (*Actinomeris alternifolia* (L.) DC.)			X						
Yellow ginger (*Hedychium flavescens* Carey)									X
Yellow-rocket (*Barbarea vulgaris* R. Br.)	X	X							

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[5] Botanical names taken from Neal, M. C., Gardens of Hawaii, (Honolulu) Bishop Mus. Spec. Pub. 50, 924 pp., 1965. Nectar and pollen plant names taken from Dyce, E. J., Beekeeping in the 50th State, Gleanings Bee Cult. 87: 647–651, 1959, and Eckert, J. E., and Bess, H. A., Fundamentals of Beekeeping in Hawaii, Hawaii Univ. Bul. 35, 32 pp., 1952.

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BEEKEEPING REGIONS IN THE UNITED STATES

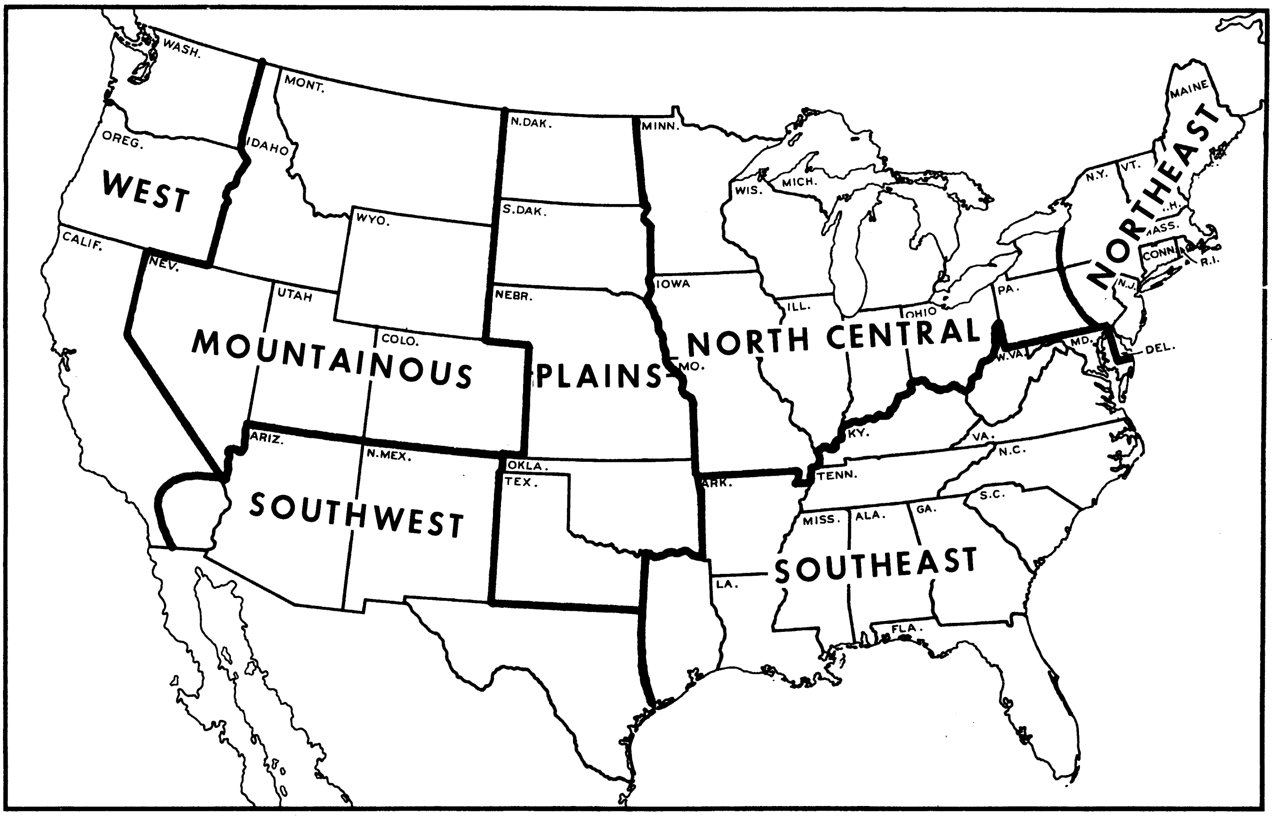
By W. P. Nye, *apiculturist, Entomology Research Division, Agricultural Research Service*[1]

Based on flora, beekeeping methods, and land topography the continental United States can be divided into seven geographical regions (fig. 1). Each of these regions is discussed here from the standpoint of honey production and methods of beekeeping operations.

The flora, climate, and nature of the terrain determine the system of management practiced by the beekeeper. For example, in the Apalachicola swamps of the Southeast, hives are placed on scaffolding for protection from flood waters. In the Southwest, shade must be provided to protect the hives from the hot sun (fig. 2). Colonies in the North and mountainous areas must be protected from the cold (fig. 3), in certain forested areas from bears, and on the desert from drifting sand.

Some locations must be paid for by the beekeeper, others are furnished free. Where the bees are desired for pollination, the beekeeper is usually paid for their services.

Most beekeepers move their colonies at night (if moving is necessary) when the bees are inside the hive. But when daytime temperatures exceed 110° F. in the Southwest, bees are more easily moved at midday when they are inside the hive rather than at night when they tend to cluster on the entrance.



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BN-30051

Figure 1.—Beekeeping regions of the United States.

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[1] In cooperation with Utah Agricultural Experiment Station.

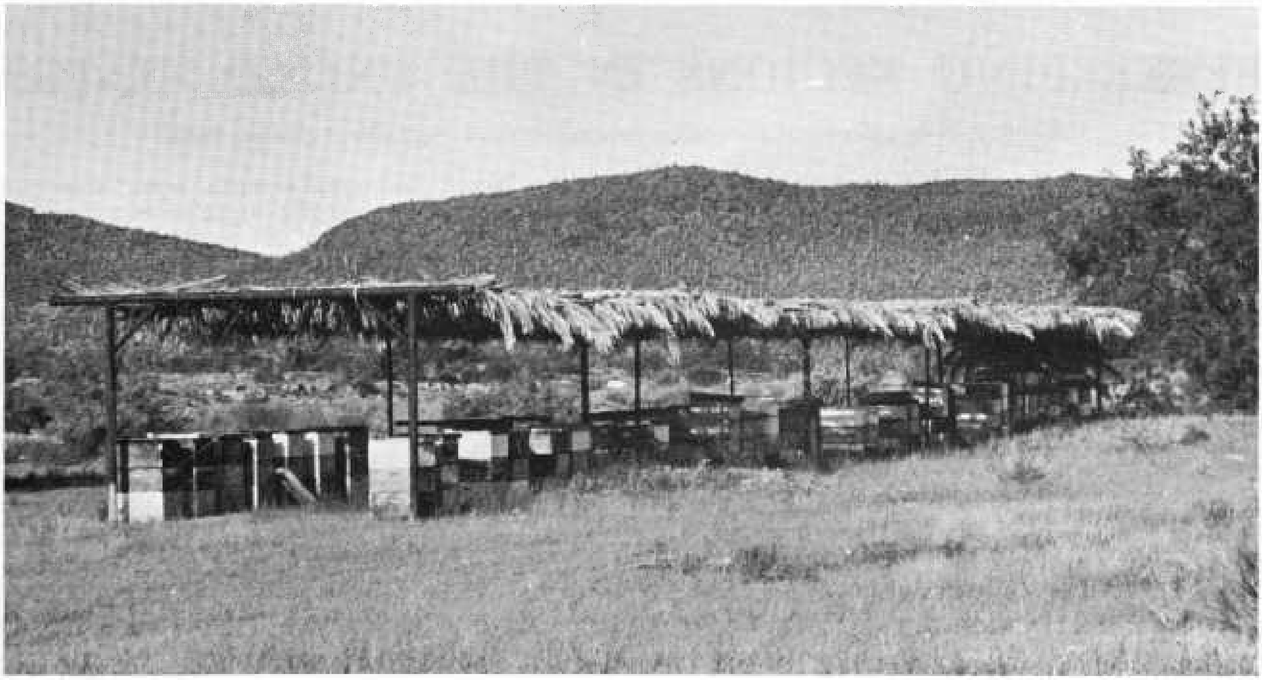

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FIGURE 2.—Typical apiary under a ramada that partially shades colonies in hot Southwest.

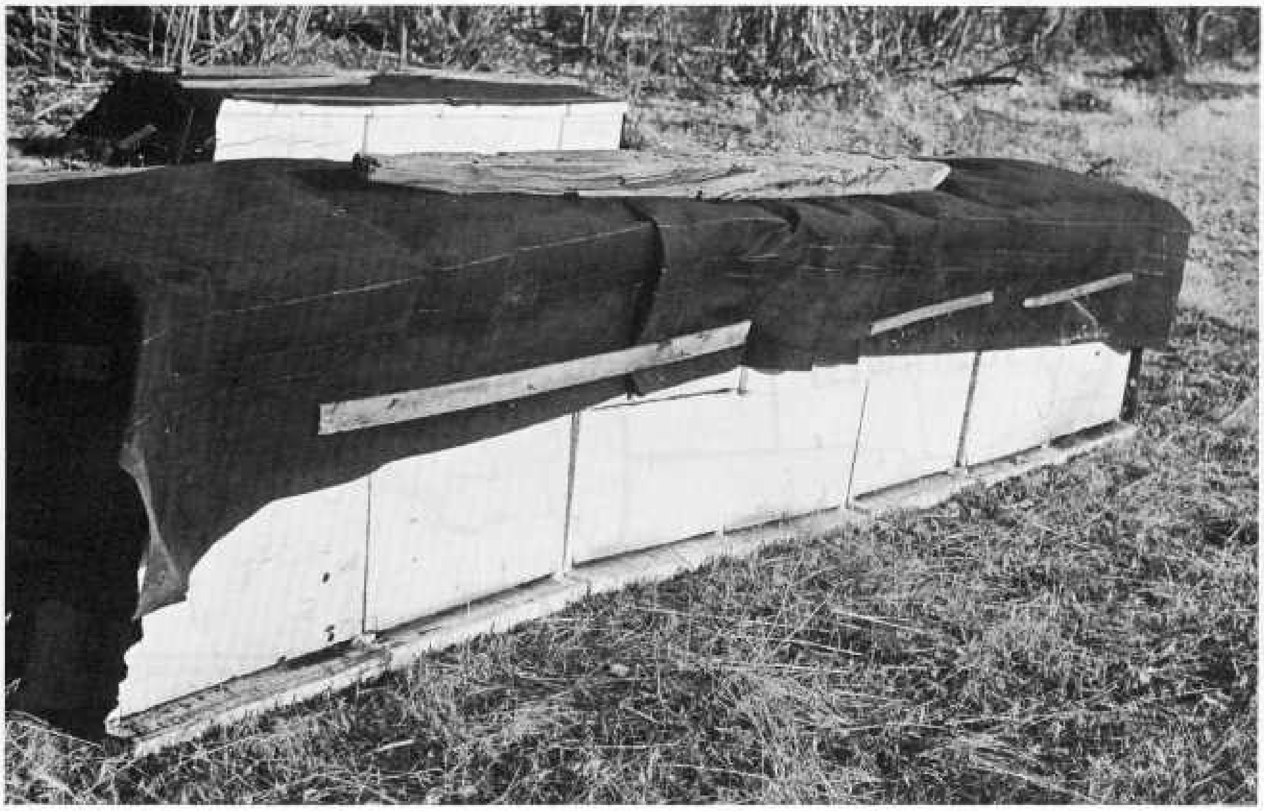

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FIGURE 3.—Typical winter pack in plains region. Colonies placed side by side in groups with 6 or more inches of dry straw on top and wrapped in single layer of tar paper.

Northeast

The severe winters, short summers, and hilly or mountainous nature of the Northeast produce a variety of plants but no major source of honey. Whiteclover, basswood, black locust, birdsfoot trefoil, various berries, and wild flowers contribute to producing a mixture of honey, much of which is sold locally to residents acquainted with the types produced, and some of the highest prices for honey are obtained here. Few commercial beekeepers are in the Northeast.

The average honey production per colony is only 33 pounds, but occasionally locations produce much higher averages. An estimated 187,000 colonies are in this region.

The colonies are seldom moved except the few belonging to commercial or semicommercial beekeepers, who rent their bees for pollination of blueberries, cranberries, other fruits, or cucumbers.

Colonies are located where there is good air drainage, protection from the cold winds, and exposure to as much winter sun as possible. For additional protection from cold winters, many colonies are "packed," or wrapped with insulation and tar paper, leaving only the entrance exposed. Winter loss is usually high and is replaced with packages of bees and queens purchased from southern beekeepers. Shade in summer is unnecessary.

Most beekeepers overwinter their colonies in two- or three-story, 10-frame-deep Langstroth hives. When the honey flow starts, they add one or two extra deep supers for surplus honey storage or one or two shallow supers for section or comb honey production.

North-Central Region

The bulk of the honey from the north-central region comes from whiteclover, alsike clover, and alfalfa, with minor surpluses from basswood, black locust, and raspberry. All of this is high quality honey. Clover and alfalfa are the predominant American honeys. Less desirable grades come from aster, goldenrod, and smartweed. The variety of other plants, however, insures something for the bees to work on from spring until frost. The bulk of comb honey produced by the bees in 1-pound sections comes from this region.

There are approximately 1,205,000 colonies, many of which belong to commercial beekeepers. The average production of surplus honey per colony is 58 pounds.

Some colonies are killed in the fall and the equipment is stored; then hives are restocked in the spring with packages of bees and a queen is purchased from southern beekeepers. Others are wrapped with insulation and tar paper for winter protection. Some are left with ample stores of honey and pollen in locations protected from wind and exposed to warming sunlight. Still others have most of the honey removed, and the hive is reduced to a single brood nest that is trucked to the Southeast, where it is allowed to build up and be divided to form new colonies. It is returned to the North in the spring for fruit pollination before the main honey flow. Midsummer shade is beneficial (fig. 4). Little migratory beekeeping occurs other than movement of the colonies to the Southeast for increase.

Some colonies are rented for pollination of fruits, legumes, and cucumbers.

Southeast

The production of honey per colony in this region, 33 pounds, is the same as in the Northeast but lower than elsewhere. An estimated 1,595,000 colonies are located permanently in the Southeast. In addition, many thousands of colonies are trucked here from the northern areas during the winter, then returned to the North in the spring.

Most of the queen breeders and package bee shippers of the country are located within the Southeast. An estimated 660,000 pounds of live bees and an equal number of queens are shipped from here annually. Some of these beekeepers produce no surplus honey for sale to supplement their sale of live bees and queens. Some of the northern beekeepers pick up their package bees and queens in van-type air-conditioned trucks for safe transportation to their northern locations.

Except for sizable areas in Florida, little pollination is provided on a cost basis in this region. Bees are rented for occasional fruit orchards and legume seed and melon fields. In Florida, bees are rented for citrus, cucurbits, and other fruits and vegetables.

In the mountainous area sourwood is the prevailing quality honey, along with tulip poplar and the clovers. Sourwood honey is almost water white, does not granulate readily, and is so esteemed that it usually passes directly from producer to consumer at far above the price of other honeys.

In the lower elevations gallberry becomes the predominant source. In the Apalachicola swamp area, tupelo, famous for its high levulose content and nongranulating characteristics, is also an excellent honey. Farther south in Florida, citrus is the major source, with clovers the major source toward the Mississippi Delta, then cotton becomes important. Various other honeys from light to dark and from mild to strong are produced in the Southeast.

Considerable migratory beekeeping occurs, for the long season permits harvest of a crop of honey in one area before another harvest commences elsewhere.

BN-30066

FIGURE 4.—Apiary sheltered by hardwood forest in north-central region. Hives composed of 11-frame 6⅝-inch-deep hive bodies.

Cut-comb honey production is common, that is a chunk of comb in a jar of liquid honey. Little section honey is produced.

Little work is necessary to prepare bees for winter. They are usually wintered in two- or three-story hives. The problem is to have ample stores of honey and pollen in the colony in the fall. This is necessary for the strong colonies needed in the early spring for package bee production or the early honey flows.

Colonies benefit from shade during the summer in the Southeast, and shade is essential in the southern part for maximum colony production.

Plains Region

The bulk of the honey from the plains region comes from sweetclover and alfalfa, much of it produced by commercial beekeepers.

In this region about 396,000 colonies produce 76 pounds of honey per colony. Colonies are wintered and operated similarly to colonies in the north-central region. Shade is not generally necessary, although partial or thorough shading during extremely hot midsummer days is beneficial. The highest production per colony is obtained in the plains region. One reason is that the sweetclover and alfalfa fields are relatively large and can support many colonies, and many of the apiaries belong to commercial beekeepers.

Some of the colonies are trucked to southern areas for the winter, some are packed (fig. 3), some are killed and then restocked in the spring, and others receive no special winter treatment.

Colonies are used to a limited extent in the pollination of alfalfa, sweetclover, and cucumbers.

From this region westward to the Pacific, where migratory beekeeping is practiced to a greater extent than elsewhere, the California-style top and bottom rather than the telescoping top and reversible bottom are used as they permit better stacking of colonies on a truck.

Mountainous Region

The major source of honey is alfalfa (fig. 5). About 434,000 colonies produce on an average 52 pounds of honey per colony. More than half the colonies belong to commercial beekeepers, who may manage 2,000 or more colonies with only part-time summer help.

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FIGURE 5.—Unsheltered colonies located for alfalfa honey production and pollination.

Honey production is almost entirely dependent on irrigation, although in recent years alfalfa is being grown on dry land. Weed spraying is reducing the sweetclover acreage.

In the migratory beekeeping from this area west and south, the colonies are usually moved at night. The hive entrances are not closed but the truckload is usually covered with a plastic screen.

Some colonies are packed during the winter, which is extremely cold and dry—factors that improve survival chances over damp cold areas. Many of the colonies are placed three or four back to back, then packed as a group. Colonies not packed are located where they have wind protection and good air drainage.

Spring buildup is slow and fall flows are rare. Shading is unnecessary. Ample comb space for ripening honey is important and seems to act as heat insulation.

Migratory beekeeping is extensive. For example, in the Delta area of central Utah in the summer of 1966, there were over 40,000 colonies, but almost none wintered there. Some colonies are moved hundreds of miles to desirable areas. Many are moved south or west for the badly needed spring buildup, then returned for the summer flow. Some colonies are killed in the fall and restocked in the spring.

Not much honey is retailed by the producer in the mountainous region.

Southwest

In this hot semiarid region there are 230,000 colonies that produce 63 pounds of honey per colony. The major sources of honey are alfalfa, cotton, and mesquite. Other sources include citrus, catclaw, tamarix, safflower, wild buckwheat, and other desert shrubs.

Summer shade is highly important (fig. 2). Artificial shade is often provided. Winter protection is unnecessary. Some colonies are wintered in a single brood nest with one or two shallow supers, but most are in two or three deep supers. Nearby water is essential, and if it disappears even for only a day, the colonies may perish. Migration from one honey flow to another is common.

Colonies are used extensively in pollination of alfalfa and melons and to a less degree for citrus, onions, and cotton. A few package bees and queens are produced, but largely bees are kept for production of honey by commercial operators. Apiaries of 100 colonies or more are not unusual.

West

About 717,000 colonies in this region produce 58 pounds of honey per colony. This production is rather meaningless because of differences due to extreme variations in temperature, rainfall, elevation, and flora. Clover, alfalfa, citrus, sage, wild buckwheat, cotton, star-thistle, and fireweed are the major honey sources.

The region varies in rainfall from only an inch or two in the desert areas to more than 60 in the rain-forest area, in elevation from below sea level to snowcapped mountains, and in temperature from dry and hot to humid and extremely cold. Colonies in the mountains must be protected from the cold and with fences from bears, whereas colonies in the lower ranges to the south must be protected from the heat.

Migratory beekeeping is practiced by most of the commercial beekeepers, and four or more moves per year are not uncommon. An average beekeeper will winter his bees on the coast, move to almonds, then manzanita and sage, then to alfalfa and cotton, and back to the coast for the fall flow. Productive accessible locations are difficult to find. Many colonies are reduced to a single story for moving, then given extra supers in which to expand. The California-style top and bottom are almost exclusively used in this region. Most commercial beekeepers use mechanical hive hoists that lift one or more colonies at a time onto the truck.

This excessive migratory operation has increased the bee disease problem, because the colonies have so many more chances to be located in areas where disease exists. Conversely, the migratory ability blends well with the use of colonies for pollination. The placement of 2,000 colonies from several beekeepers in a solid square mile of alfalfa grown for seed is not unusual. Use of bees for pollination is extensive. An estimated half of all colonies are used some time during the year for pollination hire.

In addition to honey production and pollination services, there are wax salvage plants. Diseased equipment is taken to these plants and the wax is steamed from it and salvaged. The equipment is used again.

Some of the beekeepers operate many thousands of colonies. Under such operation the apiary rather than the colony is considered a unit. Such manipulations as requeening, supering, and removing honey are performed on all colonies regardless of their relative condition. More than 300,000 pounds of bees and 250,000 queens are shipped annually from the West.

MANAGING COLONIES FOR HIGH HONEY YIELDS

By F. E. MOELLER, *apiculturist, Entomology Research Division, Agricultural Research Service* [1]

Colonies of bees existing in the wild away from man's control will produce small surplus crops of honey above their requirements for survival. Such surplus will vary depending on the region or locality, but will seldom exceed 30 to 35 pounds. In the same area subject to the same nectar resources, colonies properly managed will produce surplus honey crops of 150 to 200 pounds. Intensive two-queen colony management can often result in surplus crops of 500 pounds or more with the same resources available. The key to these differences is management.

Proper management employs practices that harmonize with the normal behavior of bees and brings the colony to its maximum population strength at the start of the bloom of major nectar-producing plants. Management practices are similar in basic principle wherever bees are kept and vary only as regards timing for the desired nectar source of the region or locality concerned.

Regardless of the type of hives or equipment used, proper management aims at providing colonies with unrestricted room for brood rearing, ripening of nectar, and storage of honey, plus provision of adequate food requirements, both pollen and honey, for the time of year concerned. Swarming is minimized and the storing instinct encouraged when proper management is used.

Preparing Colony for New Season

In the temperate regions of the northern hemisphere, August to October is the time when the beekeeper prepares his colonies for the coming year. This is when the major honey flows are usually past and the bees must be made ready for the coming winter.

All queens of questionable performance with only a small amount of brood of irregular pattern (fig. 1, *A*) should be replaced. Frequently the bees of the colony will replace or supersede queens of subnormal performance even before the beekeeper senses a problem. Some queens may be satisfactory in their second year; queens less than a year old are usually best.

To requeen a colony, certain principles of queen acceptance must be borne in mind: (1) Strong colonies more reluctantly accept a queen than weaker ones, (2) temperamental bees are more reluctant to accept a new queen than gentle bees, (3) young bees accept a queen more readily than older bees, (4) the colony to be requeened should first be made queenless, and (5) the queen to be introduced should be in egg-laying condition.

There is less risk in requeening a colony by giving it a laying queen with some of her own brood and bees than by giving it a queen in a shipping cage. A new or valuable queen should first be introduced into a small colony or divisions of one in a queen shipping cage. After she is laying, the small colony can be united with a large one.

A drone-laying queen can be replaced if she is discovered while the colony is still strong. If the colony is weak, the bees should be removed and the equipment added to another colony.

Assuming colony conditions and the condition of the queen are favorable, the effect of environmental or working conditions and the time of year are factors that affect queen acceptance. Best acceptance is usually obtained when some nectar is available in the field.

One possible period for requeening is during the broodless period of late fall. Queens are easily introduced at this time, and the bees are passive to their presence. However, the uncertainty of the weather, the difficulty of finding old and shrunken queens, and the danger of inciting robbing make this time of year less desirable for requeening than the summer.

Brood rearing declines in late summer and fall, and many normal colonies are completely broodless during much of November and December, particularly if the colony has no pollen. Older queens stop brood rearing sooner than younger queens.

Brood rearing should be encouraged as late in the season as possible. This can be assured by providing vigorous young queens in late summer, by preventing undue overcrowding and restriction of the brood nest with honey, and by encouraging pollen storage.

In areas where fall honey flows occur, partially filled supers should be kept on the colonies, especially if the brood nest is heavy.

If brood rearing is restricted by a crowded brood nest or because of poor queens, the colony may enter the winter with a high percentage of old bees that will die early in the winter. Such colonies may

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[1] In cooperation with Wisconsin Agricultural Experiment Station.

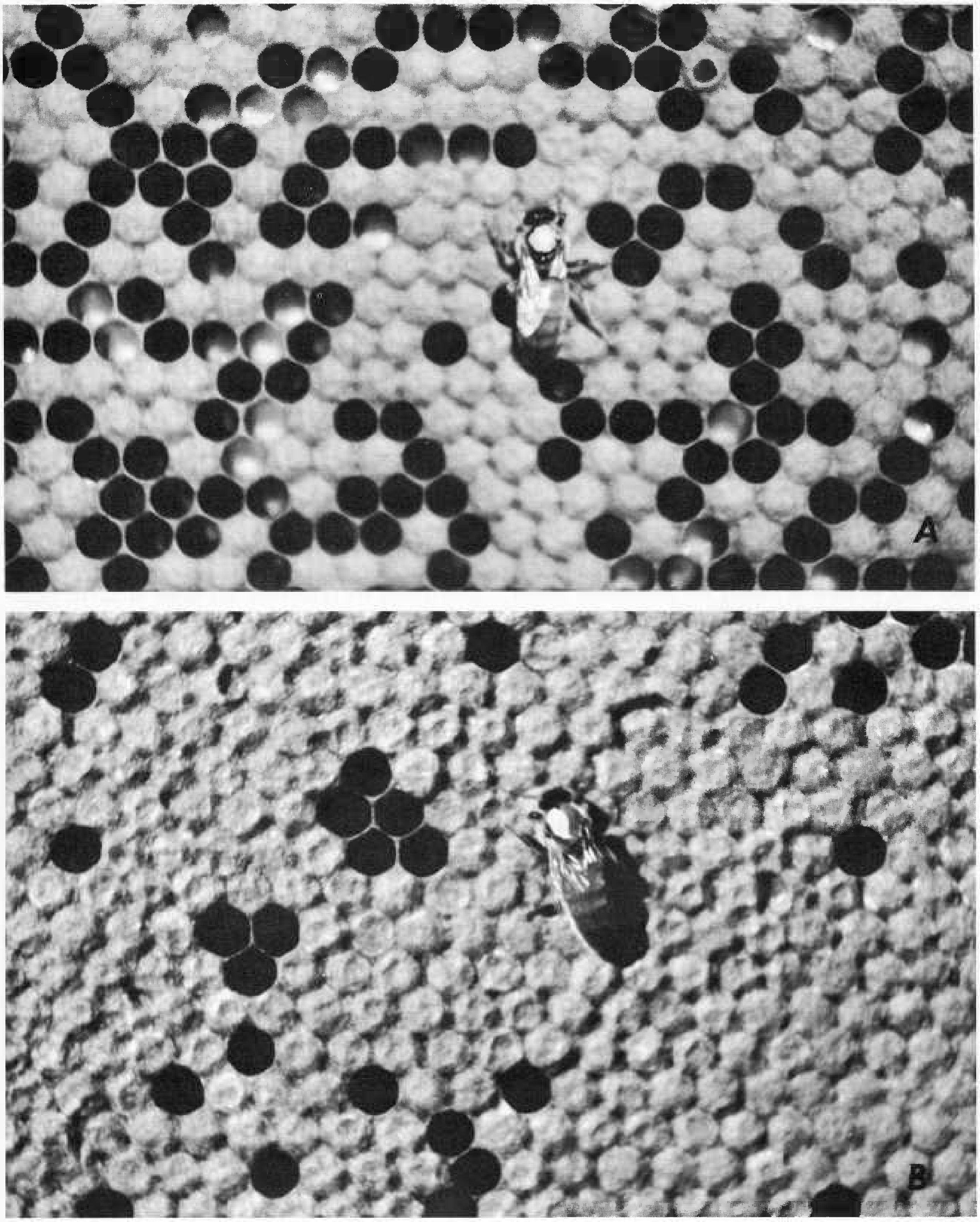

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Figure 1.—Queens with (*A*) irregular and (*B*) good brood pattern.

later develop serious nosema infections and perish before spring. A colony should start the winter with about 10 pounds of bees and plenty of honey to carry it to the next spring.

Preparing Colony for Winter

Population

The strength of a colony of bees is relative and difficult to describe. A "strong" colony to one beekeeper might be "weak" to another. Colonies with less than 10 pounds of bees should be united to stronger ones or several weaker ones combined. At between 40° and 50° F., 10 pounds of bees will cover practically all the combs of a three-story hive wall to wall and top to bottom. Naturally as the temperature drops the cluster will contract.

The beekeeper must see that at no time is the available space for brood rearing reduced because of overcrowding with honey from the fall flow. A balance must be maintained between crowding the colony to get the brood chambers well filled with honey and adding space to relieve brood rearing restriction. Partially filled supers kept on colonies in the fall may be necessary. Any subnormal colony should not be overwintered, but should be united with another colony.

A colony may appear to have an adequate fall population, but if the bees are old, it will weaken rapidly as winter advances and may starve to death, even with abundant honey in the hive, because the cluster is too small to cover the honey stores.

Food Reserves

The colony should have a minimum of 500 square inches of comb filled with pollen in the fall. To insure uninterrupted brood rearing in late winter and early spring, the beekeeper may need to supplement this. The average colony of bees under intensive management may consume about 60 pounds of honey between the last fall flow and the first available food from the field in the spring. A weak colony may consume 20 pounds or less, but the very best colony will consume 80 pounds or more. To insure the survival of the top quality colony, 90 to 100 pounds of honey should be left on it in the fall. A colony of bees not rearing brood will consume an average of about one-eighth pound of honey per day or 5 pounds per month. When brood rearing begins, the consumption of honey is greatly accelerated. Brood rearing should commence in midwinter and accelerate as temperatures moderate in late winter and early spring.

When brood rearing is discouraged or curtailed, the colony will consume less winter stores but will emerge in the spring much weaker and with a population of primarily old bees. Such colonies will have difficulty replacing the small amount of honey they used over winter, whereas other colonies that have had normal, unimpeded rearing of brood will soon be able to replace all the honey they consumed over winter plus a substantial surplus.

Organization

To accommodate the best queens in standard Langstroth 10-frame hives, a minimum of two hive bodies and preferably three should be used for year-round management. In the fall most of the honey should be located in the top hive body. With experience the beekeeper can soon learn to estimate the weight of hive bodies or frames by lifting them. A frame full of honey should weigh approximately 5 pounds. The top hive body should contain 40 to 45 pounds of honey. This means that all frames in the top hive body will be full of honey except for two or three frames in the center. The second body should contain 25 to 30 pounds of honey and some pollen. The bottom hive body should contain 20 to 30 pounds of honey plus pollen. If in the fall the combs in the top hive body are not filled, the beekeeper should reorganize them and if necessary feed additional sugar sirup so that this top hive body is well filled with stores.

As the winter progresses the cluster of bees will shift its position upward as the stores are consumed. A colony of bees in a cold climate can starve with abundant honey in the hive if the honey is below the cluster.

With the advent of cold weather, the bees cluster tightly in the interspaces of the combs. Usually there are no bees in the bottom part of the hive near the entrance. For this reason an entrance cleat or reducer should be used to exclude mice. One-inch auger holes drilled into the hive bodies of the brood nest just below the handholds are helpful. In late summer these auger-hole entrances are closed with corks so that the bees will fill the combs near them. During winter the top auger-hole entrance should be open. This allows the escape of moisture-laden air and affords a flight exit for the bees during warm spells. (Fig. 2.)

Packing the Hive

Many beekeepers in the coldest parts of the country consider that some form of protection around the hive is essential. Others believe that colonies with strong populations and ample stores need no further protection. Factors to consider in deciding whether or not to pack are the cost of material and labor and any savings in honey or bees. Packing will not replenish colonies deficient in honey, pollen, or bees, replace poor queens, or cure bee diseases. Packed colonies will consume slightly less honey. However, the difference is negligible. The most important consideration in preparing colonies for winter is a strong population and adequate stores.

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FIGURE 2.—Colony during winter showing top auger-hole entrance.

When outside temperatures are near freezing, the temperature at the surface of a cluster of bees ranges between 43° and 46° F. As the temperature decreases, the cluster contracts and the bees in the outer insulating shell concentrate to provide an insulating band of 1 to 3 inches in depth. Metabolism and activity of the bees in the center of the cluster maintain a desired temperature. This may be around 92° if brood rearing is in progress. The temperature of the area of the hive not occupied by bees will be similar to the external temperature. This is true whether the hive is packed or not. The difference is that the temperature in the unpacked hive changes more rapidly and responds more quickly to that outside the hive. Heavy packing is worse than no packing, because during warm periods in midwinter when the bees should fly, those heavily packed do not fly at all.

Late Winter Manipulation

If colonies are inspected in late winter or early spring, adjustments can be made to save colonies that might be lost otherwise. Even weak or medium-strength colonies can often be saved if honey is moved into contact with the cluster. A strong colony with insufficient honey can starve if additional food is not provided at this time.

From this period until the bees can forage, such colonies can be fed either full combs of honey, or if these are not available, a gallon or two of heavy sugar sirup (two parts sugar by volume to one part water) can be poured directly into the open cells of empty combs.

Spring Buildup

Overwintered colonies will usually start brood rearing in midwinter and continue into the summer unless the stored pollen is all consumed before fresh pollen is available. If the supply is exhausted and not supplemented, brood rearing will slow down or stop entirely when it should proceed without interruption.

For best results in honey production, a beekeeper should have strong populations of young bees for the honey flow. Colonies emerging in the spring with predominantly old bees must build a population of young bees for later flows by using the early sources of pollen.

Some beekeepers trap pollen at the hive entrance from incoming bees by means of a pollen trap such as that described in U.S. Department of Agriculture ARS 33–111, A Simplified Pollen Trap for Use on Colonies of Honey Bees. This pollen is dried or frozen until needed, then mixed with sugar, water, and soy flour, and fed to the colony as a supplement to its natural supply (fig. 3). Various other types of pollen supplements and substitutes have been described and some are available on the open market.

Supplements containing pollen are eaten more readily by bees and generally give better results than those containing soy flour or other material without pollen. Pollen supplement is preferred by the bees in direct proportion to the amount of pollen it contains. The less pollen the supplement contains, the less is eaten. Substitutes made without pollen tend to be dry and gummy. A pound of pollen will make approximately 12 pounds of pollen supplement (see p. 55).

Swarm Control in Single-Queen Management

After pollen becomes abundantly available in the spring, the beekeeper should provide ample space for brood rearing and honey storage.

The natural colony behavior is to expand its brood nest upward, and a simple manipulation utilizing this tendency is to shift the empty frames or emerging brood to the top of the hive and the youngest brood and honey to the bottom part. This permits the expansion of the brood rearing upward into this area (fig. 4). Subsequent reversal of brood chambers can be made at about 10-day or 2-week intervals until the honey flow starts.

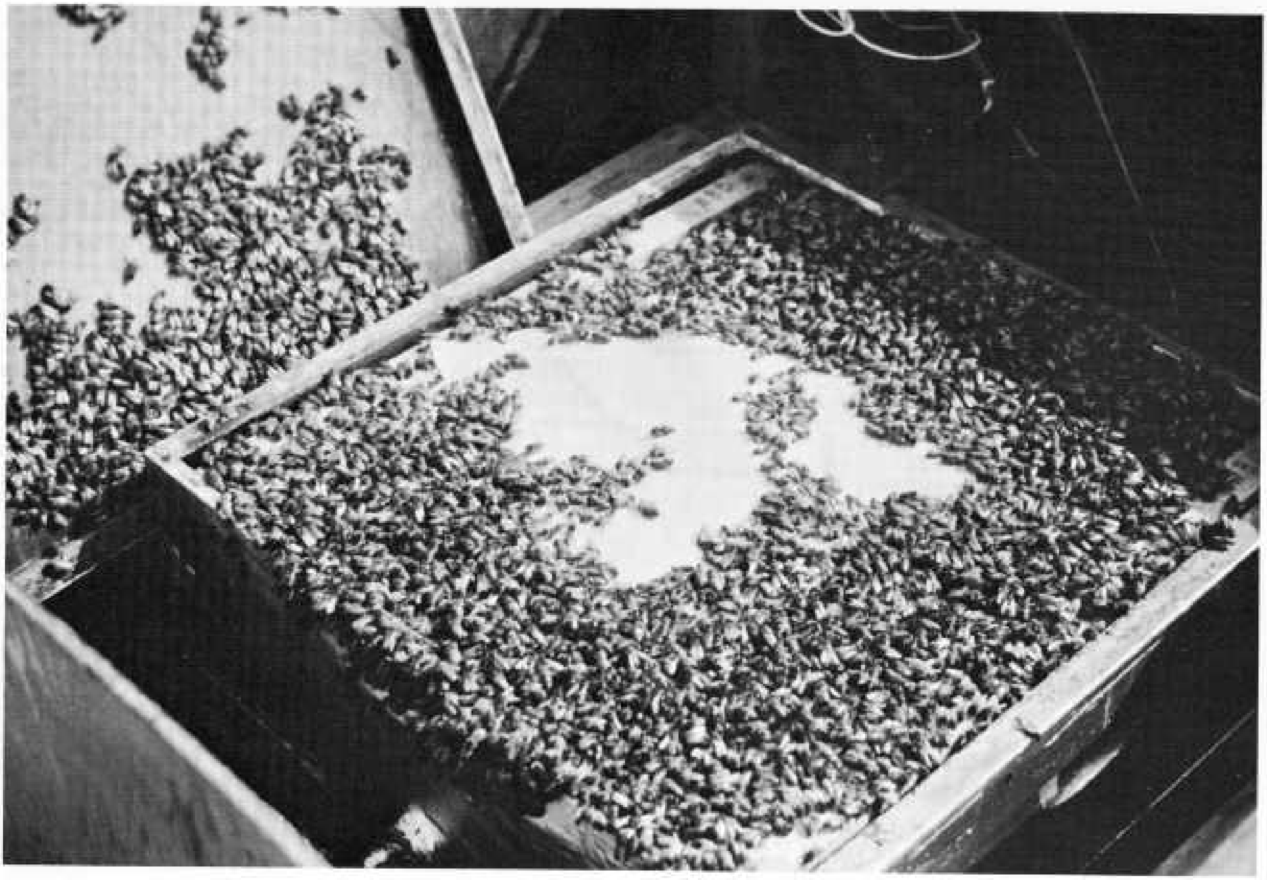

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FIGURE 3.—Strong colony feeding on pollen supplement cake during March.

As soon as the three brood chambers are filled with bees, the first super should be given whether or not the honey flow is in progress. If this is done, most colonies with a vigorous queen will not swarm. However, any queen cells the beekeeper sees as he reverses the brood chambers should be removed. A simple method of reversing brood chambers is to lower the hive backward to the ground, separate the brood chambers, interchange the first and third hive bodies, and return to position.

After the honey flow starts, the danger of swarming lessens and brood chamber reversal can be discontinued. At the start of the honey flow, "bottom supering" should be used. The empty super should be placed above the top brood chamber but below the partially filled supers (fig. 4).

After the supers have been filled and the honey has been extracted, they should never be put directly over the brood nest, but should be placed on top of the partially filled supers to prevent the queen seeking them and laying eggs in them. Why such combs are attractive to the queen is not known.

Two-Queen System

The establishment of a two-queen colony is based on the harmonious existence of two queens in a colony unit. Any system that insures egg production of two queens in a single colony for about 2 months prior to the honey flow will boost honey production.

The population in a two-queen colony may be twice the population of a single-queen colony. Such a colony will produce more honey and produce it more efficiently than will two single-queen colonies. A two-queen colony usually enters winter with more pollen than a single-queen colony. As a result of this pollen reserve, the two-queen colony emerges in the spring with a larger population of young bees and is thus a more ideal unit for starting another two-queen system.

To operate two-queen colonies, start with strong overwintered colonies. Build them to maximum strength in early spring. Obtain young queens about 2 months before the major honey flows start. When the queens arrive, temporarily divide the colony. Replace the old queen and most of the

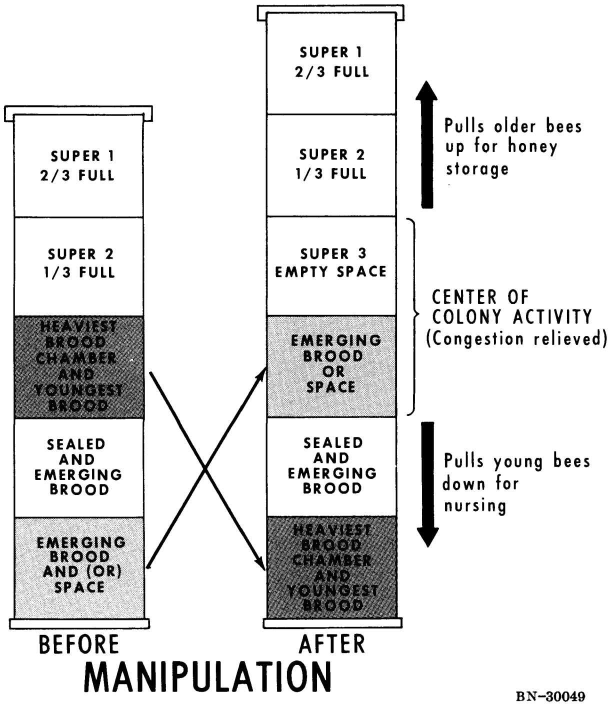

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FIGURE 4.—Basic colony manipulation for swarm control.

younger brood plus about half of the population in the bottom section. Cover with an inner cover or a thin board and close the escape hole. The division containing most of the sealed and emerging brood, the new queen, and the remainder of the population is placed above. The upper unit is provided with an exit hole for flight.

At least two brood chambers must be used for the bottom queen and two for the top queen. Two weeks after her introduction, remove the division board and replace it with a queen excluder. The supering is double that required for a single-queen operation. In other words, where three standard supers are necessary for a single colony, six will be required for a two-queen colony.

When supering is required, larger populations in two-queen colonies require considerably more room at one time than is required for single-queen colonies. If a single-queen colony receives one super, a two-queen system may require two or even three empty supers at one time.

The brood chambers should be reversed to allow normal upward expansion of the brood area about every 7 to 10 days until about 4 weeks before the expected end of the flow, after which the honey crop on the colony may be so heavy as to preclude any brood nest manipulations. Thereafter give supers as they are needed for storage of the crop. As the honey is extracted, the supers are returned to the hive to be refilled. They should never be replaced directly over the top brood nest, unless a second queen excluder is used to keep the queen out of them. The top brood nest may tend to become honey bound. If this occurs, reverse the upper and lower brood nests around the queen excluder. This puts the top honey-bound brood nest on the bottom board and the lighter brood nest with the old queen above the excluder.

There is no advantage in having a second queen when about a month of honey flow remains, because eggs laid from this time on will not develop into foragers before the flow has ended. However, entering the brood nest during the middle of the flow to remove one of the queens is impractical. Uniting back to a single-queen status can be done after the bulk of the honey is removed from the colony. By this time some of the colonies may have already disposed of one queen. When this happens, all that needs to be done is simply to remove the queen excluder and operate the colony as a single-queen unit.

Improved Stock

Production of honey is one major criterion in selecting honey bee stock and breeding for improvement. Superior stock must also be reasonably gentle, not prone to excessive swarming, maintain a large but compact brood nest, and winter well. It should ripen its honey rapidly, seal the cells with white wax, and use a minimum of burr comb. To obtain all the desirable characters in a superior stock, specific inbred lines from many sources must be selected and developed and then recombined into a genetically controlled hybrid. When this is done, hybrid vigor or heterosis usually results.

Queens of common stock reared under favorable conditions and heading well-managed colonies will probably be more productive than poorly reared queens of superior stock. Queens of superior stock reared under favorable conditions will require a higher standard of management than is demanded of common stock. To realize the maximum benefits from improved stock, the beekeeper must provide unrestricted room for brood rearing, ripening of nectar, and storage of honey.

To realize the maximum benefits from improved stock, the queen breeder should produce the best queens possible, and the honey producer receiving these queens should manage them in such a way that they can develop their maximum colony populations.

Disease Control as Affected by Good Management

If colonies are operated for highest honey yields, they must be kept in optimum condition (fig. 5). This includes rigid control of all bee diseases. For information about bee diseases, see pages 86–96.

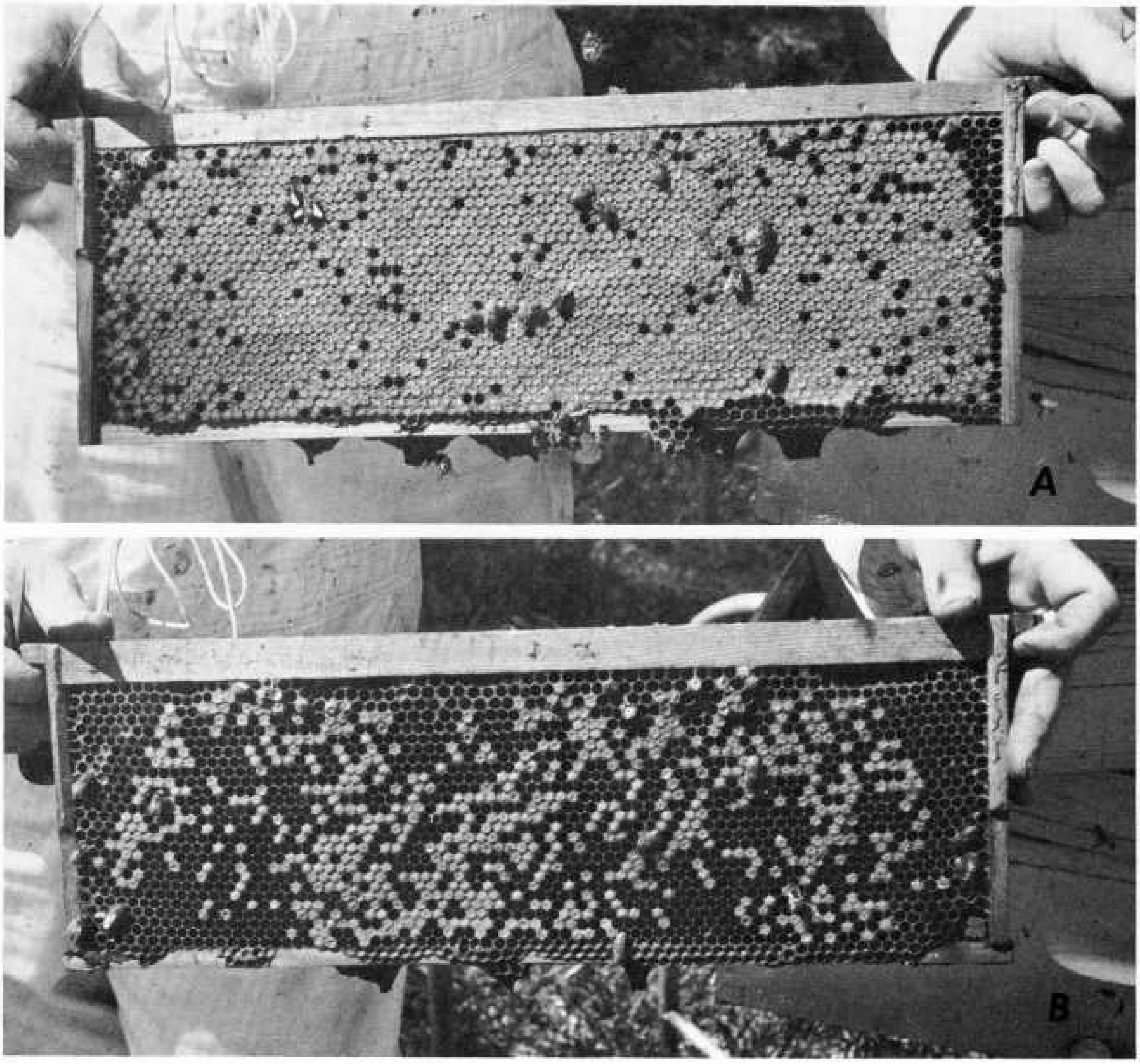

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FIGURE 5.—Brood combs showing (*A*) healthy brood necessary for high honey production and (*B*) diseased brood, which results in weakened colonies and low honey production.

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BEE BEHAVIOR

By STEPHEN TABER III, *apiculturist, Entomology Research Division, Agricultural Research Service* [1]

Bee behavior refers to what bees do—as individuals and as a colony. By studying their behavior we may learn how to change it to our benefit.

Two very practical discoveries of bee behavior made our beekeeping of today possible. One was the previously mentioned discovery by Langstroth of bee space. The other was the discovery by G. M. Doolittle that large numbers of queens could be reared by transferring larvae to queen cells. The discovery of the "language" of bees and their use of polarized light for navigation have attracted considerable interest all over the world.

Much has been learned about the behavior of insects, including bees in recent years. As an example, the term "pheromone" had not been coined in 1953, when Ribbands summarized the subject of bee behavior in his book, The Behaviour and Social Life of Honeybees. A pheromone is a substance secreted by an animal that causes a specific reaction by another individual of the same species. Now many bee behavior activities can be explained as the effect of various pheromones. Unfortunately for apiculture much of the study of pheromones has been connected with insects other than the honey bee.

Recently we have learned how certain bee behavior activities are inherited, and this information gives us a vast new tool to tailor-make the honey bee of our choice. Further studies should reveal other ways to change bees to produce specific strains for specific uses.

The Honey Bee Colony

The physical makeup of a colony has been described (p. 5). An additional requirement of a colony is a social pattern or organization, probably associated with a "social pheromone." It causes the bees to collect and store food for later use by other individuals. It causes them to maintain temperature control for community survival when individually all would perish. Individuals within the colony communicate with each other but not with bees of another colony. Certain bees in the colony will sting to repel an intruder even though the act causes their death. All of these, and perhaps many other organizational activities, are probably caused by the social pheromone.

There is no known governmental hierarchy giving orders for work to be done, but a definite effect on the colony is observed when the queen disappears. This effect seems to be associated with a complex material produced by the queen that we refer to as "queen substance." There is also evidence that the worker bees from 10 to 15 days old, who have largely completed their nursing and household duties but have not begun to forage, control the "governmental" structure. Just what controls them has not been determined.

These and many other factors make an organized colony out of the many thousands of individuals.

The Domicile

When the swarm emerges from its old domicile and settles in a cluster on a tree, certain "scout bees" communicate to it the availability of other domiciles. At least some of these domiciles may have been located by the scout bees before the swarm emerged. The various scouts perform their dances on the cluster to indicate the direction, distance, and desirability of the domiciles. Eventually the cluster becomes united in its approval of a particular site. Then the swarm moves in a swirling mass of flying bees to it. Agreement is always unanimous.

Wax Combs

As soon as the swarm enters the new domicile, food is collected and wax comb is built. The wax they use is secreted in tiny flakes from glands on the underside of the worker bee abdomen—but only when fresh food is available. The wax is molded by the bee mouth parts to form the intricate comb. The first comb consists of about 25 cells per square inch. This is the size worker bees are reared in. After there is a considerable amount of worker brood and increased population of bees, comb containing larger cells is built. This comb is used for rearing drones.

Although most references indicate that the presence of drone cells, even in small quantities, is objectionable, it is natural and normal for these cells to be present. They may have a morale-boosting or possibly some other beneficial effect.

The space between combs inside a colony varies greatly. Worker brood comb is about an inch thick. The open space between brood combs in a natural cluster is about three-eighths inch but varies from one-fourth to 1 inch.

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[1] In cooperation with Arizona Agricultural Experiment Station.

The space between honey storage combs is much more uniform than between brood combs. The space left between capped honey cells is usually one-fourth inch or even less—room enough for one layer of bees.

As the colony ages, the combs that were first used for rearing worker bees may be converted to honey storage comb; areas damaged in any way are rebuilt. These changes usually affect the bee space and result in combs being joined together with "brace" comb. Strains of bees show genetic variation in building these brace combs.

All these cells are horizontal or nearly so; vertical cells are used for rearing queens. Why horizontal cells are used for the rearing of brood and for honey and pollen storage, whereas vertical cells are built only for queen production is unknown.

Flight Behavior

When several thousand bees and a queen are placed in new surroundings—which happens when the swarm enters its new domicile or a package of bees is installed, or a colony is moved to a new location—normal flight of some workers from the entrance may occur within minutes. If flowering plants are available, bees may be returning to the hive with pollen within an hour. Bees transferred by air from Hawaii to Louisiana and released at 11:30 a.m. were returning to the new location with pollen loads within an hour. Package bee buyers in the Northern States have noticed similar patterns in bees shipped from the South.

What causes this virtually instant foraging by bees? What determines whether they collect pollen, nectar, or water? If food and water in the hive are sufficient, why should they leave to forage? Does a pheromone or a hormone cause this flight activity? Answers to these questions can lead to directing bees to specific duties we desire accomplished.

Swarming

The basic causes of swarming are not understood. Usually a consistent sequence of events occurs prior to swarming, but the actual swarm may not emerge even if all the events occur.

Workers are first reared in great numbers; then comes a period marked by the rearing of both workers and drones. Large quantities of pollen and nectar are brought into the hive. This crowds the brood nest and restricts the number of eggs the queen is able to lay. From 10 to 50 queen cells are produced, and shortly after the first one is sealed the swarm issues.

Swarms usually emerge from the hive in the late morning and often prior to the main flowering or honey-flow period. The more intense the flowering period, usually the more intense the swarming "fever" in an apiary. Some genetic lines of bees are much more prone to swarm than others.

One likely cause of swarming may be a change in production of certain pheromones by the queen bee that affects the workers. Swarming can often be discouraged by giving the bees more room above the brood nest area into which they can expand.

Housecleaning

Certain waste material accumulates in a normal colony. Adult bees and immature forms may die. Wax scales, cappings from the cells of emerging bees, particles of pollen, and crystallized bits of honey drop to the floor of the hive. Intruders, such as wax moths, bees from other colonies, and predators, are killed and fall to the floor. Worker bees remove this debris from the hive. In some ants this behavior pattern is controlled by certain pheromone-like chemicals. When these chemicals are applied to live ants of the same colony, their sisters bodily haul them out to the graveyard. A pheromone of a similar nature may occur in the honey bee colony.

The cleaning behavior associated with removal of larvae and pupae that have died of American foulbrood in the cells is known to be genetically controlled by two genes. It is modified by honeyflow conditions. What makes this discovery important is not only that it should help in developing bees more resistant to this and related bee diseases, but also that we can now expect to find that many of the other behavior characteristics of bees can be modified to suit special needs, with mutual benefit to beekeepers and farmers.

Brood Rearing

The seasonal changes in egg production by the queen and the subsequent rearing of brood by the workers are thought to be mainly dependent on the supply and abundance of nitrogenous and carbohydrate food. However, brood rearing slows down and stops in the fall, then starts again during midwinter in both Louisiana and Wisconsin, States geographically and climatically dissimilar. The buildup of fat bodies in fall and winter bees coincides with similar physiological changes in other species of insects, such as the boll weevil going into a period of diapause or inactivity. Initiation or control of diapause has been shown to be regulated by quantity and quality of light.

An important aspect of bee behavior is the possible effect of the 24-hour or circadian rhythm on daily brood rearing activities.

Much of the brood rearing activity cycle of colonies during the year can be related to the available forage or plants in bloom. Colonies in different parts of the country show fluctuations in brood production and in their subsequent colony populations that are coordinated with forage conditions.

Colonies in the Northeastern and Midwestern United States increase their brood rearing and bee populations during maple-dandelion-fruit bloom periods and show an intense swarming tendency prior to bloom of clovers. The brood and adult populations generally and slowly decline during late summer, but increase in areas with abundant acreages of aster, goldenrod, and smartweed. A severe decline in brood rearing follows the first killing frost. But in areas of New York, Pennsylvania, and Wisconsin, where the late flowering buckwheat is grown, greatly increased brood rearing, population increase, and even swarming occur in the early fall.

Beekeepers in the Western United States depend on flowering of irrigated agricultural crops and indigenous plants stimulated by infrequent rains for buildup of brood and adult bee populations. In the Southwest the farmers on irrigated land need bees on specific, predictable dates for pollination of their crops. The beekeeper who must supply these bees is dependent on unpredictable rainfall to provide natural food for his colonies to develop brood and bee populations needed for this service.

In the Southeastern States many different floral sources bloom abundantly at different but specific times of the year. Brood rearing and colony expansion commence early, and high populations are maintained with relatively little difficulty from swarming. Brood rearing usually declines somewhat during high summer temperatures when few flowering plants are available for bee activity, then picks up again late in the summer and continues until a killing frost.

Variation in the quantity of brood reared by colonies of bees nationwide is obviously affected by the immediate local environment. Yet with these apparent differences there are also similarities associated with photoperiods or other external stimuli rather than the quantity of food available.

Temper and Its Control

The temper or gentleness of bees determines their inclination to sting. Many factors affect their temper, including the genetics or inheritance of the bee, environment of the hive, and manipulation of the colony by the beekeeper. The temper of the colony can be temporarily controlled by man with a certain amount of smoke. Exactly why and how smoke affects bees is unknown, even though it has been used by beekeepers worldwide for over a hundred years. The amount of smoke needed to control the temper of a colony varies with time, temperature, and various other external factors, as well as with the inherent gentleness of the colony. Ruthless manipulations that injure or kill bees create more need for smoke than careful manipulations. The right amount of smoke to use on a colony is learned only by experience.

Temperature Control by Bees

Bees are paradoxical in that they are individually cold-blooded insects but collectively behave like a warm-blooded animal. During periods of high temperature they bring in water, which on evaporation cools the cluster to the desired temperature. During periods of low temperature they cluster tightly and generate and conserve heat to hold the temperature up so that the center of the bee cluster rarely gets colder than 80° F. Neither the exact mechanism of cooling nor the building up of heat in the cluster is understood. None of the proposed theories have been proved.

Colony Morale

"Colony morale" generally refers to the well-being of the colony. If the colony morale is good, the bees are doing what is desired of them, including increasing the colony population, making honey, and pollinating flowers. Many factors seem to affect colony morale. For example, if the queen is removed from a colony during a honey flow, the daily weight gains immediately decrease, although the bee population for the next 3 weeks is unaltered. Also when a colony is preparing to swarm, the bees practically stop gathering pollen and nectar. Improper manipulations or external environment also affects colony morale.

Known Pheromone Activity

Some of the bee colony pheromones and their biological action are known to beekeepers. The Nasanov or scent gland was described over a hundred years ago. The biological behavior activity of its pheromone is best seen when a swarm is hived. When the bees first enter the new domicile, some bees stand near the entrance and fan. At the same time, they turn the abdominal tip downward to expose a small, wet, white material on top of the end of the abdomen. This seems to affect the other bees, for within several minutes all will have settled and entered the new hive. When bees find a new source of food, they mark it with the same scent gland. A Canadian research team has recently reported isolation and identification of this pheromone.

Colony odor refers to the odor of an individual colony. Because each colony odor is different, the colonies cannot be combined in the same hive without fighting and killing one another. Colony odor probably results from a combination of endogenous (pheromone or pheromone-like materials) and exogenous (food accumulation and food interchange) materials in each hive and seems to be recognizably different for every colony.

The usual procedure for the beekeeper when colonies are to be combined is to place a newspaper between the two sets of bees. By the time the bees have eaten through and disposed of the newspaper, their odors have intermingled and become indistinguishable. During heavy honey flows, differences between colonies seem to disappear, and colonies can be united without difficulty.

One of the most interesting and complex pheromones, originally termed "queen substance," is now believed to be a complex of different chemical pheromone compounds, which stimulates a large number of complex behavior responses. Its presence in virgin queens in flight attracts the drone for mating from an unknown distance. Its presence in virgin and mated queens prevents the ovaries of the worker bee within the hive from developing and the worker bees from building queen cells. It keeps swarming bees near the queen. Its decrease is a cause of swarm preparation or supersedure. Queen substance is produced in glands in the queen's head. If these glands are removed, the queen presumably produces no more queen substance, yet the queen and the colony go on much as they did before. The quantity and quality of queen substance vary in virgins and mated queens of different ages.

The alarm or sting pheromone, which also may be a complex of pheromones, has been tentatively identified by a Canadian research team. When a bee stings, other bees in the immediate vicinity also try to sting the same spot. In this case the sting pheromone provokes other bees to sting the same place, and they in turn provoke additional stings ad infinitum. Smoke blown onto the area seems to neutralize this effect.

Whether the genetic basis for a difference in temper is in the quantity of the alarm pheromone or pheromones produced or in the reception organs of other bees is unknown.

Other Known Methods of Bee Communication

Besides the known and possible methods of bee communication or language that have been mentioned involving the chemical pheromones, there are, of course, others. The best known is the so-called "dance" of the returned forager bee. This dance tells other bees precisely in which direction to search for food and how far they should fly, the type of food they will find, and the relative quantity. Minor genetical variations in individual dance behavior exist. How this genetic variance can be used in an economic way is unknown. The cluster itself and individual bees in the field make subtle noises or sounds, all of which are not at present understood. One such sound seems to tell the bees to stay home. Utilization of this sound could lead to protection of bees from harmful pesticides.

Experienced beekeepers recognize a difference in sound between a colony with a queen and one without, between a "mad" bee and an undisturbed one, and between normal and cold or starving bees. Individual queens and even worker bees emit squeaky sounds called "piping" and "quacking."

When a bee returns from a foraging trip and performs a dance, she communicates the kind of "plant" or "flower" on which she was foraging by releasing a taste or the perfume of the flower through nectar regurgitation or on body hairs. This has prompted other experiments designed to train or force bees to collect or work a desired crop. These experiments have so far been unsuccessful. The reason for the failures may well be that the bee language code has not been completely translated. We are still unable to "talk" effectively to the bees and "tell" them what we want done.

Bees also recognize and are guided by different colors but are unable to communicate these colors. Their eyes are receptive to the polarization of the light in the sky and this aids in their navigation.

Age Levels of Bees Correlated With Work Habits

The bee is adaptable to many environments. Honey bees native only to Europe, Asia, and Africa have adapted well to all but the polar regions of the world. Part of this adaptability lies in the capacity of the individual bee to "sense" what must be done, probably through reception of colony pheromones, then to perform the necessary duty.

Under normal conditions there are bees of all ages in the hive. The age of the bee determines in general its daily activity. However, when conditions become abnormal, age is no longer a criterion of duties. If a colony is made up of old bees, for instance, some of them will become physiologically young, and conversely if it is made up of all young bees, some will become physiologically old and take on duties normal to such bees. The reasons and causes for bees changing work in this manner are unknown.

Behavior and Activities Outside the Hive

Genetically we have found that some bees produce more honey than others, but we do not know why. The individual bee may collect more because of its own genetic inheritance. The colony may store more honey because of the queen's inherited ability to lay more eggs, resulting in a greater total population of bees in the hive, or because the bees are inherently longer lived.

These activities would have the same gross effect of increasing the population of the colony.

We can, as "bee controllers," affect the bee's environment in conjunction with its inheritance. There is no reason to believe that bees work better when in want. Since evidence indicates the reverse, there should always be an ample supply of reserve honey in the hives.

Another environmental factor is colony manipulation. A beekeeper's disturbance of the colony during the honey flow results in a marked decrease in the amount of honey stored for that day and even the following day. Colonies of bees should not be needlessly disturbed; however, manipulation to give them extra room to expand the cluster or store food is necessary.

Pollination—Crop Problems

A problem associated with bee behavior is in getting bees to work on a particular field. Growers of seed and fruit crops rent bees in ever-increasing quantities. They want the bees they rent to stay on their acreage.

One method being explored at the present time takes advantage of inherited behavior differences. Today a bee is being bred that is specifically suitable for alfalfa pollination. Bees specifically designed genetically to pollinate certain other crops will eventually be developed.

In conjunction with these is genetic variability in the attractiveness of plants to bees. Nectar and pollen availability in plants can be accidentally eliminated by breeding. When this occurs, there is a loss of a potential honey crop, but more important can be the loss of a seed or fruit crop because the plant no longer attracts pollinators. A beekeeper visiting Europe and seeing the large acreages of potatoes cannot help but wonder what would happen to the European bee industry if a strain or variety of potatoes were developed that would yield pollen and nectar for bees.

Contradictory Behavior of Foraging Bees

Probably the biggest problem in adequate pollination that must be solved pertains to the foraging activity of the bees. Individual bees usually confine their foraging area to a relatively small block of a few square yards or to a single tree. On the other hand, the foraging area of a colony comprises entire square miles—a circle with a radius approximating 2 miles—with the collective effect that foraging bees shift about, readily affected by the dance intensity of other returning foragers.

This contradiction could be resolved by breeding bees with greatly expanded individual foraging areas but with a reduced radius of colony activity, possibly three-fourths mile.

Control of Foraging

A major goal is to control the foraging bee and get it to more effectively pollinate the plant. Bees should be attracted to areas where they are desired, e.g., pollination areas, and repelled from areas where there is danger to them from insecticides or where they endanger people. Work with other insects—both social and nonsocial—indicates that this could be accomplished by chemical and physical means.

Actually beekeepers have been using various chemicals to control bees in the hive for some time. Smoke, a combination of chemicals in gaseous form, and various chemical repellent compounds have been used for years to repel bees.

There is considerable evidence that different plant species produce varying attractant compounds associated with their nectar and pollen. Bees are highly attracted to the scent of recently extracted honeycomb and to the scent of honey being extracted or heated. During periods of intense honey flow, bees much prefer collecting nectar of lower sugar concentration than exposed honey. Obviously certain chemical scents associated with certain flowers and to some extent incorporated in the collected honey are highly attractive to bees.

Certain chemical extracts of pollen strongly indicate that some pollens contain compounds that stimulate collection response in bees. Isolation and identification of these bee-attractive compounds and the application of the attractant to areas requiring high bee populations for pollination should attract bees to the area.

Synthetic chemical compounds, not necessarily attractive, can probably be used if the bees are properly trained. Bees associate certain smells with food sources and communicate the smell at the food source to the colony. Isolated chemicals, which may or may not have anything to do with pheromones produced by the bee or attractant compounds produced by plants, profoundly affect bee behavior. Some of these chemicals cause the bees to fight or flee from the source, but others attract the bees.

Of immediate concern is the need for a repellent that can be applied to a field to drive off all pollinators while a pesticide is applied. Then, hopefully, when the toxic effect of the spray has disappeared, the repellent will dissipate and the bees return to work.

Research should not be confined to chemicals alone, but should be shared equally with various physical factors that can possibly attract or repel bees. In other entomological fields the research on physical methods of controlling insects is receiving intensive investigation. Different insects respond in differing ways, they are attracted to certain light wavelengths and repelled by others. Night-flying moths are repelled or go into defensive maneuvers because of bat sonar signals, whereas crickets and other members of their insect group can be collected by reproducing certain stridulations.

Particular Behavior Activities of Bees

The Drone

The time of day that drones fly in search of a mate depends on many factors, such as the geographic location, day length, and temperature. Drones usually fly from the hive in large numbers between 11:00 a.m. and 4:30 p.m. Morning or early afternoon flights last about 2 or 3 hours. Later flights are shorter. An individual drone flies for about 15 minutes before returning to the hive and may fly four or five times in one day.

When flying, drones seem to congregate in "mating areas," which may serve to attract virgin queens. These areas are usually less than 100 feet from the ground and seem to be associated with land terrain.

Some control of the time of drone flight can be obtained. The usual afternoon flight can be prevented by placing the drone-containing colony in a cool, dark room. On the following day the drones will fly several hours earlier than normal.

The Queen

The virgin queen becomes sexually mature about 5 days after emergence. She is relatively quiet in the morning and most active in the afternoon. She may begin her mating flights 5 or 6 days after emergence and may go on a number of them over several days. Mating with 8 to 12 drones will stock her spermatheca with 6 or 7 million sperm. She will begin to lay in 2 to 5 days and may continue for years.

A young, fully mated queen rarely lays drone eggs before she is several months old. After that time she seems capable of controlling the sex of the eggs by laying either fertilized or nonfertilized eggs.

The worker bees occasionally kill their queen. More frequently they will kill a newly introduced or virgin queen. To do this, 15 or 20 worker bees collect about her in a tight ball until she starves. It has generally been thought that bees "balled" strange or introduced queens because they did not have the proper "colony odor." The reason for balling is probably more complicated than that, because bees will occasionally ball their own queen. Even if the ball is broken up, the queen seldom survives. If it is broken up or after the queen is dead, the stimulus is powerful enough that the bees taking part in the queen balling are sometimes subsequently balled themselves by other bees.

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BEEHIVE AND HONEY HANDLING EQUIPMENT

By CHARLES D. OWENS, *agricultural engineer, Agricultural Engineering Research Division, Agricultural Research Service*[1]

Mechanization can save time and reduce lifting of heavy hives and supers or other containers of honey. To use labor-saving devices efficiently, certain changes in methods of operation and different types of equipment may be needed.

The hives should be easily accessible by truck and arranged so that several can be manipulated as a unit. Some type of hive hoist is needed so the beekeeper can handle heavy colonies alone. After the supers of honey are lifted from the hive onto the truck, they should be placed on easily movable skid boards for moving into the honey house. And finally, when the liquid honey is removed from the supers, other warehouse equipment is needed to move or load it for shipment to the retail packing plant.

Today bees are moved frequently to take advantage of nectar flow and to furnish pollination services. In some areas they are moved several times a year and over long distances. These moves require equipment for loading the hives. Shade and water should always be considered when colonies are to be relocated. If these are not readily available, they can be furnished to bees by artificial means.

Artificial Shade

The importance of shade is determined by the prevailing local temperature. Bees benefit from shade in all areas where the maximum summer temperature normally exceeds 80° F. If the range is between 80° and 95°, partial shade all day or full shade in the afternoon is sufficient. If the average maximum temperature exceeds 95°, bees benefit from total shade all day.

In southern California and southwestern Arizona, beekeepers build shades for the bees. These shades are usually 7 feet high, 12 feet wide, and 50 or more feet long. A 50-foot shade will accommodate 50 hives arranged in two rows back to back, with a 4-foot walkway between rows. Such shades are built with the long dimension running east and west. The shade should extend down at least halfway to the ground on each end to protect the end hives from morning and afternoon sun.

Tests made in Arizona show that a colony under solid shade produces 50 percent more honey than a similar colony exposed to the sun. Under partial shade the increase in production was proportional to the amount of shade.

A portable shade (fig. 1) has been designed for use in areas needing shade and where permanent shades cannot be used. The construction of this shade is given in detail in U.S. Department of Agriculture Leaflet 530, Shade and Water for the Honey Bee Colony. In cooler parts of the country a windbreak and good air drainage are more important than shade.

Water

Water is used by honey bees to dilute their food and to cool the hive. On a hot day a colony may use as much as a gallon of water. Therefore, hives should be located near a supply of water. Under no condition should they be placed more than a mile from water; and in warmer parts of the country they should be less than one-half mile. The water should be as close as possible so the bees utilize a minimum of energy in transporting it to the hive.

Bees will usually collect water at the nearest satisfactory source; this may be a birdbath, swimming pool, pond, or stream. The source may be on a neighbor's property, and therefore the bees become a nuisance to him. You can prevent this by making water available nearby with some type of watering device.

The water can be furnished to the bees from a barrel, tank, or directly from a pressure water system into a watering device (fig. 2). A trough filled with coarse gravel makes a good watering device. A perforated tube in the bottom of the trough gives uniform water distribution.

A coarse cellulose sponge floating in a pan or trough of water also makes a good waterer. The pan should be 2 inches deeper than the thickness of the sponge. A float on the supply line, similar to to the one in figure 2, will maintain the desired water level in the pan.

Such watering units should be thoroughly cleaned about every 2 weeks to reduce the possible spread of bee diseases. In some areas the watering unit will require protection from other animals.

Moving Colonies

Many mechanical devices can be used in loading and unloading colonies. The choice of the

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[1] In cooperation with Arizona Agricultural Experiment Station.

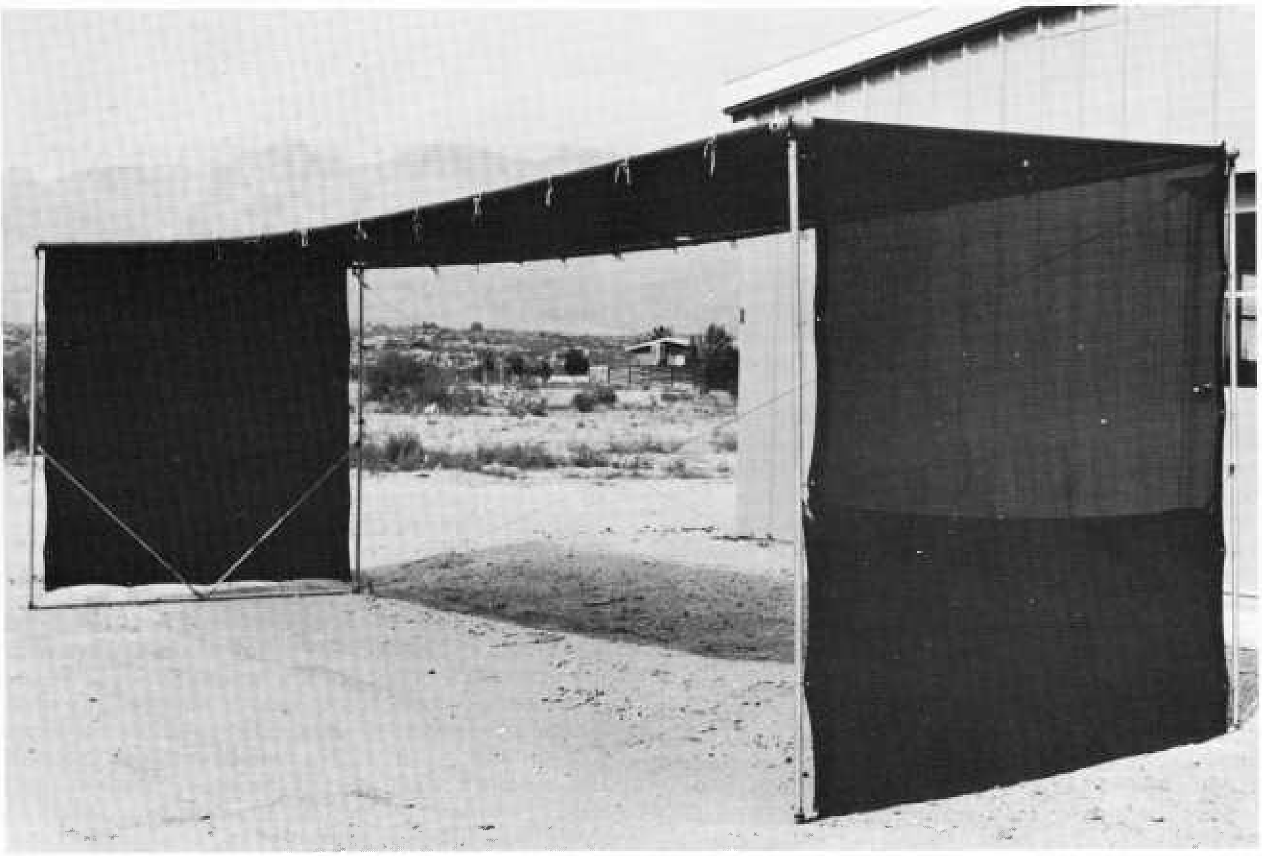

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FIGURE 1.—Portable shade made of steel tubing and covered with shade cloth.

appropriate one will depend on the number of colonies to be moved and the frequency and distance of the moves.

The least expensive lifting device is a crane or hand winch and boom attached to the rear corner of a truck. Many types are built for industrial use. Some can even be converted to floor cranes for use in the shop or honey house. These cranes have about a 4-foot reach and their length of reach is not changeable. Where they are used, a hand cart or similar device is needed to take the hive to them and to move it after it is on the truck. With the lift, one man can place a hive on or off the truck. For the small beekeeper with infrequent moves, this may be satisfactory.

A hydraulic tailgate will lift several hives at one time. Tailgates are made to fit all sizes of trucks. The tailgate is useful for loading hives and supers of honey (fig. 3) and also as a platform on which to stand when working tall hives. The hydraulic system is powered by belt from the truck engine or power takeoff from the transmission.

Some beekeepers have designed pallets the width of the truck. These are pulled on or off the truck by special drag chains.

Boom hoists are most satisfactory for loading and unloading hives (fig. 4). With them a hive can be picked up and placed in position on the truck. Presently there are three companies manufacturing these hoists for lifting hives.

The hoist is mounted on the truck frame, usually between the cab and the truck bed. Two types of drives are used, electrical and hydraulic. An electrically powered hoist operates from the truck batteries or from a gasoline-driven generator. Today most hoists are powered by batteries. To keep the battery charged, the truck motor is kept running while the boom is being operated. Battery-operated hoists are usually more dependable than those operated by gasoline engines. The hydraulic hoist operates like the tailgate, but it has electrical valves to control the movement of the boom.

The hoists have boom lengths of 12 to 22 feet. The simplest hoist only raises the load and the operator moves it by hand. Others level auto-

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FIGURE 2.—Four-inch eaves trough filled with coarse gravel and equipped with float water-level control.

matically and can move the load along the boom. The choice depends largely on how much it will be used. A good hoist should support a 300-pound load.

A fork on the end of the boom is used to pick up the hive. The following three methods are employed: Fork prongs are inserted under the bottom board, fingers are dropped into the hand holes, or fingers are inserted under a 1½-inch cleat nailed on each end of the hive. The cleats are usually the most satisfactory.

On special order a hoist can be obtained that will lift a pallet bearing two or four hives with a total maximum weight of 1,000 pounds. A short truck and trailer can be used if the hoist is placed on the rear of the truck where it can service both. Hives on pallets can also be loaded by a forklift mounted on a tractor. The tractor can also haul hives to places difficult to reach by truck. If the tractor is equipped with a blade, it can level the area before the hives are unloaded.

The disadvantage of a tractor forklift is that it must be hauled on a trailer behind the truck, and the combined length may exceed the State highway permissible limit. Also in fields where bees are supplied for pollination purposes, there may be insufficient room to maneuver the tractor around the truck.

Moving the Hive

Many migratory beekeepers now use either forklifts or hoists. They use cleats on the ends of the hive, and they nail the bottom board underneath. Hives are usually loaded at night, hauled to the new location, and unloaded before dawn. If the hives are loaded with open entrances, a plastic screen covering the entire load should be used.

Inspecting Hives

The hoist can also be used to lift off the supers for inspection of the colony brood nest. One commercial cart for hand moving hives is also designed to lift the supers and tip them back out of the way, so the brood nest can be inspected. There is also a stationary unit that clamps to the hive, then lifts and swings the supers aside so the brood nest can be inspected.

Removing Honey Supers

For the small beekeeper, the simplest way to remove bees from the honey super is to brush them off each comb. Another method of removing bees from supers is to use an inner cover with a bee escape. The escape board, as it is called, is placed between the supers and the brood nest the day before the supers are to be removed. All other openings into the supers must be closed so that the bees cannot return. This method works best in cool weather when the bees move at night from the honeycombs to the brood nest.

A recent innovation for removing bees from supers of honey is to blow them out. A large vacuum cleaner with a clevis tool attachment works satisfactorily. The larger household tank-type vacuum cleaner can be used if the dust bag is removed. A velocity of about 18,000 feet per minute is required. There is now an engine-driven blower built specially for removing bees. This method does not irritate the bees and it is effective.

Handling Supers

Supers of honey removed from the hive are usually placed on dripboards or on pallets on the truck. The dripboard is the size of the super and it has a metal sheet or pan to catch dripping honey. It is made to fit a handtruck for moving a stack of supers (fig. 5). The pallet holds two or more stacks

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FIGURE 3.—Loading supers on truck with hydraulic tailgate.

and is moved with a hand- or power-operated pallet truck. The supers are moved into the honey house in these stacks. Pallets with casters are sometimes used in the honey house, but they are usually not satisfactory. Generally handling the single stack on a dripboard is most satisfactory.

The handling of individual supers should be reduced as much as possible from the time they are removed from the hive until they are returned.

Handling Honey

Honey is usually sold wholesale to packers in 5-gallon cans, drums, or in bulk. For many years the 5-gallon (60 pound) can was the principal wholesale container, and small beekeepers still use it. Although single cans may be handled by hand, they are more easily handled by pallet truck. Larger quantities of honey are more easily handled in 55-gallon drums. The drums are more durable than cans and are reusable. Several industrial hand and power trucks are available for handling drums. If drums are to be stacked, a motor-driven lift truck is needed. All commercial bottlers of honey are equipped to handle both cans and drums.

Some beekeepers have built large tanks for storage of 1,000 gallons or more of honey, which is then pumped into tanks on the trucks for transfer to bottlers. One company uses air pressure to transfer honey into and out of the truck tanks.

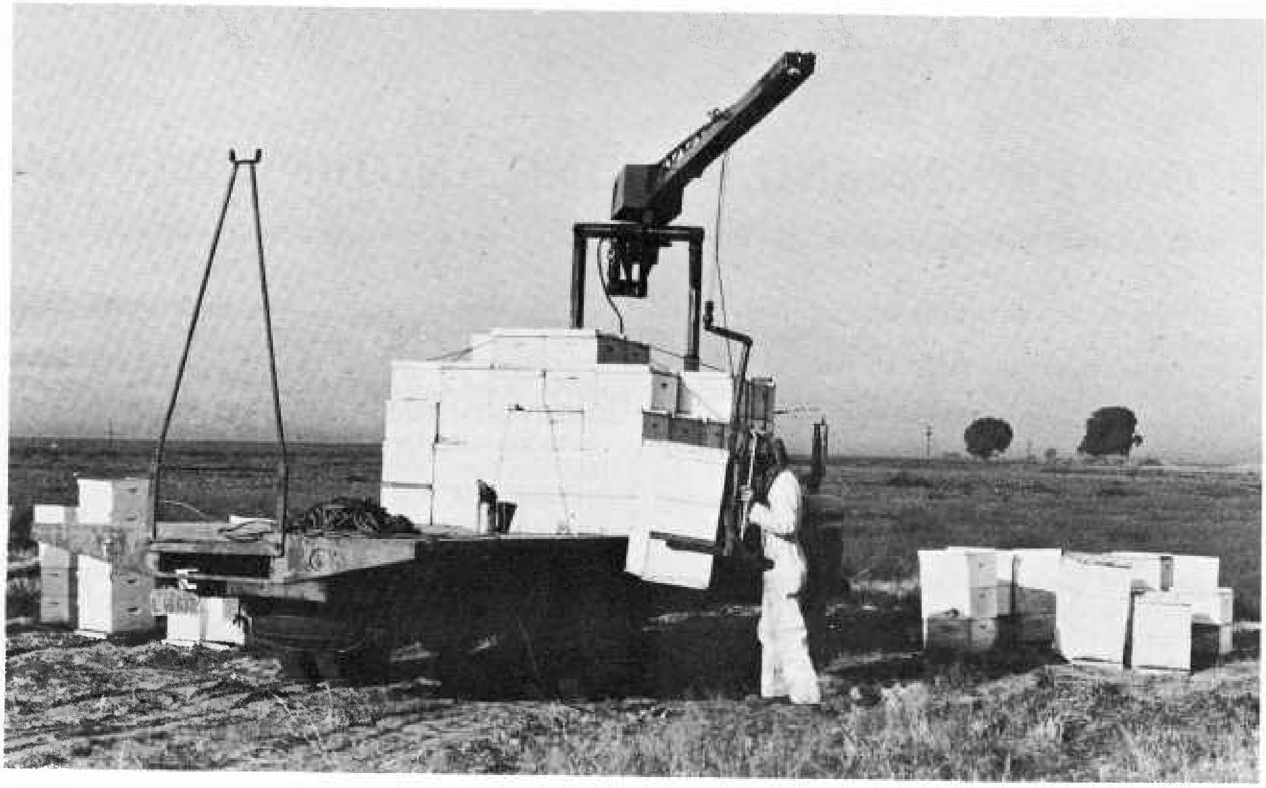

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FIGURE 4.—Loading hives with electrically powered boom loader.

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FIGURE 5.—A two-wheeled handtruck, a versatile piece of equipment around honey house, is being used to move empty supers.

HONEY PROCESSING, PACKING, AND DISTRIBUTION

By B. F. DETROY, *agricultural engineer, Agricultural Engineering Research Division, Agricultural Research Service* [1]

Honey is at its peak quality when properly cured and sealed in the comb by the honey bee. When it is converted from this state by man to suit his particular need, deterioration begins. The extent of deterioration depends on the processing methods used between the time the honey is extracted from the comb and its use by the consumer. It is the responsibility of the industry to provide a top quality product to the consumer if acceptance is to be expected.

Since most honey harvested is extracted from the combs in an extracting plant, the beekeeper should equip this plant so that the operations can be done in the most efficient possible manner to provide a high quality product for market.

Honey House

The extracting plant is generally located in a honey house. The honey house is the center of activities for the beekeeper, represents a goodly portion of his investment, and may contribute greatly to the overall efficiency of the entire operation.

The honey house may contain various other facilities in addition to the extracting plant, such as storage space for hive equipment and honey, workshops, office space, and possibly a packing or salesroom or both. The building should be designed for the work to be done in it and it should be properly equipped. Efficient arrangement, cleanliness, and ample space are of prime consideration in planning the honey house.

Types of Honey Houses

Honey houses may be one- or two-story structures. The one-story structure is probably the most common and is used by both large and small beekeepers. The building construction is more simple and the choice of a building site is not limited by terrain. Honey handling cannot be readily adapted to gravity flow, but proper use of honey pumps can overcome this disadvantage. Small beekeepers may use this type of building to particular advantage. Since all equipment can be compactly arranged on one level, it is easier to closely regulate all operations.

Two-story structures may have both floors above ground or may have one floor above ground and a full basement. If both floors are above ground, it is necessary to provide a ramp to the second floor so that it is accessible to trucks or to install elevators to move equipment and material from one floor to the other. A hillside building site will provide access to both floors without ramps and both floors are at least partially above ground (fig. 1). The main advantage of the two-story building is that the supers of honey can be unloaded at the upper level where the extracting plant is located. Extracted honey can then flow by gravity to storage or further processing on the lower floor.

Space Requirements

Careful planning prior to building a honey house may save costly additions later. The operations necessary in extracting honey and the sequence in which they are performed should be considered in detail for filling the needs of the beekeeper. Ample space should be provided for all extracting and processing equipment. The equipment chosen should be expected to operate at near-rated capacity and should be compactly arranged so that the material flows smoothly from operation to operation with a minimum of movement by the operators from area to area.

Storage space for full honey supers should be figured on the basis of the maximum number anticipated in the honey house at any one time. Uniform stack height of full supers should be used throughout the operation for efficient handling. Warm storage areas for full honey supers aid in the extracting operation. An area for storage of liquid extracted honey must also be provided. Required space should be figured on the basis of the type of bulk containers used and the height they are to be stacked.

Other areas to be included in the building will vary in type and size according to the individual beekeeper and the operations he desires to perform. They may include a room for rendering cappings, space for shop facilities, equipment-assembling area, truck storage, small packing plant, salesroom, and office space.

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[1] In cooperation with Wisconsin Agricultural Experiment Station.

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FIGURE 1.—Apiculture laboratory and honey house at University of Wisconsin. Note that lower floor is partially below ground and that entrances are at both floor levels.

Special Features

Regardless of type or size, the building should be bee tight and should provide a means of unloading filled honey supers in a closed-in area. A sunken driveway or raised platform to permit loading or unloading with the truck bed at floor level will prove to be a great labor and time saver.

The floors, walls, and ceiling should be made of materials that can be easily cleaned and maintained. Walls and ceilings should be a light color and should be of a material or paint that can be washed often. Floors should be of concrete where possible. If hardwood floors are necessary, they should be covered with ceramic tile. Any floor used must withstand heavy loads and be free of vibration. A smooth surface with ample drain facilities will make cleaning easier.

Illumination and ventilation should be carefully considered in planning the building. In areas where close operator attention is required, it is highly important to provide adequate illumination, 50 to 75 foot-candles. The entire building should have adequate lighting. Windows to provide both light and ventilation should be strategically located. Fans may be installed to reduce odors and lower humidity. All windows must be screened and provided with bee escapes.

Rooms in which fires might originate, such as the furnace room or wax-rendering room, should be built of fire-resistant material or lined with asbestos board. It may be desirable to have such facilities in another building, and if so, the buildings should be separated by at least 20 feet.

If handtrucks, motorized lifts, and fork or barrel trucks are to be used, doorways should be large enough to permit their free movement to all parts of the building.

Honey Extraction

Honey supers should be removed from the hive as soon as the honey is sealed. Extraction soon after removal may prevent crystallization in the comb. It is often possible to reuse the super on the colony before the flow ceases. Equipment in the extracting area should be arranged so that the material flows smoothly through the various operations with a minimum of interruption and with as little physical effort as possible.

Extracting equipment will differ in almost every honey house. Choice of equipment is dependent on the size of operation, physical properties of the honey, availability of labor supply, and the personal selection of the individual. In many cases the beekeeper has designed and built his own equipment or remodeled commercial equipment to meet some particular need.

Care and Storage of Supers

Supers are most easily handled if they are kept in uniform stack heights from the time the full supers are removed from the colony until the empties are returned. Stack boards or skid boards are commonly used. Skid boards placed on the truck bed receive the supers as they are removed from the colonies and are moved through the entire extracting process and back onto the truck with an ordinary warehouse truck.

More expensive types of lift trucks are sometimes used that can handle skids containing two or four stacks of supers. Castered dollies may also be used, but these are not easily hauled to and from the yards on trucks.

Hot rooms are sometimes used for storage of filled supers prior to extraction, especially in regions where cool temperature or high humidity is common. If the only requirement is to keep the honey warm to facilitate extraction, the room should be kept at 75° to 100° F. and should have a circulating fan. Warm, dry air may also be used to remove moisture from the honey, in which case slatted skid boards should be used or the supers stacked crisscross. The air should be introduced at floor level and drawn up through the stacks. Moisture-laden air should be discharged from the room. Dehumidifiers may also be used to speed the lowering of the moisture in the honey.

Supers stored for a long time should be fumigated to prevent damage by the larvae of the wax moth.

Uncapping Devices

To extract honey it is first necessary to remove the capping from the comb cells. A wide range of equipment is available for uncapping combs, from unheated hand knives to elaborate mechanical machines.

A cold knife can be used to uncap warm combs or it can be heated by placing it in hot water. It is most commonly used by the hobbyist beekeeper who has only a few hives. The steam and electrically heated hand knife and hand plane are probably the most widely used uncapping devices in this country today. In a more refined version, the knife is mounted in a frame on spring steel mounts and vibrated by an electric motor. This type, referred to as the jiggler knife, may be mounted in a vertical, horizontal, or inclined position. The knife vibrates in the direction of its length.

Machines that carry the combs of honey through an uncapping device after being fed into the machine by hand are available commercially and their use is becoming more common (fig. 2). The uncapping devices on these machines may be vibrating knives, rotating knives, flails of various kinds, or perforating rollers.

A few machines have been built by individuals that uncap the frames in the super; however, none of these machines are available commercially.

Extractors

Two types of extractors are in use in this country today—the reversible basket and the radial. Both use centrifugal force to remove the honey from the comb.

Reversible-basket extractors range in size from 2 to 16 frames per load. Honey is extracted by applying centrifugal force to first one side of the comb then the other. The comb is reversed three or four times—turned 180°—during the extracting cycle. On some of the small extractors the frames are reversed by hand with the machine stopped, whereas on others the frames are reversed by use of a brake while the machine is running. Extracting time ranges from 2 to 4 minutes at constant speed.

Radial extractors range in size from 12 to 50 frames per load. Both sides of the comb are extracted simultaneously as the combs are rotated, the centrifugal force acting radially across the face of the comb. The extracting cycle is started at 150 r.p.m. and is gradually increased during the cycle to 300 r.p.m. The time required to extract a load of combs will vary from 12 to 20 minutes depending on the temperature and density of the honey.

Special extractors have been built and used that are larger than those described and that extract the combs in the supers, special boxes, or baskets. None of these are available commercially.

Automatic electric controls have been developed for both the radial and reversible-basket extractors. These controls change the r.p.m., reverse the baskets, and shut off the motor when the cycle is completed. Mechanical controls are also available that automatically increase the speed of the radial extractor during the extracting cycle.

Care of Cappings

Cappings and honey removed from the combs in the uncapping operation must be separated to salvage the honey and wax. Caution must be taken in recovering the honey to prevent impairing the flavor, color, and aroma. The following methods are used:

(1) *Draining by Gravity.*—The cappings are accumulated in screened or perforated containers and allowed to drain, usually for at least 24 hours in a warm room. Stirring and breaking up the cappings facilitate draining.

(2) *Centrifuging.*—The cappings are placed in a specially constructed centrifugal drier or in wire baskets that fit into a radial extractor. Honey is removed from the cappings by centrifugal force as the cappings rotate.

(3) *Pressing.*—A basket-type perforated container is used to catch the cappings where some

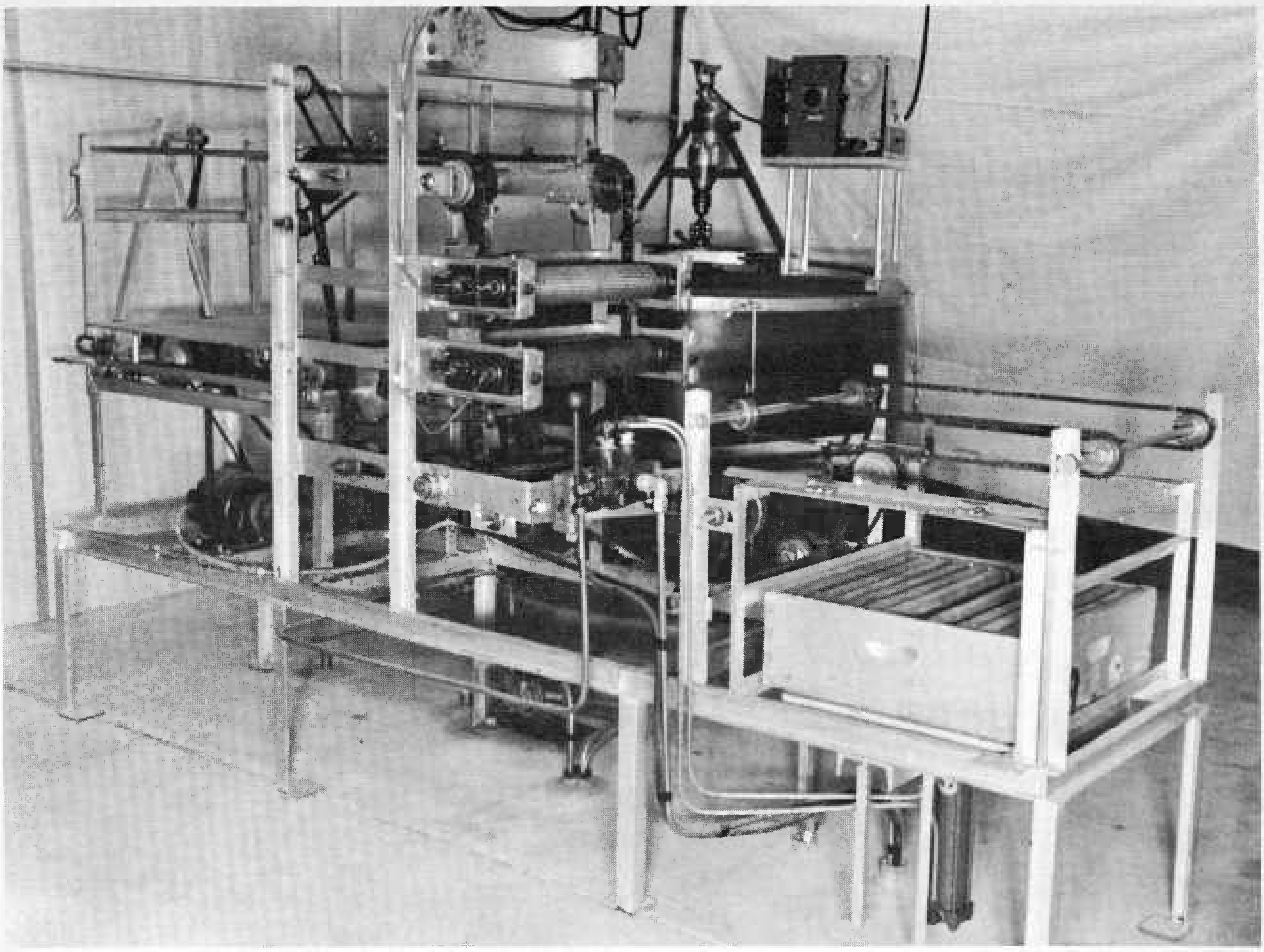

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FIGURE 2.—Semiautomatic, perforating-roller uncapping machine removes frames from super, uncaps combs, and deposits frames in extracting tubs.

gravity draining takes place prior to pressing. Usually the container is placed directly under the press ram and pressure applied to squeeze the honey from the cappings.

Honey removed from the cappings by any of these methods is undamaged. Usually the remaining cappings will contain as much as 50 percent honey by weight, which may be recovered when the cappings are melted. This honey is generally damaged by overheating and should be handled separately.

(4) *Flotation and Melting.*—The cappings melter is widely used to separate honey and cappings. The cappings and honey enter the melter tank near the bottom and are separated by gravity. Separation is facilitated by heat that softens the cappings and increases the fluidity of the honey. The cappings being less dense rise to the top where they are melted. The honey level is controlled by an adjustable height overflow enclosed by a baffle to prevent the entry of wax. A layer of cappings in various stages of liquefaction is maintained between the honey level and the heat source. Liquid wax accumulates at the top of the tank and is discharged into solidifying containers. Heat may be supplied by steam coils, electric heaters, heat lamps, or radiant gas heaters.

Various models of this type of separator are marketed. If they are properly operated, the honey obtained can be added to the remainder of the crop without damage to grade, color, or flavor.

(5) *Centrifugal Separator.*—Recent development of a centrifugal separator (fig. 3) that automatically separates the honey and dries the cappings has greatly advanced the use of mechanical uncappers. Usually all honey and cappings from the uncapper and extractor are run through the machine. Large pieces of cappings should be broken up to assure proper feeding into the separator.

Processing

Processing the honey crop beyond the extraction stage may be done by the producer, the packer, or

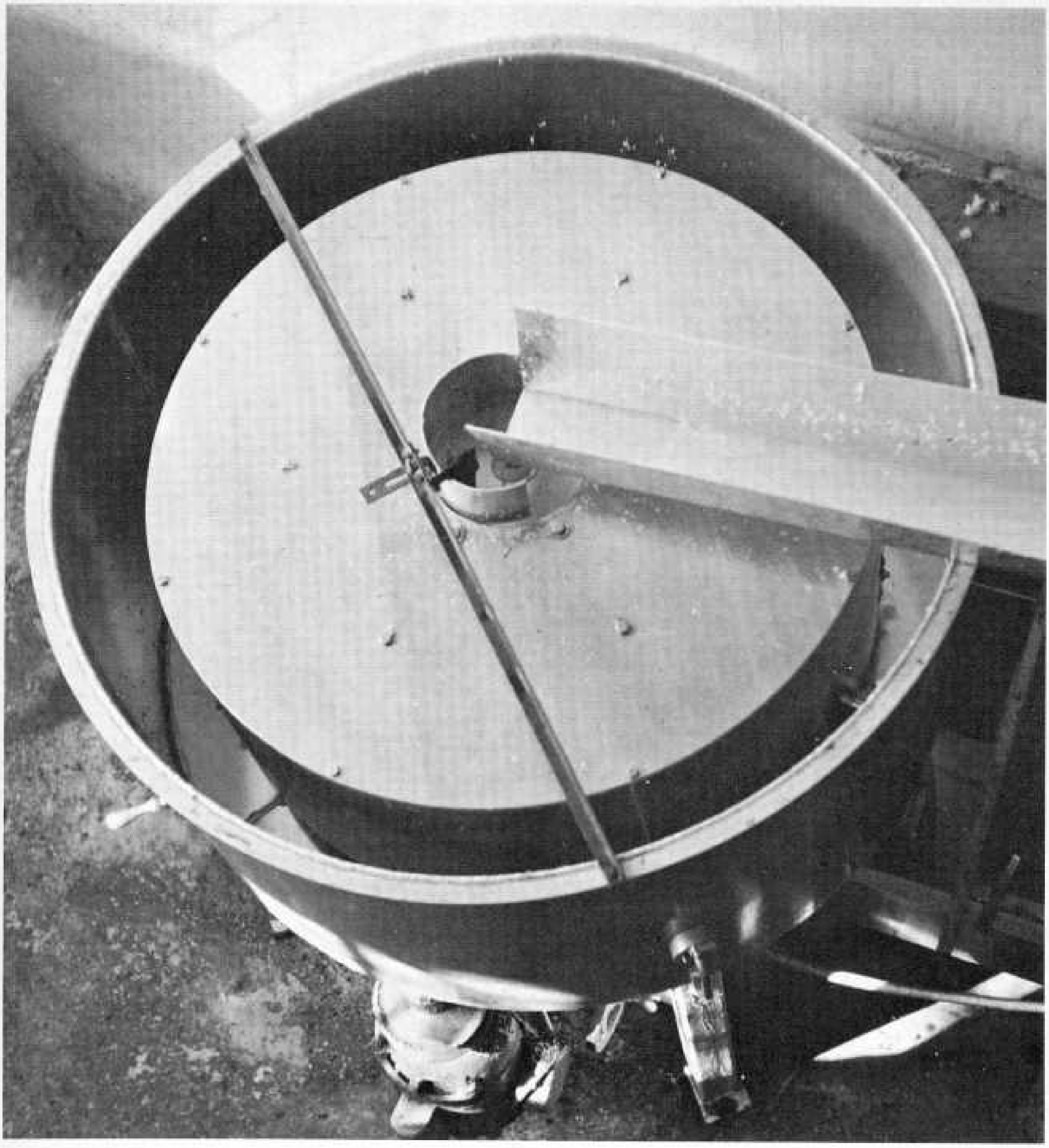

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FIGURE 3.—Centrifugal separator that separates honey from cappings.

both. Regardless of where these operations take place, they are necessary to provide the consumer with a high quality product. It is important, however, that the heating be controlled, since the flavor, color, and aroma of honey can be seriously impaired by excessive temperature over a given period of time.

The Sump and Pump

Honey from the uncapping and extracting operation usually flows into a sump. The sump is a tank, usually water jacketed, that collects honey from the extracting process so that it can be delivered for further processing at a uniform rate. The sump may contain a series of baffles or screens or both for removing coarse wax particles and other foreign material. A honey pump is generally used in conjunction with the sump; however, in some systems gravity flow can be used and the pump eliminated.

Gear pumps or vane pumps are commonly used. In cases where the centrifugal separator is used and it is necessary to pump large quantities of cappings, some other type of pump may be required. Pumps used in a continuous flow system should be supplied with honey in sufficient quantity to allow uninterrupted operation. To prevent introduction of air into the honey, the pump should run at low speed and the level of honey in the sump kept well above the pump intake. Automatic pump controls, either float type or electric liquid level control type, can be used to eliminate continual operator supervision.

Strainers

After the bulk of the wax has been removed from the honey by the sump tank, coarse straining, or centrifugal separators, it is necessary to remove very fine material. Settling of honey may prove satisfactory for some processors. The honey is first screened in a sump and then pumped into settling tanks at a temperature of at least 100° F. Sufficient time should be allowed to permit the required separation.

To be certain that all honey packed will meet the desired grade requirements, it is necessary to use some type of strainer. Many types and sizes are used and the straining media may be metal screen, crushed granite, silica sand, or cloth. Regardless of the material used, the mesh must be fine enough to produce the desired result. Cloth has the advantage of being easily cleaned; furthermore, since the initial cost is low, a cloth may be used only once and discarded.

Honey may be moved through the strainer by pressure (pumping) or by gravity flow. When cloth strainers are used in a pressure system (fig. 4), a pressure switch should be installed in the honey line to prevent excessive pressure that could rupture the strainer cloth.

Heating the honey to 115° will greatly facilitate the straining process. This increases the fluidity of the honey without softening the wax particles appreciably. Higher temperatures will soften the wax so that it may be forced into or through the straining media.

Heating and Cooling

Heat properly applied can be a great aid in handling honey. Heat also dissolves coarse crystals and destroys yeasts, and thus prevents fermentation and retards granulation. Heat may also seriously damage the color, flavor, and aroma of honey unless particular precautions are taken. Damage may result from a small amount of heat over long periods of time as well as high temperatures for short periods of time.

Several methods of heating are used successfully. Shallow pans with inclined surfaces heated by water jackets are commonly used. As the honey flows into the pan, it should be distributed over the surface by suitable baffles. Jacketed tanks may be used for heating, in which case the honey should be slowly but continuously agitated to insure uniform heating throughout the tank. Heat exchangers in which the honey is pumped quickly through a passage contained in hot water are used very successfully as flash heaters.

One design of heat exchanger is shown in figure 5. This exchanger consists of three concentric tubes in which the honey is pumped through a 3/16-inch-thick annular space between two layers of flowing hot water. Honey enters the exchanger at the bottom and is pumped in a direction opposite to the flow of water. These units may be connected in series to provide the desired amount of heating.

Precautions for cooling honey after heating are seldom practiced to a suitable degree. Immediate cooling following flash heating is essential to prevent honey damage. Equipment similiar to that used for heating can be used effectively for cooling by using cold water instead of hot. Heat exchangers are particularly effective, but may cause excessive line pressure as the honey becomes more viscous upon cooling.

Storage of Honey

Honey in bulk containers, 60-pound cans, or 55-gallon drums should be stored in a dry place at as near 70° F. as possible. Long periods of storage above 70° will damage the honey the same as excessive heating. Storage of unheated honey at 50° to 70° is inducive to granulation and fermentation. This also holds true for honey packed in bottles and other small containers. These should be stored in shipping cases to protect them from light.

Most deterioration in honey during storage can be prevented by maintaining storage temperatures below 50°. Honey stored at freezer temperatures, 0° to –10°, for years cannot be distinguished from fresh extracted honey in color, flavor, or aroma.

Producer Marketing

The producer has a choice of methods in disposing of his honey crop. He may sell his entire crop in bulk containers to a packer or dealer or he may pack a part or all of his crop and sell direct to retail stores or the consumer or both. The producer may be a member of a cooperative through which his honey is processed and sold.

Wholesale Marketing

The producer who markets his honey in bulk should keep in mind the market to be supplied

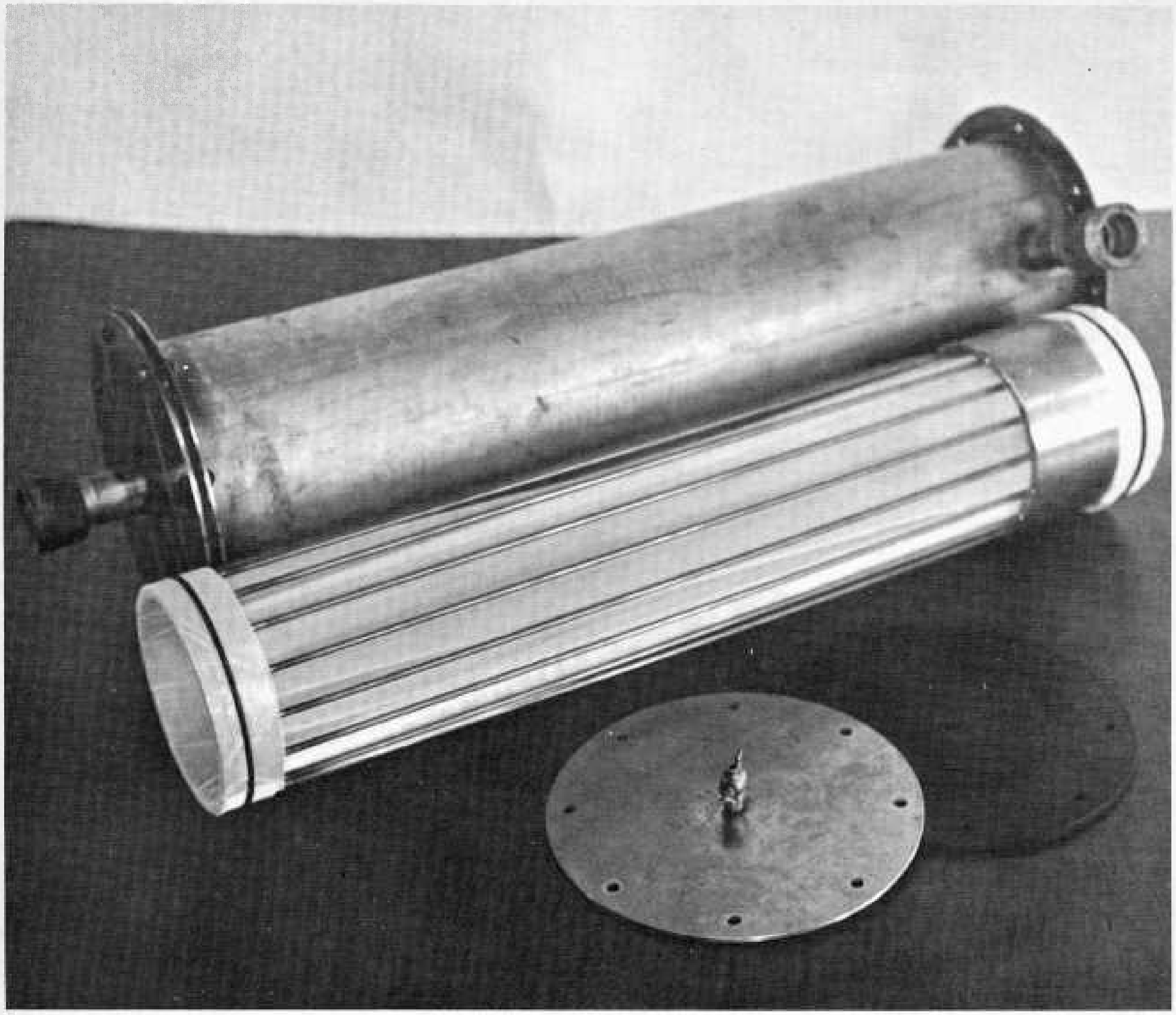

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FIGURE 4.—Cloth strainer showing containing shell, supporting framework with strainer cloth, gasket, and cover plate.

when he chooses the type of container to use. Generally these will be either the 60-pound can or the 55-gallon drum. A limited quantity of honey is moved from the producer to the packing plant in tank trailers. Careful sampling is necessary when the honey is extracted. Representative samples should be taken from each tank, each yard, or each day's run and should be carefully marked on both the sample and the containers for accurate identification.

Honey is generally sold at wholesale prices on the basis of samples, and accurate sampling will result in building confidence, understanding, and satisfaction for both producer and buyer. The producer who knows exactly what he has for sale can demand and get top market prices. The packer who knows exactly what he buys can readily process and blend to meet his particular standards without concern for discrepancies or variation.

Approximately 50 percent of the honey produced in the United States is marketed by the producer in bulk.

Producer-Packers

Honey producers who bottle and sell part or all of their honey crop are referred to as producer-packers. Almost half the honey produced in the United States is marketed in this manner.

The producer-packer receives a higher price per pound for his honey; however, he may have many additional costs. Processing equipment that will

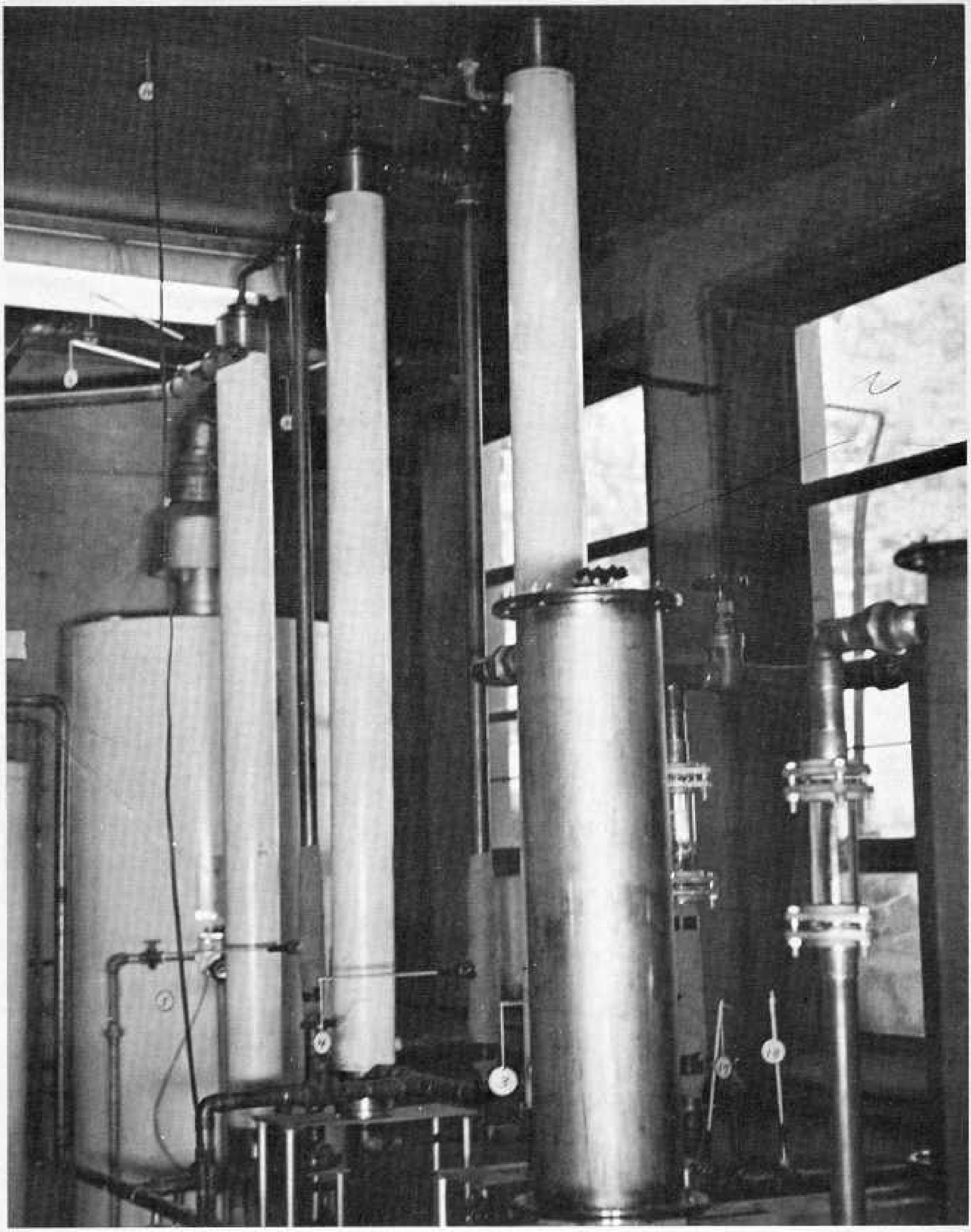

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FIGURE 5.—Concentric tube heat exchangers connected in series and used for flash heating honey. (Note strainers ahead of flash heaters.)

yield a product meeting the desired grade standards must be utilized. His honey must compete with other brands of honey and other foods backed by aggressive sales and promotion programs. He may employ a broker to move his honey into retail channels.

Many producer-packers confine their sales to salesrooms in their homes or honey houses, roadside stands, door-to-door sales, or local stores. Some have established regular sales routes to supply retailers over a wide area, and these routes are serviced at regular intervals.

Cooperative Marketing

There are several cooperative marketing organizations in the United States. These organizations may buy the member producer's crop and process, pack, and distribute the products under the cooperative label. Other organizations may only pool and market the member's production in bulk containers.

Generally the cooperative may operate as follows: Member producers are furnished with bulk containers. When the crop is harvested, the honey is put in these containers and shipped or trucked to the cooperative by the producer. The honey is then graded and the producer is paid a part of the total price. The cooperative then processes, packs, and sells the honey through its sales organization. At a later date the producer is paid the remainder of his selling price.

Cooperative marketing offers many advantages, but there are also some disadvantages just as in other types of marketing. The producer must decide which method of marketing is the most advantageous to him and market his crop accordingly.

Packing and Distribution

Honey packed for market must be of high quality, neatly packaged in clean, attractive containers, and attractively labeled. Every caution should be taken in processing and packing to insure a product of quality as near as possible to that sealed in the cell by the bee. All honey packed under a given label should be as uniform as possible to assure consumer satisfaction. An attractive, eye-catching display in a prominent location is desirable.

Most large honey packers have automatic labeling, filling, and capping equipment. Their honey is distributed and sold under their advertised brand, usually in a limited area. Few, if any, have nationwide distribution. Some have sales personnel, whereas others employ food brokers or other sales agencies to market their product. Many use warehousing facilities in areas of concentrated retail outlets.

Much honey is sold in bulk for industrial consumption, such as for the baking industry, restaurant trade, honey candies, and honey butter. Many other industries use honey in varying quantities.

Liquid Honey

Liquid honey is packed in glass, tin, plastic, and paper containers. Glass is the most popular and is used in a wide variety of shapes and sizes. Plastic containers in various shapes are becoming more and more popular. The 12-ounce plastic container makes a very satisfactory table dispenser. Special glass and plastic containers are used effectively in novelty and gift packs and are popular on the retail market.

Bottled honey should be free of air bubbles or any foreign particles and the containers must be spotlessly clean. Honey bottled by floral source should be clearly labeled as such to insure customer satisfaction.

Honey selected for bottling should be from floral sources that granulate slowly. Proper heating in the processing and bottling operation will also help retard granulation. Any bottled honey in a sales display that shows signs of granulation should be replaced immediately.

Granulated or Creamed Honey

The popularity of granulated or creamed honey is increasing in the United States. This honey is presently available in many retail food stores. It is packed in various paper, plastic, and glass containers. The desired consistency of creamed honey is soft and smooth to allow easy spreading at room temperature.

Honey used for this purpose should be from a floral source that granulates rapidly into a product of soft, smooth, fine, creamy consistency. Honeys that granulate slowly may be used by adding about 10 percent of finely ground crystallized honey. To encourage granulation the honey should be refrigerated immediately after the fine honey crystals have been added to prevent any air bubbles rising to the surface. After rapid cooling, the honey should be stored at 55° to 57° F. and that temperature maintained until the honey is completely crystallized. Cool storage is desirable.

Creamed honey will remain firm at room temperature, but will break down if subjected to high temperature or high humidity. Once it has softened or partially liquefied, recooling will not make it firm again.

Comb Honey

Comb honey is marketed in the form of section comb, cut-comb, and chunk. All forms require special care and handling, and when properly prepared they have excellent consumer appeal.

Section comb honey is produced in a special super. When removed, the sections are carefully scraped with a suitable instrument to remove the propolis. The sections are then sorted, graded, and placed in window cartons or wrapped in cellophane. Some packers seal the sections in clear plastic bags before placing them in window cartons. Sections that do not meet the required grade standards should not be marketed.

Cut-comb honey is produced in shallow supers on foundation similar to that used for sections, but in frames instead of sections. The comb honey is cut from the frames into the desired size for marketing. Sizes of cut-comb honey vary from a 2-ounce individual serving to large pieces weighing nearly a pound. The cut edges of the comb must be drained or dried in a special centrifugal drier, so that no liquid honey remains. The pieces are either wrapped in cellophane or heat sealed in polyethylene bags and packaged in containers of various styles.

One of the most attractive and appealing packs of honey is the chunk honey pack. It consists of a chunk of comb honey in a glass container surrounded with liquid honey.

When packing chunk honey, the pieces of well-drained cut-comb are placed in the container, usually glass jars. The containers are then filled with liquid honey that has been heated to retard granulation. The liquid honey should be run down the inside of the container to prevent introduction of air bubbles and should be at a temperature of 120° F. The containers should be capped and laid on their sides immediately after filling to prevent damage to the comb because of its buoyancy.

Special widemouthed jars are used for packing chunk honey. The chunk should be as wide as possible and still slip readily into the jar, and the length should extend from the top to the bottom of the container.

Probably the greatest deterrent to packing chunk honey is the tendency of the liquid honey to granulate.

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HONEY BEE NUTRITION

By L. N. STANDIFER, *apiculturist, Entomology Research Division, Agricultural Research Service* [1]

A general knowledge of honey bee nutrition aids in understanding how the individual bee grows and how the colony develops and maintains itself.

The anatomical and vital physiological systems usually associated with living animals are present in the honey bee. Food enters the alimentary canal (fig. 1) of the adult bee by way of the mouth and the long tubelike esophagus, which extends through the thorax and into the abdomen, where it enlarges to form the honey stomach. Nectar is transported in the honey stomach from the flower to the hive. Immediately behind the honey stomach is the proventricular valve. It retains the nectar load in the honey stomach, lets food pass into the midgut, but prevents food from returning. The midgut or ventriculus is a relatively large segment of the alimentary canal, lined on the inside with the peritrophic membrane. Beyond the midgut are the short, small intestine, the large intestine or rectum, and finally the anus.

The adult honey bee has six sets of paired glands located in the head and thorax. The labial glands are generally believed to be associated with the alimentary canal. They deliver their secretions at the base of the labrum. Their function is dependent on the age of the bee and on the work in which it is engaged.

The hypopharyngeal or brood food glands produce the food called royal jelly. Most of the larval food comes from these glands. They also supply the food for the adult queen and possibly adult drones. They are fully developed only in the worker bee. Royal jelly is milky in appearance, slightly acid, and rich in digestive enzymes, proteins, carbohydrates, fats, and vitamins.

The mandibular glands are saclike, single structures located immediately above the mandibles. They are extremely large in the queen, smaller in the worker, and vestigial in the drone. They do not vary in size with age or occupation. However, if the newly emerged bee does not consume adequate protein during the first few days of adult life, these glands do not develop fully.

The secretions from these glands in queens contain a compound called queen substance, which is essential for social unity of the colony. This substance is not in the glandular secretions of worker bees. Workers probably use the secretion from their glands to prepare and manipulate wax for building comb. It may also be used to soften the pupal cocoons of bees and is found in royal jelly.

The primary function of the postcerebral glands, located in the back of the head, is to provide the enzymes necessary for the digestion of foodstuff consumed by the bee.

The thoracic or salivary glands in the anterior part of the thorax secrete a carbohydrate-splitting enzyme, invertase, in large amounts.

The function of the postgenal glands in the lower inner wall of the head and the sublingual glands at the base of the bee tongue is unknown.

Two pairs of rectal glands or pellets on the sides of the rectum are associated with fat absorption.

Beeswax is secreted by specialized cells called wax glands on the underside of the abdomen of the worker bee. Generally wax glands become fully developed about the 15th day of adult life. Secreted beeswax appears as thin, delicate scales or flakes. It is a byproduct of metabolism and directly follows the digestion of large quantities of nectar or other sugars. The bees use wax to form the cells of the comb, in which food is stored and brood is reared.

When wax is needed for comb building, the 16- to 24-day-old bees fill their honey stomachs, then hang together in vertical sheets or festoons. The wax scales are secreted, then removed with the hindlegs, and passed forward to the mouth, where they are worked by the mandibles and subsequently applied to the edge of the comb. The wax glands shrink and become nonfunctional between the 20th and 25th day of adult life, or about the time worker bees become field-foraging bees.

Digestion

The movement of pollen through the alimentary canal of the adult bee reveals something of the digestive process. Ten minutes after the material is fed to the bee, the pollen grains are clustered at the proventriculus. Thirty minutes after feeding, they are within the peritrophic membrane in the forepart of the ventriculus. Ninety minutes after feeding, the peritrophic membrane-enwrapped pollen mass enters the anterior or small intestine. At the end of 2 hours the pollen is within the small intestine or just entering the large intestine

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[1] In cooperation with Arizona Agricultural Experiment Station.

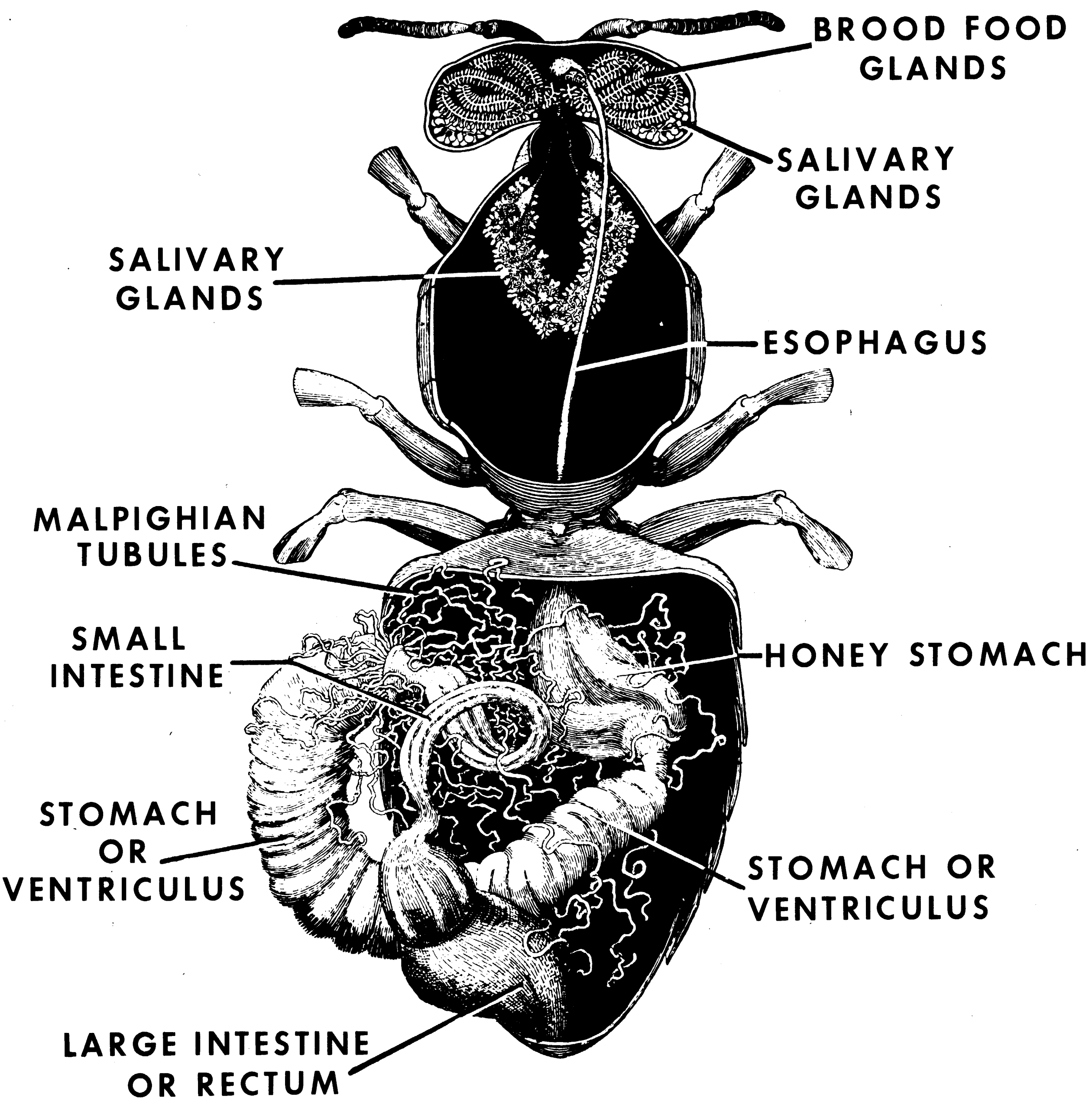

FIGURE 1.—Alimentary canal of adult worker honey bee.

or rectum. The peritrophic membrane that encircles the pollen grains in the midgut persists in the rectum for a considerable time before all is voided in the feces.

The fatty acids in pollen are made water soluble by neutralization with alkalies in the alimentary canal secretion. The proteins are broken down into peptides, and these are further hydrolyzed into amino acids.

The lipids of bee food occur chiefly in pollen. The lipid-splitting enzyme lipase is abundant in the midgut of the adult worker and drone. Its value in digesting the lipids is unknown. In higher animals lipids are digested by lipase or esterase into free fatty acids and glycerol.

Nutritional Requirements

Honey bees and other insects have no unusual nutritional requirements. They require carbohydrates, proteins, fats, minerals, vitamins, and water for growth, development, maintenance, and reproduction. Nectar and honeydew are the chief sources of supply for carbohydrates in the diet of bees, and pollen furnishes all the other indispensable constituents.

Adult bees can live on the carbohydrates glucose, fructose, sucrose, trehalose, maltose, and melezitose. They cannot utilize the carbohydrates galactose, mannose, lactose, raffinose, dextrin, insulin, rhamnose, xylose, or arabinose. Beekeepers often feed sucrose if a shortage of nectar or honey exists. Bees also utilize fruit juices and certain occasional plant juices. A small amount of carbohydrates is also obtained from pollen. The adult bee can survive on carbohydrates; however, proteins, fats, minerals, and vitamins are necessary in rearing the immature stages.

Proteins of a precise quality and definite amino acid composition are required for optimum growth and development of the brood food-producing hypopharyngeal glands and no doubt others. When nursing duties are finished (between 10th and 14th day of adult life) and field duties are undertaken, the requirements for protein decrease, and the chief dietary constituent becomes the carbohydrates obtained from nectars and honey.

Fats, like carbohydrates, are also used as sources of energy. Bees probably require and utilize some of the fats in pollen they consume. However, chemical analyses of feces show that large amounts of fats in the pollen consumed by bees pass through the digestive tract and are not utilized.

Water is necessary in the diet for diluting concentrated honey. It is also used in air-conditioning the cluster. Normally bees do not store water as they do nectar and pollen. It is collected only when needed.

The nutritional value of the enzymes, coenzymes, and pigments found in pollen is largely unknown.

Sources and Chemical Composition of Foods

Nectar

When nectar is collected, it may contain from 5 to 75 percent soluble solids (sugars), most of which is in the 25 to 40 percent range; the remainder is water. The primary sugars are sucrose, glucose, and fructose. As the nectar is manipulated and finally stored as honey, much of the sucrose is inverted to glucose and fructose, usually in about equal amounts.

Honeydew

Various species of insects secrete a material called honeydew, which bees collect and store in the comb. Honeydew has a high percentage of dextrins and melezitose. It is generally considered a poor source of carbohydrates for bees.

Plant Juices

Bees often collect juices from overripe fruit and various plant exudates that are rich in sucrose or related sugars. They usually do this only when nectar is not available.

Pollen

Pollen furnishes all the other indispensable constituents of the diet, except water, that are required for vital activity, including rearing young bees. Not all pollens are alike nutritionally, and bees grow and develop better on some than on others.

In nature bees generally utilize a mixture of pollens in their diet. This is eaten by adult bees and is fed to worker and drone larvae after they are 3 days old. Consumption and digestion of pollen by adult bees are essential, since they can only produce brood food from pollen that they have eaten. This brood food, or royal jelly, is fed to all larvae the first 3 days of life and to the queen bee throughout her larval and adult life. Royal jelly has the following approximate chemical composition (percent): Water 66, dry matter 34; of the latter, carbohydrate 13, protein 12, fat 5, ash 1, and undetermined matter including vitamins, enzymes, and coenzymes 3.

Bee-collected pollens are comparatively rich in the carbohydrates. Reducing sugars range from 15 to 43 percent, with an average of about 29 percent. The glucose, fructose, sucrose, raffinose, and stachyose content is not significant, although the bees apparently utilize those that are available. Corn pollen, for example, has a high starch content. The pollen shell is not utilized by bees, but is eliminated with the feces after the internal matter has been removed by digestive processes.

The protein value of pollen varies from 10 to 36 percent. The amino acid content of average pollen and sweet corn pollen with a crude protein of 26.3 and 26.9 percent, respectively, is shown in table 1.

TABLE 1.—*Amino acid content of average pollen and sweet corn pollen, expressed as percent of crude protein*

Component	Average pollen	Sweet corn pollen
	Percent	*Percent*
Arginine	5. 3	4. 7
Histidine	2. 5	1. 5
Isoleucine	5. 1	4. 7
Leucine	7. 1	5. 6
Lysine	6. 4	5. 7
Methionine	1. 9	1. 7
Phenylalanine	4. 1	3. 5
Threonine	4. 1	4. 6
Tryptophane	1. 4	1. 6
Valine	5. 8	6. 0

All the amino acids in table 1, except threonine, are essential for normal growth of the young adult bee. With the exception of histidine and perhaps arginine, they cannot be synthesized by bees and must be obtained from the pollens consumed.

Other constituents of pollen are as follows:

Constituent	*Amount* *Percent*
Fats	1. 3–19. 7
Minerals (ash):	
Calcium	1. 0–15. 0
Chlorine	. 6–. 9
Copper	. 05–. 08
Iron	. 01–12. 0
Magnesium	1. 0–12. 0
Phosphorus	. 6–21. 6
Potassium	20. 0–45. 0
Silicon	2. 0–10. 4
Sulfur	. 8–1. 6

Vitamins:	*Micrograms per gram identified*
Ascorbic acid	131. 0–721. 0
Biotin	. 19–. 73
D	. 2–. 6
E	0–. 32
Folic acid	3. 4–6. 8
Inositol	. 3–31. 3
Nicotinic acid	37. 4–107. 7
Pantothenic acid	3. 8–28. 7
Pyridoxine	2. 8–9. 7
Riboflavin	4. 7–17. 1
Thiamine	1. 1–11. 6

Bees also occasionally collect spores and store them as pollen. Although spores can be utilized as a proteinaceous food, they do not stimulate brood rearing and are generally considered a poor substitute for pollen.

Artificial Diets

The beekeeper can supplement the diet of nectar or honey with sucrose. This is usually mixed with about an equal amount of water and fed as sirup.

There is no substitute for pollen. Various materials, including brewer's yeast, soybean flour, dry skim milk, and egg albumin, mixed with honey or sugar water, have been fed to bees, but the colony stimulation is minor compared to that derived from fresh pollen. The addition of dried pollen trapped from colonies earlier increases the stimulation slightly.

The two most commonly used artificial diets are the pollen supplement diet and the pollen substitute diet. Their composition is as follows:

Materials	*Percent*
Pollen supplement:	
Sugar-water (2 parts sugar to 1 part water by weight)	67
Pollen-soy mix (1 part fresh dry pollen to 3 parts soybean flour by weight)	33
Pollen substitute (dry mix):	
Soybean flour	20
Casein	30
Brewer's yeast	20
Dry skim milk	20
Dried egg yolk	10

Few problems facing the apiculture industry today require immediate research attention as much as the development of an artificial or chemically defined diet for honey bees as a substitute food for pollen. Work on nutrition and physiology of the honey bee may soon lead to an artificial diet for bees.

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HONEY, ITS COMPOSITION AND PROPERTIES

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Honey is the sweet viscous fluid elaborated by bees from nectar obtained from plant nectaries, chiefly floral. After transportation to the hive in the honey stomach, this fluid is ripened and stored in the comb for food. Other definitions may be more restrictive. For example, the U.S. Food and Drug advisory definition for honey states that "Honey is the nectar and saccharine exudation of plants, gathered, modified, and stored in the comb by honeybees (*Apis mellifera* and *A. dorsata*); is levorotatory; contains not more than 25 percent water, not more than 0.25 percent ash, and not more than 8 percent sucrose." Although this definition once served a useful purpose, it is considered today to allow much too high a content of water and sucrose and is too low in ash. Both definitions exclude honeydew.

The color of U.S. honey may vary greatly, from a nearly colorless fireweed or sweetclover type through yellow, yellow green, gold, ambers, dark browns or red browns to nearly black. The variations are almost entirely due to the plant source of the honey, though climate may modify the color somewhat through the darkening action of heat.

The flavor of honey varies even more than the color. A honey may appear to have only a simple sweetness or may be mild, spicy, fragrant, aromatic, bitter, harsh, medicinal, or objectionable. This is again almost entirely governed by the floral source. In general, a light-colored honey is expected to be mild in flavor and a darker honey to be of pronounced flavor. The exceptions common to all rules sometimes endow a light honey with very definite specific flavors. Since flavor judgment is personal, one's favorite may be another's "unflavored sugar sirup" or "ill-tasting medicine." With the tremendous variety available, everyone should be able to find his own favorite honey.

Composition of Honey

The characteristic physical properties of honey—high viscosity, "stickiness," great sweetness, relatively high density, tendency to absorb moisture from air, and immunity from some types of spoilage—all stem from the fact that honey is naturally a very concentrated solution of several sugars. Because of its unique character and its considerable difference from other sweeteners, chemists have long been interested in its composition and food technologists sometimes have been frustrated in attempts to include honey in prepared food formulas or products.Limitations of methods available to earlier researchers made their results only approximate in regard to the true sugar composition of honey. Although recent research has greatly improved analytical procedures for sugars, even now some compromises are required in order to make possible accurate analysis of large numbers of honey samples for sugars.

An analytical survey of U.S. honey is reported in Composition of American Honeys, Technical Bulletin 1261, published by the U.S. Department of Agriculture in 1962. In this survey, considerable effort was made to obtain honey samples from all over the United States and to include enough samples of the commercially significant floral types that the results, averaged by floral type, would be useful to the beekeeper and packer and also to the food technologist. In addition to providing tables of composition of U.S. honeys, some general conclusions were reached in the bulletin on various factors affected by honey composition.

Where comparisons were made of the composition of the same types of honey from 2 crop years, relatively small or no differences were found. The same was true for the same type of honey from various locations. As previously known, dark honey is higher than light honey in ash (mineral) and nitrogen content. Averaging results by regions showed that eastern and southern honeys were darker than average, whereas north-central and intermountain honeys were lighter. The north-central honey was higher than average in moisture, and the intermountain honey was more heavy bodied. Honey from the South Atlantic States showed the least tendency to granulate, whereas the intermountain honey had the greatest tendency.

The technical bulletin includes complete analyses of 490 samples of U.S. floral honey and 14 samples of honeydew honey gathered from 47 of the 50 States and representing 82 "single" floral types and 93 blends of "known" composition. For the more common honey types, many samples were available and averages were calculated by computer for many floral types and plant families. In this bulletin are also given the average honey composition for each State and region and detailed discussions of the effects of crop year, storage, area of production, granulation, and color on composition. Some of the tabular data are included in this handbook.

Table 1 gives the average and the range of values found for each constituent. The range shows the great variability.

Nearly all the constituents are familiar. The levulose and dextrose are the simple sugars making up most of the honey. Sucrose (table sugar) is present in high concentration in nectar, from which honey is made. "Maltose" represents a group of several more complex sugars, which collectively are analyzed and reported as maltose. Higher sugars is a more descriptive term for the material formerly called honey dextrin.

The undetermined value is found by adding all the sugar percentages to the moisture value and subtracting from 100. The active acidity of a material is expressed as pH; the larger the number the lower is the active acidity. The lactone is a newly found component of honey. Lactones may be considered to be a reserve acidity, since by chemically adding water to them (hydrolysis) an acid is formed. The ash is, of course, the material remaining after the honey is burned and represents mineral matter. The nitrogen is a measure of the protein material, including the enzymes, and diastase is a specific starch-digesting enzyme.

Most of these constituents are expressed in percent, that is, parts per hundred of honey. The acidity is reported differently. In earlier times acidity was reported as percent formic acid. We now know that there are many acids in honey, with formic acid being one of the least important. Since a sugar acid, gluconic acid, has been found to be the principal one in honey, these results could be expressed as "percent gluconic acid" by multiplying the numbers in the table by 0.0196. Since actually there are many acids in honey, the term "milliequivalents per kilogram" is used to avoid implying that only one acid is found in honey. This figure is such that it properly expresses the acidity of a honey sample independently of the kind or kinds of acids present.

In table 1, the differences between floral honey and honeydew honey [1] can be seen. Floral honey is higher in simple sugars (levulose and dextrose), lower in disaccharides and higher sugars (dextrins), and contains much less acid. The higher amount of mineral salts (ash) in honeydew gives it a less active acidity (higher pH). The nitrogen content, reflecting the amino acids and protein content, is also higher in honeydew.

The carbohydrate composition or principal sugars in the more common types of honey are

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[1] Strictly speaking, honeydew is an excretory product of several species of insects when sucking plant juices. If it is gathered and stored by bees, it becomes honeydew honey.

TABLE 1.—*Average composition of floral and honeydew honey and range of values* [1]

Characteristic or constituent	Floral honey		Honeydew honey	
	Average values	Range of values	Average values	Range of values
Color [2]	Dark half of white	Light half of water white to dark.	Light half of amber.	Dark half of extra light amber to dark.
Granulating tendency [3]	Few clumps of crystals, ⅛- to ¼-inch layer.	Liquid to complete hard granulation.	1/16- to ⅛-inch layer of crystals.	Liquid to complete soft granulation.
Moisture percent	17.2	13.4–22.9	16.3	12.2–18.2.
Levulose do	38.19	27.25–44.26	31.80	23.91–38.12.
Dextrose do	31.28	22.03–40.75	26.08	19.23–31.86.
Sucrose do	1.31	.25–7.57	.80	.44–1.14.
Maltose do	7.31	2.74–15.98	8.80	5.11–12.48.
Higher sugars do	1.50	.13–8.49	4.70	1.28–11.50.
Undetermined do	3.1	0–13.2	10.1	2.7–22.4.
pH [4]	3.91	3.42–6.10	4.45	3.90–4.88.
Free acidity	22.03	6.75–47.19	49.07	30.29–66.02.
Lactone [4]	7.11	0–18.76	5.80	.36–14.09.
Total acidity [4]	29.12	8.68–59.49	54.88	34.62–76.49.
Lactone÷free acid	.335	0–.950	.127	.007–.385.
Ash percent	.169	.020–1.028	.736	.212–1.185.
Nitrogen do	.041	0–.133	.100	.047–.223.
Diastase [5]	20.8	2.1–61.2	31.9	6.7–48.4.

[1] Based on 490 samples of floral honey and 14 samples of honeydew honey.

[2] Expressed in terms of U.S. Dept. Agr. color classes.

[3] Extent of granulation for heated sample after 6 months' undisturbed storage.

[4] Milliequivalents per kilogram.

[5] 270 samples for floral honey.

shown in table 2. In all cases levulose predominates. There are a few types, not represented in the table, that contain more dextrose than levulose, such as dandelion and bluecurls. This excess of levulose over dextrose is one way that honey differs from commercial invert sugar. Levulose is more soluble than dextrose. Even though honey has less dextrose than levulose, the former is the sugar that crystallizes when honey granulates or "sugars." The sucrose level in honey never reaches zero, even though it may contain an active sucrose-splitting enzyme.

As noted, honey varies tremendously in color and flavor, depending largely on its floral source. Although many hundreds of kinds of honey are produced in this country, only about 25 to 30 are commercially important and are available in large quantity. As also noted, even these may show considerable variation in composition and properties. Until this survey of U.S. honey was reported, the degree of variation was not known and it retarded the use of honey by the food industry.

Honey consists essentially of a highly concentrated water solution of two sugars, dextrose and levulose, with small amounts of more complex sugars. Many other substances also occur in honey, but the sugars make up by far the greater proportion of honey. The principal physical characteristics and behavior of honey are due to its sugars, but the minor constituents, such as flavoring materials, pigments, acids, and minerals, are largely responsible for the differences among individual honey types.

Water Content

Beekeepers as well as honey buyers know that the water content of honey varies greatly. It may range between 13 and 25 percent. According to the United States Standards for Grades of Extracted Honey, honey may not contain more than 18.6 percent moisture to qualify for U.S. grade A (U.S. Fancy) and U.S. grade B (U.S. Choice). Grade C (U.S. Standard) honey may contain up to 20 percent water; any higher amount places a honey in U.S. grade D (Substandard).

These values represent limits and do not indicate the preferred or proper moisture content for

Table 2.—*Carbohydrate composition of honey types*

Number of samples	Floral type	Dextrose	Levulose	Sucrose	Maltose	Higher sugars
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
23	Alfalfa	33.40	39.11	2.64	6.01	.89
25	Alfalfa-sweetclover	33.57	39.29	2.00	6.30	.91
5	Aster	31.33	37.55	.81	8.45	1.04
3	Basswood	31.59	37.88	1.20	6.86	1.44
3	Blackberry	25.94	37.64	1.27	11.33	2.50
5	Buckwheat	29.46	35.30	.78	7.63	2.27
4	Buckwheat, wild	30.50	39.72	.79	7.21	.83
26	"Clover"	32.22	37.84	1.44	6.60	1.39
3	Clover, alsike	30.72	39.18	1.40	7.46	1.55
3	Clover, crimson	30.87	38.21	.91	8.59	1.63
3	Clover, Hubam	33.42	38.69	.86	6.23	.74
10	Cotton	36.74	39.28	1.14	4.87	.50
3	Fireweed	30.72	39.81	1.28	7.12	2.06
6	Gallberry	30.15	39.85	.72	7.71	1.22
3	Goldenrod	33.15	39.57	.51	6.57	.59
2	Heartsease	32.98	37.23	1.95	5.71	.63
2	Holly	25.65	38.98	1.00	10.07	2.16
3	Honeydew, cedar	25.92	25.16	.68	6.20	9.61
5	Honeydew, oak	27.43	34.84	.84	10.45	2.16
2	Horsemint	33.63	37.37	1.01	5.53	.73
3	Locust, black	28.00	40.66	1.01	8.42	1.90
3	Loosestrife, purple	29.90	37.75	.62	8.13	2.35
3	Mesquite	36.90	40.41	.95	5.42	.35
4	Orange, California	32.01	39.08	2.68	6.26	1.23
13	Orange, Florida	31.96	38.91	2.60	7.29	1.40
4	Raspberry	28.54	34.46	.51	8.68	3.58
3	Sage	28.19	40.39	1.13	7.40	2.38
3	Sourwood	24.61	39.79	.92	11.79	2.55
4	Star-thistle	31.14	36.91	2.27	6.92	2.74
8	Sweetclover	30.97	37.95	1.41	7.75	1.40
3	Sweetclover, yellow	32.81	39.22	2.93	6.63	.97
4	Tulip tree	25.85	34.65	.69	11.57	2.96
5	Tupelo	25.95	43.27	1.21	7.97	1.11
7	Vetch	31.67	38.33	1.34	7.23	1.83
9	Vetch, hairy	30.64	38.20	2.03	7.81	2.08
12	Whiteclover	30.71	38.36	1.03	7.32	1.56

honey. If honey has more than 17 percent moisture and contains a sufficient number of yeast spores, it will ferment. Such honey should be pasteurized, i.e., heated sufficiently to kill such organisms. This is particularly important if the honey is to be "creamed" or granulated, since this process results in a slightly higher moisture level in the liquid part. On the other hand, it is possible for honey to be too low in moisture from some points of view. In the West, honey may have a moisture content as low as 13 to 14 percent. Such honey is somewhat difficult to handle, though it is most useful in blending to reduce moisture content. It contains over 6 percent more honey solids than a product of 18.6 percent moisture.

In the 490 samples of honey analyzed in the Department's Technical Bulletin 1261, the average moisture content was 17.2 percent. Samples ranged between 13.4 and 22.9 percent, and the standard deviation was 1.46. This means that 68 percent of the samples (or of all U.S. honey) will fall within the limits of 17.2±1.46 percent moisture (15.7–18.7); 95.5 percent of all U.S. honey will fall within the limits of 17.2±2.92 percent moisture (14.3–20.1).

In the same bulletin a breakdown of average moisture contents by geographic regions is shown. These values (percent) are North Atlantic 17.3, East North Central 18.0, West North Central 18.2, South Atlantic 17.7, South Central 17.5, Intermountain West 16.0, and West 16.1.

Sugars of Honey

Honey is first and foremost a carbohydrate. Sugars make up 95 to 99.9 percent of the solids of honey and their identity has been studied for may years.

Honey was long thought to be mainly levulose and dextrose, with some sucrose and dextrins. These were considered to be poorly defined complex sugars of high molecular weight. With the advent of new methods for analyzing and separating sugars, workers in Europe, the United States, and Japan have found many sugars in honey and in some cases isolated and identified them by suitable physical and chemical methods.

Dextrose and levulose are still the principal sugars, but at least 12 more have been found in honey, namely maltose, isomaltose, turanose, maltulose, nigerose, kojibiose, leucrose, melezitose, erlose, kestose, raffinose, and dextrantriose. Most of these sugars probably do not occur in nectar, but arise because of either enzymic action during the ripening of honey or chemical action during storage in the concentrated, somewhat acid sugar mixture we know as honey. Individual honey types vary in the relative amounts of the various sugars, but each seems to have the same kinds of minor sugars.

Acids of Honey

The acids of honey, though nearly negligible on the weight basis (less than one-half percent), have a pronounced effect on the flavor. They also may be responsible in part for the excellent stability of honey against micro-organisms. At least 18 organic acids have been reported in honey, with varying degrees of certainty. Until recently it was thought that citric and malic acids were the principal ones. Now it is realized that gluconic acid is the acid present in the greatest amount in honey. It arises from dextrose through the action of an enzyme recently found in honey called glucose oxidase. Other acids reported in honey are formic, acetic, butyric, lactic, oxalic, succinic, tartaric, maleic, pyroglutamic, pyruvic, α-ketoglutaric, and glycollic.

Proteins and Amino Acids

It will be noted in table 1 that the amount of nitrogen in honey is low, on the average 0.04 percent, though it may range to 0.1 percent. If this were all from protein in honey, the corresponding protein values would be about 0.25 to 0.8 percent. Since other nitrogenous substances are known to occur in honey, the true values for protein content are somewhat lower. Little is known of the proteins of honey, except that the enzymes fall into this class. The peculiar physical properties of heather honey, which thickens to a solid on standing and thins when stirred, are reported to be due to a protein, which if added to clover honey will confer these same properties on it.

The presence of proteins causes honey to have a lower surface tension than otherwise, which produces a marked tendency toward foaming and scum formation and encourages formation and retention of fine air bubbles. Beekeepers familiar with buckwheat honey know how readily it tends to foam and produce surface scum, which is largely due to its relatively high protein content.

The amino acids are simple compounds obtained when proteins are broken down by chemical or digestive processes. They are the "building blocks" of the proteins. Several of them are essential to life and must be obtained in the diet. The quantity of free amino acids in honey is small and of no nutritional significance. Recent breakthroughs in the separation and analysis of minute quantities of material (chromatography) have revealed that various honeys contain from 11 to 21 differerent free amino acids. Proline, glutamic acid, alanine, phenylalanine, tyrosine, leucine, and isoleucine are the most common.

Amino acids are known to react slowly, or more rapidly by heating, with sugars to produce yellow or brown materials. Part of the darkening of honey with age or heating may be due to this.

Minerals

When honey is dried and burned, a small residue of ash invariably remains. This is the mineral content. As shown in table 1, it varies from 0.02 to slightly over 1 percent for a floral honey, averaging about 0.17 percent for the 490 samples analyzed.

Honeydew honey is richer in minerals, so much so that its mineral content is said to be a prime cause of its unsuitability for winter stores. Schuette and his colleagues at the University of Wisconsin have examined the mineral content of light and dark honey. They reported the following average values:

Mineral	*Light honey (p.p.m.)*	*Dark honey (p.p.m.)*
Potassium	205	1,676
Chlorine	52	113
Sulfur	58	100
Calcium	49	51
Sodium	18	76
Phosphorus	35	47
Magnesium	19	35
Silica	22	36
Iron	2.4	9.4
Manganese	.30	4.09
Copper	.29	.56

Enzymes

One of the characteristics that sets honey apart from all other sweetening agents is the presence of enzymes. These are complex protein materials that under mild conditions bring about chemical changes, which may be very difficult to accomplish in the laboratory. Enzymatic reactions are the very basis of life. Enzymes in honey can conceivably arise from the bee, pollen, nectar, or even yeasts and micro-organisms. Those most prominent are added by the bee in the conversion of nectar to honey.

Invertase, also known as sucrase or saccharase, splits sucrose into its constituent simple sugars, dextrose and levulose. Other more complex sugars have been found recently to form in small amount during this action and in part explain the complexity of the minor sugars of honey. Although the work of invertase is completed when honey is ripened, the enzyme remains in the honey and retains its activity for some time. Even so, the sucrose content of honey never reaches zero. Since the enzyme also synthesizes sucrose, perhaps the final low value for the sucrose content of honey represents an equilibrium between splitting and formation of sucrose.

Another enzyme known to be in honey is diastase (amylase). Since this enzyme digests starch to simpler compounds and starch has not been found in nectar, it is not clear what its function in honey might be. Diastase appears to be present in varying amounts in nearly all honey and it can be measured. It has probably had the greatest attention in the past, because it has been used as a measure of honey quality by several European countries.

Another enzyme recently found in honey is glucose oxidase. This converts dextrose to a related material, a gluconolactone, which in turn forms gluconic acid, the principal acid in honey. Since this enzyme had previously been shown to be in the pharyngeal gland of the honey bee, it is likely that this is the source. Here again as with other enzymes, the amount in different honeys is variable. In addition to gluconolactone, this enzyme forms hydrogen peroxide during its action on dextrose. This has been shown to be the basis of the heat-sensitive antibacterial activity of honey.

Other enzymes have been reported in honey, including inulase and phosphatase. Except for catalase, the results have not been sufficiently confirmed.

All these enzymes can be destroyed or weakened by heat. For the use of enzyme levels to indicate heating history of honey, see page 63.

Properties of Honey

Because of its unusual composition, honey exhibits some properties that may make its handling and use somewhat difficult. Means have been developed to cope with these problems. Honey also has some interesting attributes.

Antibacterial Activity of Honey

It was once thought that since milk can be a carrier of some diseases, honey might likewise be such a carrier. Some years ago this idea was examined by adding nine common pathogenic bacteria to honey. All of them died within a few hours or days. Honey is not a suitable medium for bacteria for two reasons—it is fairly acid and it is too high in sugar content for growth to occur. This killing of bacteria by high sugar content is called the osmotic effect. It seems to function by literally drying out the bacteria. However, in the resting spore form, some bacteria can survive, though not grow in honey.

Another type of antibacterial property of honey is that due to inhibine. The presence in honey of an antibacterial activity was first reported about 1940 and confirmed in several laboratories. Since then several papers have appeared on the subject. It has been generally agreed that inhibine (name used by Dold, its discoverer, for antibacterial activity) is sensitive to heat and light. The effect of heating honey on its inhibine content has been studied by several investigators. It is apparent that heating it sufficiently to reduce markedly or destroy its inhibine activity would deny it a market as first-quality honey in several European countries. In fact, the use of sucrase and inhibine assays together to determine the heating history of commercial honey has been proposed. Until recently no information on the actual nature or constitution of inhibine has been published.

It is now known that this inhibine effect is due to the accumulation of hydrogen peroxide in diluted honey. This material, well known for its antiseptic properties, is a byproduct of the formation of gluconic acid in diluted honey by an enzyme that occurs in honey, glucose oxidase. The peroxide can inhibit the growth of certain bacteria in the diluted honey. Since it is destroyed by other honey constituents, an equilibrium level of peroxides will occur in a diluted honey, its magnitude depending on many factors such as enzyme activity, oxygen availability, and amounts of peroxide-destroying materials in the honey. The amount of inhibine (peroxide accumulation) in honey depends on floral type, age, and heating.

A chemical assay method has been developed that rapidly measures peroxide accumulation in diluted honey. By this procedure different honeys have been found to vary widely in the sensitivity of their inhibine to heat. In general, the sensitivity is about the same as or greater than that of invertase and diastase in honey.

Food Value of Honey

As a carbohydrate food, honey is a most delectable and enjoyable treat. Its distinctive flavors cannot be found elsewhere. The sugars are largely the easily digestible "simple sugars," similar to those of many fruits.

Honey because of its content of simple sugars is an excellent source of energy. It can be regarded as a good food for both infants and senior citizens.

The enzymes of honey, though used as indicators of heating history and hence table quality of honey in some countries, have no nutritional value and are destroyed in the digestive process. Mineral content of honey is variable, but some darker honeys may have significant quantities of trace minerals. Although some vitamins may be demonstrated in honey, the amounts are far too low to have any meaning in human nutrition.

Granulation of Honey

A large part of the honey sold to consumers in the United States is in the liquid form, much less in a finely granulated form known as "honey spread" or finely granulated honey, and even less as comb honey. The consumer appears to be conditioned to buying liquid honey. At least sales of the more convenient spread form have never approached those of liquid honey.

Since the granulated state is natural for most of the honey produced in this country, processing is required to keep it liquid. Careful application of heat to dissolve "seed" crystals and avoidance of subsequent "seeding" will usually suffice to keep a honey liquid for 6 months. Damage to color and flavor can result from excessive or improperly applied heat. Honey that has granulated can be returned to liquid by careful heating. Heat should be applied indirectly by hot water or air, not by direct flame or high-temperature electrical heat. Stirring accelerates the dissolution of crystals. For small containers, temperatures of 140° F. for 30 minutes will usually suffice.

If unheated honey is allowed to granulate naturally, several difficulties may arise. The texture may be fine and smooth or granular and objectionable to the consumer. Furthermore, a granulated honey becomes more susceptible to spoilage by fermentation, caused by natural yeast found in all honeys and apiaries. Quality damage from poor texture and fermented flavors is usually far greater than any caused by the heat needed to eliminate these problems.

Finely granulated honey may be prepared from a honey of proper moisture content (17.5 percent in summer, 18 percent in winter) by several processes. All involve pasteurization to eliminate fermentation, followed by addition at room temperature of 5 to 10 percent of a finely granulated "starter" of acceptable texture, thorough mixing, and storage at 55° to 60° F. in the retail containers for about a week. The texture remains acceptable if storage is below about 80° to 85°.

Deterioration of Honey Quality

Fermentation.—Fermentation of honey is caused by the germination and growth of yeasts that are normally found in all honey. These yeasts, which may be in the soil of every apiary, in the honey house, and in the hive, differ from ordinary bread or wine yeasts. The obvious difference is that these yeasts can grow at much higher sugar concentrations than other yeasts, and are therefore called "osmophilic." Even so, there are upper limits of sugar concentration beyond which these yeasts will not grow. Thus the water content of a honey is one of the factors concerned in spoilage by fermentation. The others are extent of contamination by yeast spores (yeast count) and temperature of storage.

Honey with less than 17.1 percent water will not ferment in a year, irrespective of the yeast count. Between 17.1 and 18 percent moisture, honey with 1,000 yeast spores or less per gram will be safe for a year. When moisture is between 18.1 and 19 percent, not more than 10 yeast spores per gram can be present for safe storage. Above 19 percent water, honey can be expected to ferment even with only one spore per gram of honey, a level so low as to be very rare.

When honey granulates, the resulting increased moisture content of the liquid part is favorable for fermentation. Honey with a high moisture content will not ferment below 50° F. or above about 80°. Honey even of relatively low water content will ferment at 60°. Storage at temperatures over 80°, to avoid fermentation, is not practical as it will damage honey.

E. C. Martin, of Michigan State University, has studied the mechanism and course of yeast fermentation in honey in conjunction with his work on the hygroscopicity of honey. He confirmed that when honey absorbs moisture, which occurs when it is stored above 60-percent relative humidity, the moisture content at first increases mostly at the surface before the water diffuses into the bulk of the honey. When honey absorbs moisture, yeasts grow aerobically (using oxygen) at the surface and multiply rapidly, whereas below the surface the growth is slower.

Fermenting honey is usually at least partly granulated and is characterized by a foam or froth on the surface. It will foam considerably when heated. An odor as of sweet wine or fermenting fruit may be detected. Gas production may be so vigorous as to cause honey to overflow or burst a container. The off-flavors and odors associated with fermentation probably arise from the acids produced by the yeasts.

Honey that has been fermented can sometimes be reclaimed by heating it to 150° F. for a short time. This stops the fermentation and expels some of the off-flavor. Fermentation in honey may be avoided by heating to kill yeasts. Minimal treatments to pasteurize honey are as follows:

Temperature (°F.)	*Heating time (minutes)*
128	470
130	170
135	60
140	22
145	7.5
150	2.8
155	1.0
160	.4

Quality Loss by Heating and Storage.—The other principal types of honey spoilage, damage by overheating and by improper storage, are related to each other. In general, changes that take place quickly during heating also occur over a longer period during storage with the rate depending on the temperature. These include darkening, loss of fresh flavor, and formation of off-flavor (caramelization).

To keep honey in its original condition of high quality and delectable flavor and fragrance is possibly the greatest responsibility of the beekeeper and honey packer. At the same time it is an operation receiving perhaps less attention from the producer than any other and one requiring careful consideration by packers and wholesalers. To do an effective job, one must know the factors that govern honey quality, as well as the effects of various beekeeping and storage practices on honey quality. The factors are easily determined, but only recently are the facts becoming known regarding the effects of processing temperatures and storage on honey quality.

To be of highest quality, a honey—whether liquid, crystallized, or comb—must be well ripened with proper moisture content; it must be free of extraneous materials, such as excessive pollen, dust, insect parts, wax, and crystals if liquid; it must not ferment; and above all it must be of excellent flavor and aroma, characteristic of the particular honey type. It must, of course, be free of off-flavors or odors of any origin. In fact, the more closely it resembles the well-ripened honey as it exists in the cells of the comb, the better it is.

Several beekeeping practices can reduce the quality of the extracted product. These include combining inferior floral types, either by mixing at extracting time or removing the crop at incorrect times, extraction of unripe honey, extraction of brood combs, and delay in settling and straining. However, we are concerned here with the handling of honey from its extraction to its sale. During this time improper settling, straining, heating, and storage conditions can make a superb honey into just another commercial product.

The primary objective of all processing of honey is simple—to stabilize it. This means to keep it free of fermentation and to keep the desired physical state, be it liquid or finely granulated. Methods for accomplishing these objectives have been fairly well worked out and have been used for many years. Probably improvements can be made. The requirements for stability of honey are more stringent now than in the past, with honey a world commodity and available in supermarkets the year around. Government price support and loan operations require storage of honey, and market conditions may also require storage at any point in the handling chain, including the producer, packer, wholesaler, and exporter.

The primary operation in the processing of honey is the application and control of heat. If we consider storage to be the application of or exposure to low amounts of heat over long periods, it can be seen that a study of the effects of heat on honey quality can have a wide application.

Any assessment of honey quality must include flavor considerations. The objective measurement of changes in flavor, particularly where they are gradual, is most difficult. We have measured the accumulation of a decomposition product of the sugars (hydroxymethylfurfural or HMF) as an index of heat-induced chemical change in the honey. Changes in flavor, other than simple loss by evaporation, may also be considered heat-induced chemical changes.

To study the effects of treatment on honey, we must use some properties of honey as indices of change. Such properties should relate to the quality or commercial value of honey. The occurrence of granulation of liquid honey, liquefaction or softening of granulated honey, and fermentation as functions of storage conditions has been reported; also, color is easily measured.

As indicators of the acceptability of honey for table use, Europeans have for many years used the amount of certain enzymes and HMF in honey. They considered that heating honey sufficiently to destroy or greatly lower its enzyme content or produce HMF reduced its desirability for most uses. A considerable difference has been noted in the reports by various workers on the sensitivity to heat of enzymes, largely diastase and invertase, in honey. Only recently has it been noted that storage alone is sufficient to reduce enzyme content and produce HMF in honey. Since some honey types frequently exported to Europe are naturally low in diastase, the response of diastase and invertase to storage and processing is of great importance for exporters.

A study was recently made of the effects of heating and storage on honey quality and was based on the results with three types of honey stored at six temperatures for 2 years. The results were used to obtain predictions of the quality life of honey under any storage conditions. The following information is typical of the calculations based on this work.

At 68° F., diastase in honey has a half-life of 1,500 days, nearly 4 years. Invertase is more heat sensitive, with a half-life at 68° of 800 days, or about 2¼ years. Thus there are no problems here. By increasing the storage temperature to 77°, half the diastase is gone in 540 days, or 1⅓ years, and half the invertase disappears in 250 days, or about 8 months. These periods are still rather long and there would seem to be nothing to be concerned about. However, temperatures in the 90's for extended periods are not at all uncommon: 126 days (4 months) will destroy half the diastase and about 50 days (2 months) will eliminate half the invertase. As the temperature increases, the periods involved become shorter and shorter until the processing temperatures are reached. At 130°, 2½ days would account for half the diastase and in 13 hours half the invertase is gone.

A recommended temperature for pasteurization of honey is 145° F. for 30 minutes. At this temperature diastase has a half-life of 16 hours and invertase only 3 hours. At first glance this might seem to present no problems, but it must be remembered that unless flash heating and immediate cooling are used, many hours will be required for a batch of honey to cool from 145° to a safe temperature.

If we proceed further to a temperature often recommended for preventing granulation, 160° F. for 30 minutes, the necessity of prompt cooling becomes highly important. At 160°, 2½ hours will destroy half of the diastase, but half of the more sensitive invertase will be lost in 40 minutes. This treatment then cannot be recommended for any honey in which a good enzyme level is needed, as for export.

The damage done to honey by heating and by storage is the same. For the lower storage temperatures, simply a much longer time is required to obtain the same result. It must be remembered that the effects of processing and storage are additive. It is for this reason that proper storage is so important. A few periods of hot weather can offset the benefits of months of cool storage—10 days at 90° F. are equivalent to 100–120 days at 70°. An hour at 145° in processing will cause changes equivalent to 40 days' storage at 77°.

Perhaps the easiest way for an individual to decide whether he has storage or processing deterioration in his operation is to take samples of the fresh honey, being careful that they are fairly representative of the batch, place them in a freezer for the entire period, then allow them to warm to room temperature, and compare them by color, flavor, and aroma with the honey that has been in common storage. In some parts of the United States the value of the difference can reach 1½ cents per pound in a few months. Such figures certainly would justify expenditures for temperature control.

The individual storing honey is on the horns of a dilemma. He must select conditions that will minimize fermentation, undesirable granulation, and heat damage. Fermentation is strongly retarded below 50° F. and above 100°. Granulation is accelerated between 55° and 60° and initiated by fluctuation at 50°–55°. The best condition for storing unpasteurized honey would seem to be below 50°, or winter temperatures over much of the United States. Warming above this range in the spring can initiate active fermentation in such honey, which is usually granulated and thus even more susceptible.

Some progressive producers and packers are now using controlled temperature storage for honey, particularly in the warmer regions. Using the data we now have, we can definitely state that reducing the storage temperature of honey by 10° to 15° F. will reduce the rate of honey deterioration to about one-third to one-sixth of that at the higher temperature. Such a temperature reduction, which can easily be attained by air-conditioning, would reduce HMF production to one-third, enzyme loss to one-fifth to one-sixth, and darkening rate to about one-sixth of the rate at the higher temperature. Loss of flavor and freshness would be expected to be reduced similarly. Thus honey can at any time of the year be more nearly like honey at its very best—fresh from the comb at extraction time.

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QUEEN AND PACKAGE BEE PRODUCTION

By William C. Roberts and Warren Whitcomb, Jr., *apiculturists, Entomology Research Division, Agricultural Research Service* [1]

Rearing Queens

For the amateur who desires to rear a few queens, many methods are available. Most of them are described in the references at the end of this section. For those desiring to rear less than 20 queen cells at one time and not more than 50 queens during a season, we suggest the following procedure: Select the best colony as a breeder to produce the queen cells. Rear them after the main honey flow is over by two easy manipulations.

First, remove the queen with one frame of brood and two frames of honey with adhering bees to a hive body in another location. The queenless colony will start a dozen or more queen cells within 24 hours. These will be produced throughout the brood nest. Cut out and save the largest and most uniform cell. Be sure that the cell selected is not damaged. Destroy all unused cells. Return the queen and three frames to the center of the brood nest of the parent colony. If the bees are not robbing, there will be little chance of losing the queen by this method.

Finally, make an additional colony or nucleus by again removing from another colony three frames of brood, honey, and adhering bees. Gouge a cavity near the top of the center comb about ¾ inch wide and 1½ inches long. Gently press the queen cell into it so the queen will have room to emerge from the cell tip. Replace the comb and leave the new hive closed for 2 weeks. Repeat this process for each queen desired.

The commercial queen breeder does not use this inefficient method. He transfers female larvae from worker cells into artificial queen cell cups and uses special queenright or queenless cell-building colonies to rear them. By this method hundreds of cells can be produced continuously.

Commercial Queen Production

In the United States there are many commercial queen breeders who rear annually several thousand queens each. They are concerned with quantity production of high quality queens. High quality queens are necessary for repeat sales, and quantity production is necessary for profitable operations. Customer demand determines the kind or breed of queens produced. Each queen breeder uses methods that suit his own particular conditions.

Queen cells are started when worker larvae are transferred or grafted into wax cells and placed in special cell-starting colonies. Two queenless types are in common use. The "swarm box" is composed of approximately 4 pounds of bees confined in a box with combs of honey and pollen. The "queenless colony" is a hive with 6 pounds or more of bees and an open entrance permitting the bees to fly. In each of these types about 50 queen cells can be started. The cells are left in these starters for 24 to 36 hours and then transferred to the cell-finisher colonies. If the queen breeder uses the "double graft" method of producing queens, he removes the larvae from the started queen cell and replaces them with other young larvae that are allowed to remain.

Some cell-finisher colonies are queenless, others are queenright. They are populous colonies with 10 pounds or more of bees and with both brood and bees of all ages. They must have ample food—both honey and pollen. The queenless cell finisher requires the addition of brood and bees at regular intervals. The queenright cell finisher has a brood nest and queen below the excluder. The queen cells are placed between frames of brood in the upper part of the colony. Started queen cells are added every 3 or 4 days. The frame containing the started queen cells is placed between the frames of unsealed brood.

A few queen breeders start and finish queen cells in the same queenless colony. Others start and finish the cells in a queenright cell-builder colony.

Good cell builders properly handled produce good queen cells and poor cell builders produce poor queen cells. The developing queen larva feeds for only 5 days. If it is properly and adequately fed during this period, a good virgin queen results. If inadequately fed during this period, a poor queen results. The best queen rearing methods are those that provide for well-fed larvae during the 5-day feeding period. Malnutrition results in small queens with fewer ovarian tubules.

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[1] In cooperation with Louisiana Agricultural Experiment Station.

Queen cells are removed from the cell-builder colonies 9 or 10 days after grafting. Ten-day old cells go directly to the small mating hive or nuclei, but 9-day cells are kept for 1 or 2 days in an incubator maintained at brood rearing temperatures. On the 11th day after grafting, the virgin queen emerges from the queen cell. Emergence may be delayed by keeping the queen cells at a slightly lower temperature during the late pupal stage of the queen.

Many types and sizes of mating nuclei are in use. Most queen breeders use a three-frame nucleus containing a feeder. The frames vary in size from about 3 or 4 inches to deep Langstroth frames. Many are established with bees, brood, and honey. Others are started without brood or honey, and the feeder is filled with sugar sirup. The amount of bees needed to stock a nucleus varies from one-fourth to three-fourths pound. If brood is given, only one frame of brood is placed in each nucleus. Many nuclei are started with only two combs, allowing space for adding the bees to the nucleus box. Nuclei are usually closed for 12 hours if brood is given, but may be kept closed for 2 or 3 days if no brood is used. When only two frames are used in installing the bees in the nucleus, the third frame is added 4 days later. Many queen breeders make up nuclei in a building and confine them there for a day or two before moving them to the mating yard.

To insure proper mating, the queen breeder should have an adequate supply of mature drones at all times during the mating periods. Special drone-producing colonies should be maintained in the apiaries containing the nuclei. Producers who do not maintain plenty of drones usually have many inadequately mated queens.

Fourteen days after a queen cell is given to a nucleus, it should have a mated queen with eggs and young larvae. Such queens are ready for shipment and can be removed. Another queen cell can then be given. Many breeders prefer to wait until the next day after removal of a laying queen before giving another queen cell.

If the queen is to be shipped by mail, the queen cage should have candy and 7 to 10 attendant worker bees. If the queen is to be placed in a package of bees for shipment or if she is to be placed in a queen bank for storage, she should be caged without attendant bees and without queen cage candy.

A queen bank is a colony without a laying queen and sometimes without brood. Often 200 to 500 queens in cages are stored in one such colony. They can be kept in a queen bank for a month or longer if sufficient populations are maintained.

Some queen breeders prefer to ship large orders of queens in queen cage carriers rather than adding queen cage candy and attendants to each queen cage. A carrier consists of two Langstroth frames holding 36 queens in each frame, one frame of honey, and about 1½ pounds of bees. A three-frame standard nucleus box with screen top and bottom makes a satisfactory carrier package for shipment.

A commercial queen breeder will obtain 200 to 400 queen cells from each cell-building colony each month of operation. This is enough to supply queen cells for 100 to 200 nuclei. Few queen breeders average more than 50 mated queens for each 100 cells put into nuclei.

Improvements in the technique of artificial insemination of queen bees may soon eliminate the need of nuclei and possibly cut the cost of queen production. Ninety-five percent survival of queens mated artificially is not uncommon with present techniques.

The greatest customer demand for package bees and queens occurs in March, April, and May. Consequently, the large producers are located in areas with a climate that permits economical production before and during these months. Locations in the South and in California, with mild winters and early springs, are ideally suited for early production of populous colonies. The choice locations are those that have not only a favorable climate but also good floral sources of nectar and pollen.

An area without a good nectar flow can be satisfactory, but a good pollen flow is essential. Many producers feed sugar sirup to their colonies during February and March. Others find it necessary to feed continuously during their most active season. There is no substitute for an abundant pollen income during the spring and fall. Pollen storage in the fall is necessary for early spring buildup. Without adequate pollen sources after the middle of February the colonies will curtail brood production.

The queen and package bee production in the United States today is a $5 million industry. More than 1 million queens and over 500 tons of bees are produced and sold to beekeepers in the United States and Canada each year.

Package Bee Production

Commercial shipments of package bees for replacing or starting new colonies in the honey-producing regions were apparently first made in 1912 by H. C. Short from Fitzpatrick, Ala. The demand for package bees increased greatly after World War I and shipments of queens reached a peak about 1947. The Railway Express Agency probably handled 80 to 90 percent of all bee shipments during the 1920's and 1930's. Since then truck, air, and mail shipments have become increasingly important. Approximately 80 percent of all package bees are now trucked to northern honey producers.

The requirements for producing a maximum crop of bees and a maximum crop of honey are basically similar. Prolific queens, adequate equipment, abundant stores at the proper time, a knowledge of local nectar and pollen sources, and a system of management planned for the particular environment are necessary for both crops. Fundamental differences are (1) the length of time during which colonies must be stimulated for maximum brood production, (2) the amount of equipment used, and (3) the maintenance. The shipping season lasts for 2 to 3 months for the bee-producing colony as opposed to a honey-flow period of 3 to 6 weeks for the honey-producing colony. Three deep bodies are used for the bee-producing colony and a minimum of three deep bodies for the honey-producing colony. After each shaking, a population of about 18,000 bees—the level that gives the maximum production of brood per bee—is required for the bee-producing colony as opposed to a population of 60,000 or more bees for maximum honey production.

Methods of producing package bees have been carefully studied. A system of management that is successful in Baton Rouge, La., will be described, and it can be easily adapted to other areas.

Preparing colonies for package bee production should begin in August, with a check of colonies for good queens and the replacement of failing queens. August and September can be a danger period in many parts of the shipping area because of lack of honey flow—almost a necessity for successful queen introduction—and especially because of lack of pollen. Productive colonies will have mostly young bees in mid-November, although the colony may be nearly broodless. There should be 50 to 70 pounds of honey and 200 to 600 square inches of pollen in three deep bodies of good combs. About one-half the honey should be in the top body and the remainder fairly equally divided between the other two bodies of the brood nest. Three to six good combs of pollen should be placed near the center of the lower brood chambers. In good colonies most of this pollen will be used before the start of brood rearing in January. Lack of honey stores can be corrected by feeding sugar sirup. A deficiency in pollen can be partially corrected by giving pollen cakes after brood rearing starts.

Colonies should reach maximum populations at the start of the shipping season. This means that colonies should be stimulated to sustained brood production for 8 to 10 weeks before colonies are to be shaken. The greatest production of brood per bee is in colonies with approximately 18,000 bees. The greatest colony yield of bees is obtained by shaking about 4 pounds of bees at regular 10-day intervals so that a population level of approximately 18,000 bees is maintained. At the start of the shipping season the strongest colonies may have 35,000 to 45,000 or more bees. Such colonies may have 5 pounds of bees shaken at 10-day intervals, but removing more than 6 pounds of bees at a single shaking results in decreased brood production.

Three-story colonies are necessary during the buildup period to supply the area for eggs and brood that a prolific queen requires together with the comb space necessary for honey and pollen stores. In order to decrease labor in handling hive bodies, most of the honey can be placed in the bottom body at the beginning of the shaking period and only the top two bodies manipulated. This three-story colony can be manipulated with essentially the same labor requirements as a two-story colony, but because of the space and food reserves in the bottom body the brood production will be higher. A maximum of 37 pounds of bees has been shaken from a single colony and an average of 32 pounds of bees per colony from 10 colonies during a 60-day period without detriment to the colonies.

Methods of getting the bees into the shipping package vary widely depending on local honey-flow conditions, the type of package used, and how it will be transported. Two widely used methods include (1) shaking the bees from combs in the brood nest, which requires more labor but allows a constant check on the condition of the queen and colony, and (2) the smoke-up or drive-up method, by which bees are smoked or driven by a repellent up onto combs in the top body, then shaken off. By this method the brood nest combs are not removed. The recently developed forced-air method of removing bees from honey supers may be adapted for package bee removal. Bees are sometimes shaken through a funnel directly from the comb into the package, or into a "shaker box," from which they are later measured into packages. Both of these methods are satisfactory and widely modified by individual shippers.

A recent survey of commercial package bee shippers shows that most of them ship about 10 pounds of bees from each colony during the shipping season.

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BREEDING AND GENETICS OF BEES

By OTTO MACKENSEN, *apiculturist, Entomology Research Division, Agricultural Research Service*[1]

Until recently, progress in inheritance studies and breeding better bees has been slow. This has been due not only to the inability to control mating but also to a general lack of understanding the breeding biology of the honey bee. After the technique of artificial insemination was perfected, progress accelerated.

With the tremendous gene pool provided by the many geographic races of the world, the possibilities should be great for developing better bees. Since much of the beekeeper's basic operating expenses are the same regardless of the quality of bees used, a more productive bee can increase his profits rapidly. Greater uniformity of an improved stock would help to reduce operating expenses.

A single superior strain is not enough. We need different strains adapted to different environments and methods of management and also strains or hybrids bred for specific purposes such as pollination of specific crops.

Honey Bee as a Breeding and Genetic Subject

The honey bee presents special problems and also several distinct advantages to the breeder and student of genetics. These arise from its parthenogenetic and social nature as well as its mating habits and peculiar method of sex determination. Of course, the basic laws of genetics apply. It is a matter of understanding how they operate in the honey bee.

The honey bee queen and worker develop from fertilized eggs and therefore their bodies contain two sets of chromosomes and genes and are said to be *diploid.* The drone develops from an unfertilized egg and has only one set of chromosomes and genes in all the cells of his body and is said to be *haploid.* Eggs and sperms are called *gametes* by the geneticist.

In the formation of eggs a reduction division takes place so that each egg receives a random assortment (only one member of each pair) of the genes of the queen. Since the drone has only one set of genes, no reduction takes place and his sperms are all identical to the composition of the drone himself. The separation of genes going into the gametes followed by the creation of new combinations by fertilization is called *segregation and recombination.* This is the mechanism that brings about genetic variation between individuals in a family. Since all the sperms produced by a drone are identical, no variation between sisters (queens or workers) is introduced from the drone.

A gene may change so that it has a different effect. Such a change is called a *mutation.* Both the mutant and the parent gene are referred to as *alleles.* The position of these genes on the chromosomes is called a *locus.* There can be several alleles of a given locus, each having a different effect on the body part or the behavior, which is affected by genes of this locus.

A gene may be *dominant* to another allele, completely masking its effect. The other gene is then called *recessive.* When the two genes at a locus are alike, the individual is said to be *homozygous* for that gene, and if they are different, the individual is said to be *heterozygous.* The drone, having only one gene of a pair, is said to be *hemizygous.* A recessive gene must be homozygous to find expression in queens and workers but always finds expression in the hemizygous condition in the haploid drone.

The two members of a gene pair may have different expressions when they are heterozygous than when each is homozygous. Genes at different loci may also react with each other to cause various effects. When one considers that there may be thousands of loci with interaction of genes at different loci as well as interaction of alleles, it becomes apparent that the possibilities for genetic variation are tremendous.

The honey bee colony is a family consisting of the queen mother, the father represented by the sperm in the spermatheca of the queen, all the biparental worker progeny developing from fertilized eggs, and the maternal drones developing from unfertilized eggs. If the queen mated with one drone, the workers are full sisters in the sense that they all have the same father and mother. Genetically they are more closely related than the full sisters of diploid animals, because the sperms of the drone are identical. These have been called "supersisters." If the queen mated with several drones, as is the case in nature, there are as many groups of half sisters as there were drones involved in the mating. The normal colony established by natural

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[1] In cooperation with Louisiana Agricultural Experiment Station.

mating may then be looked upon as a superfamily made up of several subfamilies.

The fact that the drone develops from an unfertilized egg has several consequences of interest to the bee breeder. Each egg of a queen contains a random assortment of her genes, and since her eggs develop into drones without fertilization, all genes find expression and these drones show the gametic ratio. This is illustrated in figure 1, which shows the inheritance of a single pair of genes, the recessive mutation hairless (*h*), which causes almost complete hairlessness over the whole body, and its dominant wild-type allele (*H*), the gene determining development of normal body hairs.

This diagram shows a heterozygous queen (*h*/*H*) mated to a wild-type drone (*H*). The queen produces two types of eggs (*h* and *H*), which without fertilization develop into drones, one-half of which are hairless (*h*) and one-half wild type (*H*). This is called the gametic ratio. The drones are, therefore, in effect "flying gametes." Since they can be produced in great numbers, this arrangement is a great convenience to the geneticist. The worker bees are all wild type, having developed from eggs fertilized by sperm carrying the dominant wild-type allele (*H*) and are indistinguishable. This is the simplest possible illustration. Of course, there are thousands of pairs of genes acting and the queen's eggs represent random assortments of these genes, all of which can find expression in the haploid drone.

If we mate a black drone with a yellow queen, the worker progeny will be hybrid containing genes from both races and will be intermediate in color, whereas the drones in this colony will be yellow like the mother. This phenomenon is very useful to the breeder. When he wants many drones of a given stock, he can let queens of this stock mate naturally to any type drone and still produce from them the type drones he wants.

When the Italian race was first introduced into this country, it was yellower than the common dark bee. If the beekeeper wished to change common to Italian stock, he first obtained a few Italian queens, reared daughters, let them mate naturally to common drones, and then used the resulting colonies to produce pure Italian drones. He then reared virgins from an Italian colony and let them mate naturally with the mixture of Italian and common drones. In the following generation he selected the yellowest virgins, which were probably Italian. Thus by rigid selection he could change his stock to Italian in two generations and in one season. This emphasis on selection for yellow contributed to the development of the American Golden Italian bee.

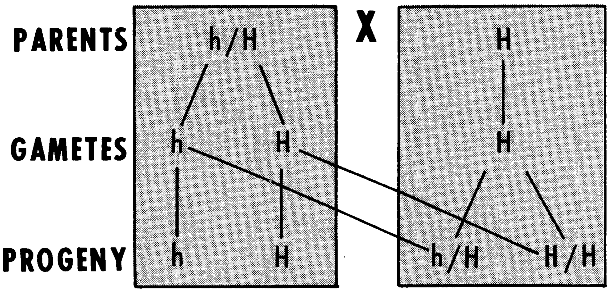

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FIGURE 1.—Inheritance of recessive gene hairless (*h*) and its wild-type allele (*H*) in cross of heterozygous queen with wild-type drone.

Parthenogenesis makes possible the equivalent of self-fertilization of queens. A virgin queen is first made to start laying by carbon dioxide treatment, caged outside the hive for a few days to shrink her ovaries and stop egg production, and then is inseminated with sperm taken from her sons. This makes possible very fast inbreeding if such is desired.

The cells of the drone body, and, therefore, the sperm he produces all have the same set of chromosomes and genes. This means that one-half of the genetic makeup of the worker bees of a colony is identical provided the mother mated with a single drone. This adds uniformity to the workers of a colony. When a series of queens is mated individually to drones of one queen, differences between the resulting colonies are largely due to the genetic differences between the drones, which represent the gametes of their mother. When we select from among these colonies, we are selecting the best gametes of the queen. When we rear breeding individuals (queens) from these selected colonies, we are breeding descendants of the desired gametes. The colonies of such a series are, therefore, in a way equivalent to individuals.

We can take advantage of these facts in making genetic analyses of colony behavior, which is difficult to study because it is a product of the action of many individuals. First, inbred lines are established by inbreeding and selection for extremes of the characteristic under study. For example, one might select for high and low preference for alfalfa pollen. The two lines are crossed and drones of a hybrid queen are mated individually to queens of the high and low lines. It is assumed that the maternal inheritance of the worker bees is identical in each of the resulting colonies, since it came from an inbred line, and that differences between colonies are mainly due to the genetic contributions made by the drones, each drone having contributed a random sample of the genes of his mother and thus a study of gene segregation is possible.

Since some characteristics such as body color can be recognized in the breeding individuals themselves, selection of breeding individuals is simple. Many of the characteristics of economic importance, such as swarming tendency and propolizing tendency, are determined by the worker population of the colony as a whole, and for such characteristics the colony is the test unit. We cannot breed this unit. We can in effect breed the queen by using her sons, because, as we have seen, they represent her germ cells. For breeding females we can only use virgin queens that are sisters to the workers of the colony.

Control of Mating

In recent years the bee breeder has learned much about mating. Queens fly some distance from their hive to mate. How far is not known. Queens are almost invariably flying alone when they have completed their circling of the queen yard and disappear into the distance. Using genetically marked stock, more queens have been shown to mate with drones at a distant location than at the home location. Just where mating takes place under various circumstances has not been determined.

What the bee and queen breeder would like to know is what arrangement he needs to make to get the maximum pure mating. Until better experimental data are available, this goal can probably best be reached by saturating the queen yard and the area around it with as many drones of the desired type as possible. To accomplish this, the drone-producing colonies should be placed from 1 to 3 miles from the mating yard in all directions as well as in the mating yard. At the same time the area should be free of colonies producing undesired drones for at least 5 miles.

Since queens mate with several drones, single drone mating in nature is probably extremely rare. This fact together with the ever-present chance that the queen has met with an undesired drone makes natural mating of limited value to the scientific breeder and geneticist, who must use artificial insemination. This is impractical for the commercial bee breeder.

The equipment needed for artificial insemination includes a stereoscopic microscope, a device for administering carbon dioxide as an anesthetic, and the insemination apparatus itself (fig. 2), consisting of the manipulating stand, holding hooks, queen holder, and syringe. The queen is allowed to back into the queen holder tube until the end of her abdomen projects. She is secured by means of a stopper, through which carbon dioxide is flowing, and placed in the manipulating stand. Then the chitinous plates at the tip of the abdomen are separated with the holding hooks to expose the genital opening. Semen is taken into the syringe from the drone and injected into the oviducts while a valvelike fold is held aside with a probe.

To collect semen the drone is made to partially ejaculate by squeezing the head and thorax, and then the abdomen is squeezed to complete the process. The cream-colored semen is easily distinguished from the white mucus. The average drone delivers about 1 microliter of semen.

Queens inseminated with semen from a single drone will nearly all lay fertilized eggs initially, and a few of them may continue to do so for a year or more. To approximate natural insemination, either two injections of 4 to 6 microliters on separate days or a single injection of 12 microliters can be given. Larger injections of up to 18 microliters can be given without injury, but efficiency (percentage of sperms reaching the spermatheca) decreases as the dose increases. Ninety percent or more of the queens inseminated can be expected to start laying.

Carbon dioxide initiates oviposition in addition to acting as an anesthetic, but the exposure during two inseminations is sometimes not enough. Therefore, an additional treatment for 10 minutes is given on the day following the second insemination. When one insemination is made, a treatment is given on each of the following 2 days.

Sex Determination

Beekeepers have long noticed that after several years of line-breeding, the brood of their strain began to deteriorate in viability, having a "spotted" or a "pepper box" appearance. They found that introducing "new blood" by purchasing breeding queens from another bee breeder would quickly correct the situation. The deterioration was thought to be due to a weakening through the general bad effects of inbreeding, which may have been true to some extent, but now it has been determined that much of this is due to the peculiar sex determination mechanism of the honey bee. It is essential that the bee breeder understand this mechanism.

Dzierzon in 1845 was the first to recognize that males (drones) are parthenogenetic, that is, develop from unfertilized eggs, and that females (queens and workers) develop from fertilized eggs. This still holds true, but in recent years it has been discovered that this is only a part of a very much more complicated system. It has now been well established that sex is determined by a series of allelic genes at the sex (X) locus, which are designated xa, xb, xc, etc. Females (queens and workers) are always heterozygous, that is, they contain two of these alleles that are different, as, for example, xa and xb. A queen of this composition produces eggs of which one-half are xa and one-half are xb. Since the drones normally found in the hive develop from unfertilized eggs, one-half of the sons are xa and produce only xa sperm and the other half are xb and produce only xb sperm. All haploid drones are viable.

When an egg such as xa is fertilized by a sperm carrying a different sex allele such as xb, a queen or worker having the composition xa/xb will result.

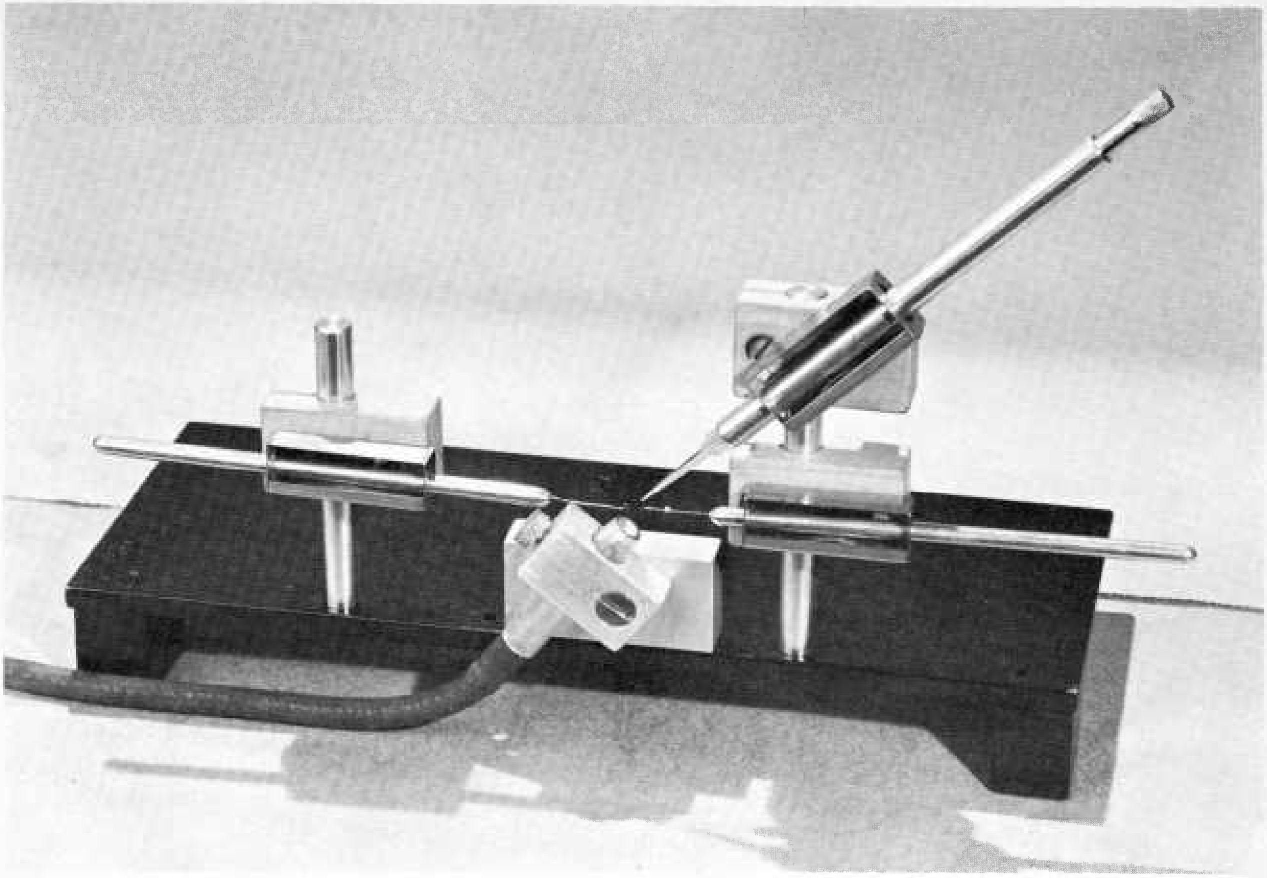

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FIGURE 2.—Artificial insemination apparatus.

If it is fertilized by a sperm carrying a similar allele such as *xa*, this homozygous combination *xa*/*xa* is also a male, but it is a biparental male that will be eaten by the nurse bees within a few hours after hatching. When a queen (*xa*/*xb*) is mated to a single drone carrying a different sex allele such as *xc*, then all the progeny resulting from fertilized eggs will have dissimilar sex alleles (*xa*/*xc* and *xb*/*xc*) and will be viable females (fig. 3, *A*). Efficiency in the brood nest will be high and a populous colony will result. If, on the other hand, she is mated with a single drone having a similar sex allele such as *xa*, then one-half of her progeny resulting from fertilized eggs will be *xa*/*xb* females and viable and one-half will be homozygous biparental (*xa*/*xa*) males and be eaten by the bees (fig. 3, *B*). In addition to wasting the queen's energy, the diploid males live for more than 3 days before removal and thus reduce efficiency in the brood nest and a weak colony results.

Inbreeding reduces the number of sex alleles in the population and increases the proportion of biparental males. Outbreeding brings new sex alleles into the population and increases the proportion of females among fertilized eggs. It is, therefore, more important to avoid inbreeding in bees than in other domesticated animals and plants.

Multiple mating obscures the effect of sex alleles. If a queen mates only with drones having sex alleles similar to her own, the viability of her brood is 50 percent, and its poor quality is very noticeable. Ordinarily this rarely occurs in nature because drone populations contain several sex alleles. If all her mates carry dissimilar alleles, the viability of her brood is theoretically 100 percent. If she mates with a mixture of the two types of drones, the viability ranges between 50 and 100 percent depending on the proportion of the two types of sperm. The reduced viability of a multiple mated queen could easily be overlooked if only one or two of the eight to 10 drones she mated with had similar alleles to her own. Multiple mating and the tendency to mate far from the hive may be evolutionary adaptations to the sex-determining mechanism, since both would be favored in natural selection because they both tend to increase efficiency in the brood nest.

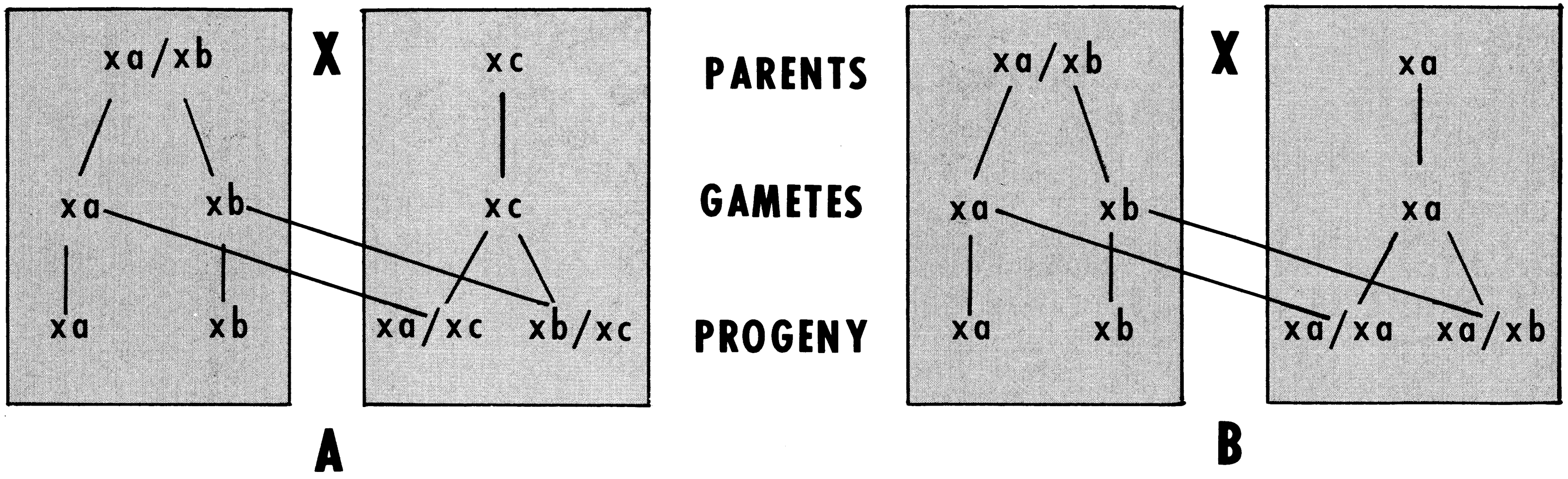

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FIGURE 3.—Types of progeny resulting from mating of queen to drone with sex allele unlike her own (*A*) and to drone with sex allele similar to her own (*B*).

The Gene Pool

The honey bee population of the world varies tremendously. Through the ages many rather distinct geographic races have evolved through natural selection. These races with their various characteristics, some desirable and some undesirable, form the gene pool, or raw material, available to the bee breeder. The four races of honey bees (*Apis mellifera* L.) that have been of most value to the bee industry are briefly described.

The European brown bee or dark bee *A. mellifera mellifera* L. is native to Europe north and west of the Alps. It is black with short legs and broad body. Colonies of these bees develop slowly in the spring to populations of medium strength in the summer and winter. They winter well in severe climates, being conservative of their winter stores. The bees run from the combs very readily when manipulated, are often aggressive, have a weak disposition to swarm, and are susceptible to brood diseases and the wax moth. The Dutch or "heather bee" is a special strain of this race that was selected for swarming tendency by the beekeepers of the heather areas of northern Europe. Each year they could kill the bees in the heaviest skeps, obtain the honey, then the following spring restock each skep with a new swarm.

The Italian bee *A. mellifera ligustica* Spinola is native to Italy north of Sicily. It is smaller and has a more slender abdomen then *A. m. mellifera*, with yellow bands on the front segments of the abdomen. It is variable in color in Italy. It breeds from early spring to late fall, developing exceptionally strong colonies and using up reserve stores. It winters with a high population and high food consumption. It is calm on the combs, is gentle, builds comb readily, caps honey white, propolizes sparingly, and has a weak disposition to swarm. It tends to rob and drift more than other races.

The Carniolan bee *A. mellifera carnica* Pollmann is native to the Austrian Alps, the northern Balkan region, and the Danube Valley. Early Carniolan bees had a bad reputation for swarming, but since about 1930 a well-planned breeding program in Austria has resulted in productive strains with little tendency to swarm. This is a slender, long-tongued bee, with black chitin and short gray hairs that give it a gray appearance. Brood rearing starts early and advances rapidly, building the colony to a strong population early. This bee reduces brood rearing later in the year, winters with a small cluster, and conserves its food. It is disposed to swarming because of its rapid spring development. It is quiet on the combs, is very gentle, drifts very little, does not rob, and is resistant to brood diseases. It is an excellent bee for an early honey flow.

The Caucasian bee *A. mellifera caucasica* Pollmann is native to the Caucasus Mountains of Russia. In appearance this bee is much like the Carniolan bee except that it is not so gray and has variable amounts of yellow on the abdomen depending on the region from which it comes. It is a good brood producer, building to strong colonies, but is slow to reach full strength. It has the longest tongue of all races. It is gentle, is calm on the combs, caps honey flat, swarms very little, propolizes very heavily, and is inclined to drifting and robbing. It stores honey close to the brood nest and winters well.

The honey bees that were brought to America by the early settlers and spread throughout the land to become the common bee of this country were very probably of the *A. mellifera mellifera* race because their characteristics were similar. The worst characteristics of our early common bee were susceptibility to European foulbrood, a tendency to swarm and sting, and a strong tendency to run off the combs and out of the hive when manipulated. The Italian bee imported in 1859 became popular rapidly and soon was almost universally accepted by beekeepers in this country. It still remains the dominant race. A great deal of mixing must have occurred as this transition took place.

Both Caucasian and Carniolan bees have been imported at various times and are still being propagated, particularly the former. In addition, several other races have been introduced and propagated on a limited scale until they were discovered to be inferior. Among these were Cyprians, Syrians, and Egyptians, all of which sting excessively. Vestiges of the genes of these races may still remain in this country. This, then, is the gene pool that has been in the hands of the American beekeeper since importations were stopped in 1922 by law to prevent introduction of the mite *Acarapis woodi* (Rennie), the cause of acarine disease.

Importation and Maintenance of Stock

Special methods for importing stock without danger of introducing acarine disease have been developed. One of these is a method of shipping semen. The semen of 30 to 40 drones is placed in a capillary glass tube, 1.8 to 2.0 mm. in diameter, with an artificial insemination syringe. Each time the syringe is emptied, the semen is forced down to the bottom of the tube with a centrifuge at 10,000 r.p.m. When loaded, the tube is sealed on a flame as near the semen as possible. When finished, the tube contains about 20 mm. of semen and 10 to 15 mm. of air. Properly protected these tubes are placed in an envelope, sent airmail, and used immediately on arrival at destination. Several successful overseas shipments have been made. Some viable offspring have been obtained by using semen handled in this way and stored for 68 days at room temperature.

Another method consists in transporting eggs, larvae, and pupae. Mites do not live on these stages. Shipment by air led to only very limited survival because of rough handling, but transport in an incubator carried as personal luggage was very successful. Queen and drone pupae were removed from the comb a few days before emergence and placed in gelatin capsules, the eggs were put on wax-paper slips in vials, and worker larvae 24 hours old were deposited on royal jelly. At destination the queens and drones were introduced into queenless nuclei, and queens were reared in the usual manner from the worker eggs and larvae. Offspring were obtained after artificial insemination. To date, six stocks have been imported rather successfully.

No doubt these techniques will be used to great advantage in the future. However, the importation of stock should be purposeful. The stocks should be studied in their native land, and only those of proven superiority or with a specific desired character should be considered for importation. A recent importation of the African bee *A. mellifera adansonii* Latreille to Brazil has apparently been regretted because of its viciousness, and this bee is spreading throughout the country. On account of the techniques involved, this method can only be utilized by research laboratories.

Once imported, the stocks must be maintained during their period of immediate use and also for future use. Since only a limited amount of breeding material of any one stock can be imported and maintained and since artificial insemination must be used, inbreeding and reduced vigor are unavoidable. This often leads to greater susceptibility to disease and to wax moths. Several queens must be maintained at all times to insure survival of the stock. Mutations are much easier to carry, because inbreeding can be avoided and several mutations can be carried in the same stock. Nevertheless as mutations useful to research accumulate, the maintenance will become a burden in research laboratories. Many valuable stocks have been lost because of neglect due to the more immediate urgency of other research. There is a definite need for a center, the principal function of which is the maintenance of valuable breeding and genetic stocks, of both domestic and foreign origin, for distribution to research workers and bee breeders who can properly use them.

Breeding Methods

Selection is only effective when there is heritable variation. As we have seen, this variation is very great in the honey bee, because it is a naturally outcrossed species, mating in the air away from the hive and therefore very heterogeneous. Great variation occurs not only between races but within them. Our task is to sort out the good qualities from the bad and at the same time not be misled by the effects of the environment.

Testing for Selection

In testing colonies for the purpose of selection, the bee breeder must be certain that the test colonies have an equal opportunity to develop and produce. They should be in one location if possible. If single colonies are selected at different locations, they should be evaluated and chosen on the basis of the average performance of the yard they are in. A colony bringing in a medium honey crop in a low producing location may be as good a selection as a much higher producing colony in a high producing location. When groups of colonies are to be compared and they cannot all be placed at a single location, equal numbers should be placed at each of several locations.

A test yard should be established in an area where there are some trees and shrubs for bees to use as landmarks in locating their hives rather than in an open field. The colonies should be placed in irregular positions as far apart as possible and equally exposed to the elements. If the colonies are placed in regular rows, returning field bees tend to drift into the end ones and thus these colonies have a distinct advantage. Manipulation should be such that all colonies have an equal opportunity to perform.

Selection is simple for characteristics expressed in the queen and drone. However, we have noted that for most characteristics of economic importance, the colony as a whole is the unit of performance on which selection of breeding individuals is based. A superior colony is chosen on the basis of brood rearing qualities expressed through the queen and in the behavior of the workers.

In basing selection on performance of a single colony, one takes the risk that this high performance is accidental and will not be transmitted. It is, therefore, safer to hold colonies over to the next year while the progeny colonies are being tested. Then those whose progeny colonies perform best can be chosen as breeders.

Important qualities to look for in the queen are longevity and egg-laying capacity. If at all possible, a queen should be tested for 2 years. Workers should be observed for such characteristics as fast buildup in the spring, wintering ability, willingness to enter supers and draw comb, swarming tendency, good handling qualities such as quietness on the combs, temper, resistance to disease, and honey production. Such characteristics as length of tongue, size of honey stomach, wing area, and other physical characteristics are secondary. If they are advantageous, they will automatically be selected along with honey production. Long-tongued bees do seem to gather more honey from red clover, which has a long narrow corolla tube that makes the nectar out of reach for the shorter tongued bees.

Methods for the Commercial Breeder

The common method of breeding practiced by queen breeders is known as line-breeding. It can be defined as breeding and selection within a relatively small closed population. The bee breeder's colonies constitute such a population to the extent that mismatings with drones outside his stock do not take place. In line-breeding some inbreeding is inevitable. Its main effects are (1) fixation of characteristics so rapidly that effectiveness of selection for good qualities is reduced and the stock loses vigor and (2) the detrimental results from homozygous sex alleles. These effects can be largely avoided by using as many breeding individuals as possible for every generation.

The bee breeder will naturally breed from the best colonies, and this is good practice. However, there are good and poor methods of breeding the selected colonies. He may select one or more outstanding colonies and rear queens from them, which are mated to the general run of drones of his stock. These are used to requeen his producing colonies, which he observes the following year. From these he again selects several of the best colonies to use as breeders for his queen production and repeats the procedure.

If he uses any one breeder for 2 years in succession, some virgin queens will mate with some drones of their sisters reared the previous year. If only one breeder was used the previous year, then all virgins will mate with sons of their sisters. Such close inbreeding brings together similar sex alleles and reduces the effectiveness of selection by increasing homozygosity too rapidly. Using a single but different breeder each year would also be too much inbreeding. He should use as many breeders as is practical, the more the better, and requeen all his production colonies each year to prevent backcrossing to the same source of drones.

The bee breeder can go a step further to prevent inbreeding if he is not averse to keeping some records. He can breed from several outstanding queens that are not highly related, for example, A, B, C, and D, keep track of their queen progeny, and thus establish queen lines A, B, C, and D, respectively. In requeening his stock he should use equal numbers of daughter queens from each line, and after testing for a season, select at least one from each line to be used as grafting mothers the following year. The larger the number of queen lines the better. If the bee breeder selects for certain physical characteristics, but without sacrificing other qualities, to make his stock uniform and distinctive, he will be better able to recognize mismated queens and can avoid using them as breeders.

If after several years his stock begins to show a spotted brood pattern, he may introduce "new blood," but before doing so he should first test several promising stocks from other bee breeders to determine whether they have qualities he wishes in his own stock. At least 10 colonies of each stock should be compared in a single yard outside the mating range of his queen mating yard.

These are methods that the commercial queen breeder can use without undertaking complete control of mating by isolated mating stations or artificial insemination and extensive records.

Hybrid Breeding

When one crosses inbred lines, strains, or races or even some related individuals, one often gets hybrid progeny superior to either parent in growth and vigor that does not carry through to the following generations. This is called hybrid vigor or heterosis. The cause is not thoroughly understood, but it is thought to be due in part to combining the dominant genes of the two parents in the hybrid and thus are covered up many detrimental recessive genes that were homozygous in one of the parents. Many of the genes that become heterozygous will have their greatest favorable effect in that state and thus contribute vigor to the hybrid. Since the honey bee is a highly outcrossed animal in nature, one would expect an accumulation of such genes in its germ plasm.

Hybrid breeding seems to be a good solution to the bee breeder's special problems; however, since it requires good control of mating, it is not for the average bee breeder. Hybrid breeding programs are now being conducted by qualified organizations. The procedure is very much like that practiced in the production of corn hybrids. The first step is to develop many inbred lines. Then these are crossed in various combinations to determine those that produce the best hybrids, which can then be produced in quantity as long as the component lines are maintained.

Usually four lines are combined to make four-way hybrids. For example, such a hybrid involving lines 1, 2, 3, and 4 might be produced as follows: An inbred queen of line 3 artificially mated to drones of line 4 is used as a breeder queen to produce hybrid (3 × 4) queens. These are allowed to mate naturally and are used to produce drones. Queens of line 1 are then mated to drones of line 2 and hybrid virgins (1 × 2) reared for mating to the above-mentioned drones. The cross is then (1 × 2) × (3 × 4). As foundation stock for his hybrid queen production, the queen breeder receives queens of line 3 mated to line 4, from which he rears many queens and lets them mate naturally for use in his mass drone production. He also receives inbred queens of line 1 mated to line 2, from which he rears the queens (1 × 2) to be mated to (3 × 4) drones and sold. Thus with very few queens of the foundation stock, he can rear thousands of queens for the market. The resulting colonies will be headed by two-way hybrid queens, which will be uniform in appearance, whereas the worker bees will be four-way hybrids and variable in appearance unless the color markings of the bees of the parent lines were very similar.

Comparative tests of hybrids have shown their superiority. Increased productivity of 34 to 50 percent over the average of line-bred strains has been reported. Segregation and random mating in the generations following hybridization are likely to result in only mediocre colonies. Hybrids are an end product, and to make proper use of them it is necessary to requeen every year. For these reasons they have been unpopular with some beekeepers.

In the present hybrid breeding programs, lines are inbred rapidly with practically no selection. The highly inbred lines are difficult to maintain while tests are being made, and most of them are discarded, resulting in a considerable waste of effort. Lines bred on a broader basis with selection for desirable characteristics and for different sex alleles may in the future produce far better hybrids. This type of hybrid breeding and race crossing needs to be explored more thoroughly.

Mutations and Inheritance of Characteristics

More than 20 useful mutations have been discovered and an ever larger number are being maintained by research laboratories. In addition to being the working tools of the geneticist, they are useful in bee behavior and other studies. For example, the recessive gene cordovan (*cd*) that changes the black body pigment to brown without reducing vigor has been used as a marker in studies on mating flight range, multiple mating, and pollination behavior. Eye color mutations have been used to prove the sex-determining mechanism. Mapping the loci of these genes on the 16 chromosomes will have to await discovery of many more mutants. Only three cases of linkage (two gene loci on the same chromosome) have been reported. Since most mutations are recessive and since the drone is haploid, mutants are most easily found by examining the drones. A mutation may appear in a single drone or in many drones of a single colony. Since worker bees tend not to tolerate abnormal individuals, many of the mutations that occur escape discovery. Beekeepers can be very helpful to the geneticist by watching for abnormalities and reporting them to a research laboratory.

Since characteristics of economic importance respond to selection, we can assume that they are heritable to at least some extent. Few thorough investigations have been made to determine just how they are inherited. Some work has shown that tongue length, stinging behavior, and distribution of body pigment are determined by many genes. Preference for alfalfa pollen also appears to be an inherited character, because high and low preference lines have been selected. Resistance to American foulbrood seems to be a matter of removal of diseased larvae by the worker bees and is governed entirely by two recessive genes. As our knowledge of the inheritance of specific characteristics grows, the bee breeder's task should become much easier.

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POLLINATION

By M. D. Levin, *apiculturist, Entomology Research Division, Agricultural Research Service*[1]

A farmer can provide the best agronomic practices—proper seedbed preparation, fertilization, soil moisture, cultivation, pest control, and harvesting methods—and fail to obtain a bountiful crop if he neglects to provide for pollination. Many of his fruit crops, legumes, vegetables, and oilseed crops depend on bees for assistance in reproduction, and therein lies the basis for the most important contribution made by any insect to agriculture—pollination by bees.

The function of a flower is to produce seed. In a typical flower (fig. 1), the essential female parts are the ovary, style, and stigma. The typical male part is the anther. It produces pollen, which contains the male sex cell. These parts may vary greatly in shape or number. The ovary becomes, botanically speaking, the fruit; the style is a columnar extension of the ovary. At the tip of the style, which may be expanded or otherwise modified, is the receptive stigma. In many plants the stigma has a sticky surface to which pollen grains adhere and on which they germinate.

To produce seed, pollen must move from the anther to a receptive stigma. This is *pollination.* When pollen adheres to the stigma, it germinates and produces a pollen tube that grows through the stigma and the style to the ovary. *Fertilization* takes place in the ovary when the nuclei of the male germ cell in the tip of the pollen tube unite with the nuclei of the female germ cell.

Pollen transfer from an anther to the stigma of the same flower or to the stigma of another flower on the same plant is referred to as *self-pollination.* The transfer of pollen from an anther of one flower to the stigma of a flower on another individual plant is called *cross-pollination.* Therefore, cross-pollination in the horticultural sense refers to the transfer of pollen between flowers on plants with different genetic constitutions.

In plants adapted for self-pollination, the pollen grains are often transferred from the anther to the stigma by gravity or the movement of parts within the flower. Some plants are self-sterile or have floral parts modified or so arranged that the plant is clearly unable to pollinate itself. In such cases, pollen has to be transferred by external agents. Many plants combine adaptations for both cross- and self-pollination in different flowers or at different stages of the life cycle of the flowers. For such plants, cross-pollination usually results in better seed or fruit production, but automatic self-pollination insures that some seeds will form even if external agencies fail.

Some plants produce pollen that is light and easily blown about by wind. They are referred to as *wind-pollinated* plants. Others produce pollen that is heavy and sticky, not blown easily from flower to flower, but they require other agents, usually insects, to transfer it. They are usually referred to as *insect-pollinated* plants.

Agents of Pollen Transfer

Wind, gravity, and insects are the main external agents of pollination. Wind or gravity disperses pollen of corn and other grasses, coniferous trees, many deciduous fruit and nut trees, and such crops as castorbeans, spinach, and beets.

Bee Pollination

Many of our fruits, vegetables, legumes, and oilseed crops are insect pollinated. Although many kinds of insects visit flowers and effect accidental pollination, the amount is small. Bees are the most efficient and only dependable pollinators, because they visit flowers methodically to collect nectar and pollen and they do not destroy the plant by feeding on it in the pollination process. Although various species of bees contribute to the pollination of our crops, an estimated 80 percent of this pollination is done by the honey bee.

Modern agriculture has come to depend greatly on the honey bee to fulfill its pollination needs. This species has several valuable qualifications for this role.

Beekeepers maintain honey bees at a high population level in many agricultural areas of the United States for the honey and wax they produce. Bee colonies can be easily concentrated when and where needed to satisfy pollination requirements, and by using techniques developed for honey production their number can be increased in a relatively short time. The honey bee is adapted to many climates and can successfully revert to its original wild condition in most parts of the world, quickly becoming part of the natural reservoir of pollinators.

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[1] In cooperation with Arizona Agricultural Experiment Station.

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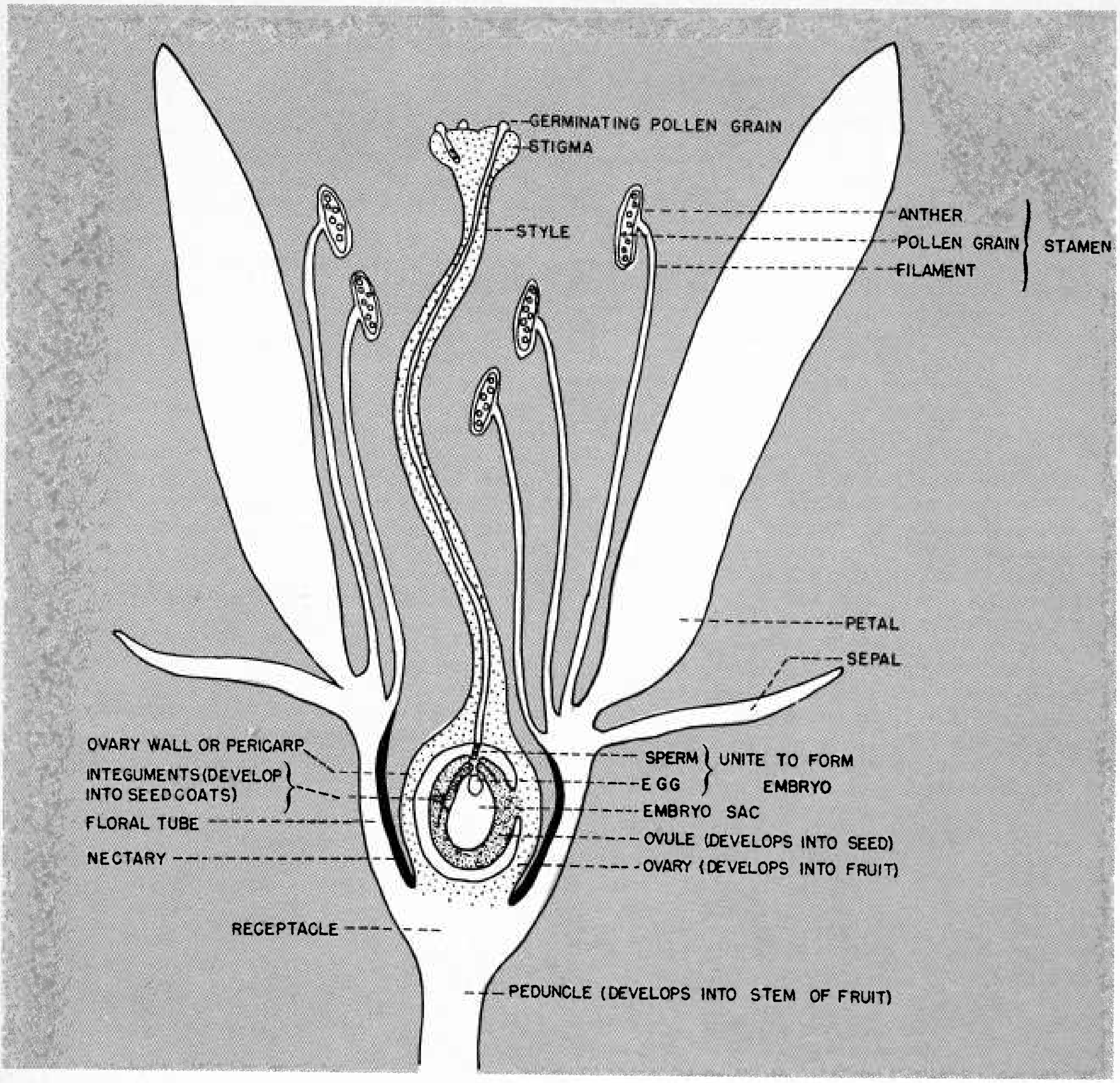

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FIGURE 1.—Longitudinal section of a typical flower.

As a species the honey bee has an extremely wide host range. It visits a larger variety of flowers than any other insect. However, an individual bee on a single foraging trip usually confines itself to one species of plant, avoiding nonproductive interspecific visits.

Its size and hairiness enable it to accumulate on its body pollen grains that later come in contact with the floral stigma during subsequent bee visits. Its natural instinct to store enough pollen and nectar to carry the colony through the winter and other dearth periods stimulates it to visit flowers long after its current needs are met.

Honey bees are most active between 60° and 105° F. At temperatures exceeding 90° many foragers shift to collecting water to cool the hive.

Strong winds slow down flight activity and stop it completely if they exceed 25 miles per hour. Hot winds reduce nectar secretion and indirectly reduce flight. Cloudy days usually reduce flight and cause bees distantly located from a pollen source to be more easily deterred from foraging than bees located nearby.

The population of the colony affects its response to unfavorable climate. A strong colony is less sensitive to unfavorable climatic conditions than a weak colony and sends out many more foragers at marginal temperatures. Also genetic differences between bees affect their foraging.

Therefore, the crop to be pollinated should be in good physiological condition to produce the maximum amount of pollen and concentration of nectar to attract bees and compete with other crops or flowering weeds within the foraging area. Some crops compete well as sources of nectar (whiteclover, alfalfa, cucurbits), others as pollen sources (safflower, red clover), and still others attract both nectar and pollen collectors (sweetclover, cruciferous crops).

In many instances the plants competing for bee visitation are weeds rather than agricultural plants. Most weeds can be eliminated from an area by chemical or cultural treatments, although this may not be practical or even desirable, because weeds often serve as a needed food source for the bees. When other agricultural crops are involved, the grower can sometimes reduce competition by timing the bloom period of the target crop so the pollination period will miss that of the competing crop. If this is impractical, he may need enough bees to saturate both the competing crop and the crop to be pollinated. This last is the method most often attempted for overcoming plant competition.

Pollinator Competition

Occasionally where wild pollinators are abundant, competition may develop between them and honey bees. Beekeepers in such situations complain that the wild bees pollinate the flowers before the honey bees can collect a crop of honey. On the other hand, growers sometimes object to the presence of honey bees in areas where wild bees are effective pollinators. Neither complaint has been verified experimentally.

Forager Distribution

The first orchard pollination recommendation stated that bees within 2 to 3 miles would supply adequate pollination. We now know that bees pollinate most effectively within 200 yards of their hives. Therefore, to achieve the most efficient distribution of foragers, the colonies should be distributed at intervals of 175 to 200 yards. Also beginning foragers work close to the hive, then disperse more widely with age and orientation. Therefore, it is essential that a pollinating colony should have plenty of these beginning foragers.

Individual foragers tend to limit their work area on any one trip to a few square yards. They will return to this area repeatedly if it has adequate points of orientation. On large poorly landmarked fields of uniform bloom, they seem unable to find their way back repeatedly to the same spot. The effect this has on the foraging efficiency of the bee or the pollination of the crop is unknown. It could favor cross-pollination.

Directing Bees to Target Crops

Because bees do not always visit flowers of a particular crop where pollination is desired, many attempts have been made to direct bees to a crop. Feeding the bees sugar sirup flavored or scented with extracts of flowers from the field where visitation is desired does not increase pollination in the field. Spraying the field with a sugar solution is also valueless. Some tree fruit pollination has been achieved with pollen dispersal by bees from hive-entrance inserts. However, bees will not continue to visit a crop that does not yield nectar or pollen, and no technique has ever resulted in sustained visitation.

Progress is being made in breeding plants more attractive to bees and in breeding bees that show preference for a particular crop. Recent research has demonstrated conclusively that the preferences shown by bees for certain crops or even varieties can be intensified by selective breeding. The "tailormade bee" is not too far off.

Pollination of Agricultural Crops

The following list includes seed and fruit crops grown in the United States that require insect pollination or that show definite increases in yield or quality as a result of the pollinating activity of bees. Not included are ornamentals, medicinal plants, and most spices, many of which are also insect pollinated.

- Leguminosae:
  - Alfalfa
  - Clovers:
    - Sweetclovers:
      - Annual white
      - Annual yellow
      - Hubam
      - Sour
    - True clovers:
      - Alsike
      - Arrowleaf
      - Ball
      - Berseem
      - Crimson
      - Persian
      - Red
      - Strawberry [1]
      - White, Ladino
  - Guar
  - Horsebean (broadbean) [1]

- Leguminosae—Continued
  - Lespedeza (bush)
  - Lima bean [1]
  - Trefoil
  - Vetch (hairy)

- Liliaceae (Allium):
  - Garlic
  - Leek
  - Onion

- Malvaceae:
  - Cotton [1]
  - Kenaf
  - Okra [1]

- Cruciferae:
  - Broccoli
  - Brussels sprouts
  - Cabbage
  - Cauliflower
  - Chinese cabbage
  - Collard
  - Kale

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[1] Pollination beneficial.

Cruciferae—Continued
- Kohlrabi
- Mustard
- Radish
- Rape
- Rutabaga
- Turnip

Cucurbitaceae:
- Cantaloup (muskmelon)
- Citron
- Cucumber
- Honeydew melon
- Persian melon
- Pumpkin
- Squash
- Watermelon

Umbelliferae:
- Carrot
- Celeriac
- Celery
- Parsley
- Parsnip

Miscellaneous:
- Asparagus
- Buckwheat
- Flax [1]
- Lotus
- Safflower [1]
- Sunflower

Fruits and nuts:
- Almond
- Apple
- Apricot
- Avocado
- Blackberry
- Blueberry
- Cherry
- Chestnut
- Coffee [1]
- Cranberry
- Dewberry
- Gooseberry
- Grape
- Huckleberry
- Macadamia nut
- Mandarin
- Mango
- Nectarine
- Orange [1]
- Passion fruit
- Peach
- Pear
- Persimmon, native
- Plum
- Prune
- Raspberry
- Strawberry
- Tangelo
- Tangerine
- Tung

[1] Pollination beneficial.

The 1963 farm value of the crops included in this list that required bee pollination amounted to approximatily $1 billion. The farm value of the additional crops benefited by bee pollination was approximately $6 billion.

When hybrid seed and fruit-production methods are developed for other crops, the list will doubtless increase.

Pollination Practices

History

The pollination of plants by bees was first described by Sprengel in 1793. However, fruit pollination requirements were not intensively studied until M. B. Waite's publication on Pollination of Pear Flowers in 1895. Most of the research on pollination in the early 1900's was conducted by horticulturists, who became aware of the need for pollen vectors and cross-pollination to obtain commercial crops of fruit in the many varieties being developed. They recognized that interplanting of compatible varieties should be based on knowledge of bee foraging behavior. Renting of colonies for apple pollination started about 1910. This practice grew rapidly in the next 20 years. Now thousands of colonies are used each year in Washington, New York, and other apple-producing States.

The need by horticulturists for this information encouraged apiculturists to study bee foraging in orchards during the early decades of the century. Their research provided a good background for the expanded pollination research that was stimulated during World War II by the need for increased legume seed production. Since 1940, research and agronomic practices have largely centered around the use of honey bees as pollinators of legume seeds.

After scientists in the U.S. Department of Agriculture proved that high populations of honey bees combined with insect control could greatly increase alfalfa seed production, the practice of renting bees for alfalfa seed production rapidly expanded. The recognition of grower benefits from renting bees carried over to other crops, and today paying for pollination by honey bees is a common practice in many parts of the United States.

Growers of tree fruits, legume and vegetable seeds, all kinds of cucurbits, oilseeds, and many other crops rent bee colonies to distribute pollen on the large scale required by modern agriculture. Bees are usually rented only where pollination problems are extreme; far more incidental pollination is supplied free by colonies managed by beekeepers for honey production.

Specific Crops

Legumes

Most legumes are attractive to bees and adapted to benefit from their visits. Many of the clovers produce seed abundantly when bee pollinated.

Alfalfa.—Alfalfa is one of the legumes that presents several unusual pollinating problems. Before pollination can take place, the sexual column, containing the stamens and pistil, must be released from the keel petals confining it. This irreversible "tripping" occurs when a bee inserts its tongue into the throat of the flower. When the sexual column is released, it strikes the underside of the bee's head and deposits pollen. At the same time it contacts pollen left on the bee from a prior flower visit. Since most lines of alfalfa are relatively self-incompatible, the pollen must come from a genetically different plant to cause cross-pollination and seed production.

Many efforts have been made to contrive mechanical devices to trip alfalfa flowers. None have been successful, mainly because mechanical tripping without pollen distribution results in self-pollination and low seed set. Furthermore, self-pollinated seeds produce less vigorous plants.

Honey bees visit alfalfa flowers readily, but many of them learn to collect nectar from the side of the flower and avoid the tripping mechanism. Accidental tripping by high populations of "nectar collectors" can account for large seed yields. Also a certain percentage of the bees always will collect pollen from alfalfa. At certain times and under certain conditions these "pollen collectors" make up a high percentage of the total population. This is most likely to occur in the hotter, drier regions of the Southwest—probably from lack of competition by other pollen-producing plants.

About 38 million flowers must be tripped and cross-pollinated to set a 500-pound-per-acre seed crop. In California and Arizona, two to three colonies per acre are used. They supply a field population of two to three bees per square yard, 5 to 20 percent of which are pollen collectors. In northern Utah, where pollen collectors rarely exceed 1 to 3 percent, eight to 10 bees per square yard are required. Farther north and into Canada, high yields of seed from honey bee pollination are rare. In the Midwest, alfalfa pollination is largely left to chance. Seed production per acre in this area is low.

Red Clover.—Red clover competes well with other crops as a pollen source, and pollen-collecting honey bees visit the flowers freely. Because of the corolla tube length, nectar collectors have difficulty reaching the nectar unless it is especially abundant. Usually two or more colonies per acre are adequate.

Other Legumes.—Alsike, white, and crimson clovers, sweetclover, and trefoils require bees for pollination, but are visited freely. Colonies store surplus honey crops from them even at a high population density. In contrast, Ladino clover requires two or more colonies per acre to supply the two bees per square yard required for good pollination. But because it is a poor nectar yielder, colonies at this density will have difficulty maintaining themselves.

Hairy vetch is rather attractive to bees. Small fields surrounded by uncultivated land are usually well pollinated, but honey bee colonies must be imported for large acreages.

Nuts and fruits

Almonds require large numbers of bee visitors for adequate pollination. The almond grower wants the heaviest set possible, because a heavy set means nuts with smaller kernels, which are in greatest demand. In California, where most of the almonds in the United States are produced, the pollinating season frequently starts in February. Cool cloudy weather at that time often inhibits bee flight to only an hour or two each day. Strong, vigorous colonies capable of supplying sufficient foragers are sometimes difficult to obtain. This emphasizes the need for at least two populous colonies per acre, which many beekeepers cannot easily supply so early in the season. Also the colonies should be distributed in the groves, which is difficult after heavy or continued rains. Therefore, supplying bees for almond pollination presents a bee-management problem. In addition, many compatibility problems occur among the many varieties grown, and almond groves must be carefully planned with this in mind.

Except for macadamia nuts in Hawaii, most other nuts are self-fertile or wind pollinated.

Deciduous Tree Fruits.—In tree fruits the degree of self-fertility varies tremendously, even within species. In apples and pears, differences in self-fertility occur between years or locations even within the same variety.

Most fruit trees are propagated by grafts, and an orchard of one variety therefore is genetically one plant. No matter how efficiently bees carry pollen between trees of the same self-sterile variety, a commercial crop cannot be set. In addition, not all varieties are compatible with each other. Therefore, orchards must be carefully planned to provide adequate distribution of good pollenizer varieties, which must (1) bloom in synchrony, (2) produce pollen abundantly, (3) be equally attractive to bees, (4) bloom heavily each year, and (5) produce fruit commercially useful or easily distinguishable.

Much of the recent research has shown the limited foraging areas of bees on fruit trees. This behavior pattern must be considered when placing pollenizer trees for the best cross-pollination. An optimum pollenizer arrangement is to have every main variety tree adjacent to a pollenizer tree. Planting pollenizers in every third space in every third row will achieve this. Since such a scattering of individual trees would interfere with efficient orchard management, growers prefer to plant all of every third row to the pollenizer variety or alternate two rows of each variety as a satisfactory compromise to provide good cross-pollination.

All varieties of sweet cherries, Japanese plums, and avocados require cross-pollination. Most varieties of apples, pears, and European plums and prunes also require cross-pollination, as do some varieties of grapes, citrus, apricots, and peaches. Some kinds, for example peaches, may not require cross-pollination, but they still need bees to transfer their pollen to the stigma.

In most cases, one colony per acre and the colonies placed in groups of 15 to 20 in the center of each 15- to 20-acre block will provide adequate bee visitation. About 300 to 350 yards or one-fifth mile between groups will give this spacing, which is a compromise between the orchardist's ideal of individual colonies well scattered through the orchard and the beekeeper's ideal of all the colonies in one location.

With pears, which compete poorly for the services of bees because of low nectar-sugar concentration, at least two colonies per acre are necessary. Pears are unusual in one other respect. One of the most popular varieties, the Bartlett, is considered self-unfruitful in the Eastern United States and in most other areas where it is grown. In spite of the usual recommendations that pollenizers be interplanted with Bartlett trees, most of the orchards in California are in solid plantings, and yet commercially profitable yields are produced. Horticulturists have found that most of the fruit obtained under these conditions is due to vegetative parthenocarpy (seedless fruit development without the immediate stimulation of pollination). Cross-pollination usually gives higher yields of seeded fruit.

Distribution of colonies for the pollination of all these tree crops should be synchronized with cultural and pest-control programs. This can be difficult because of the unfavorable weather that often prevents placement or removal of colonies at the appropriate time.

Berry Fruits.—Horticulturists have long known of the differences in self-fertility between varieties of cane fruits and other berry fruits. In the older literature they frequently mentioned the necessity for pollenizer varieties. Rarely, however, was the need for insect pollinators recognized. Perhaps this was a reflection of the abundance of natural pollinators in the small acreages at the turn of the century. With specialized agriculture, increased acreages, and associated side effects came the recognition that many of the berry fruits were dependent on insect pollinators.

Most cranberry and blueberry growers now use honey bees for pollination. Many varieties of blackberries, raspberries, and strawberries benefit from bee pollination, but these crops are frequently grown in areas where resident populations of bees are available to pollinate relatively small acreages. Where larger acreages are grown, bees should be provided for maximum production of high quality berries.

Many of the common grape varieties grown in this country are self-fertile and do not benefit from bee visitation. However, some varieties require bees and some yield better as a result of bee visitation.

Citrus.—The nectar of most citrus flowers is extremely attractive to bees, and a citrus tree in flower without bee visitors is rare. Because of the large numbers of flowers on the tree, the number of bee visits per flower during the period of pollen receptivity may be small.

Most varieties of citrus have been considered to be parthenocarpic or self-fruitful without the aid of bees. But the role of bees in citrus pollination has not been sufficiently studied to eliminate their consideration completely. In the Algerian (Clementine) tangerine and the tangelo (a cross between grapefruits and tangerines), pollenizer varieties and honey bees to carry the pollen are as important as in any other self-sterile fruit variety. The association of pollination with seed production and of seeds with size of the popular Valencia orange and several other citrus varieties indicates that bees are highly beneficial to them.

Oilseed crops

Cotton.—The principal varieties of cotton grown in this country are largely self-fertile. But the structure of the flower is well adapted to cross-pollination, and bees can increase production of some varieties as much as 25 percent. Most varieties are benefited to some extent by bees. This benefit can be in higher yields, earlier set, or better grades. For many years plant breeders have been interested in the possibilities of increasing production by utilizing hybrid vigor in cotton. When hybrid cotton production is developed on a large scale, only honey bees will be able to supply the visitation required.

The long blooming season of cotton, the reluctance of honey bees to collect and utilize cotton pollen, and the frequent lack of pollen sources in many of the areas where cotton is grown combine to create problems in maintaining colony populations at a level suitable for continued pollination. This is a situation where a suitable pollen substitute, the development of a cotton pollen-collecting strain of bees, and techniques for maintaining brood rearing are necessary.

Recent work indicates that bees can further benefit cotton by removing the extrafloral nectar on which harmful insects must feed to lay their normal number of viable eggs.

Safflower.—This close relative of the common thistle is attractive to bees and a good source of nectar and pollen, although safflower honey is a low quality table honey. Recently the acreage of this crop has been increased sharply.

The value of bees to safflower depends on the degree of self-fertility of the particular variety. Honey bee activity in safflower is being studied in anticipation of the need for bees as cross-pollinators of hybrid safflower. Only a few thousand colonies are rented for safflower pollination.

Flax.—The blossoms of flax are not strongly attractive to bees, and pollination by bees is generally not considered by growers. Actually bee pollination will increase seed production, and growers should encourage bee visitation to their flax crop.

Sesame.—There is little information on pollination of sesame. It is highly attractive to bees and benefited by bee visitation.

Soybeans.—Many varieties of soybeans are grown under various conditions throughout the United States. In some places bees work soybeans heavily, and particularly in Arkansas good crops of soybean honey are reported. Evidence is building up that bees are of value at least to some varieties under some conditions. More work on the pollination of this highly important crop should be done.

Sunflower.—Insect pollination is essential for seed production of sunflower. The acreage of this crop seems to be on the increase, and cultural programs that do not include insect pollination may result in a crop failure.

Plant breeders need to be aware of the possible increases in yield that bee activity can stimulate in those varieties in which self-fertility is low.

The value of bees when varietal selections are made in small plots well visited by bees is easily overlooked. Yields may dwindle when these varieties are grown in large acreages with inadequate pollination.

In many cases the relationship of honey bee foraging to production of many kinds of oilseeds still remains an unexplored, potentially fruitful field of investigation.

Vegetable seed crops

Carrots are attractive to a wide variety of insects including honey bees. However, only honey bees can be provided in sufficient numbers consistently, and carrot seed producers are usually conscientious about supplying colonies. Nectar and pollen collectors are equally effective pollinators. Good pollination in carrots not only insures optimum yield but affects seed size and germination. Inadequately pollinated flowers produce fewer and objectionably oversized seeds with lower rates of germination.

Onions and closely related crops are self-fertile, but require visitation by bees or other insects for either cross- or self-pollination. Many of the insects attracted to onions are small and not hairy enough to satisfactorily transfer pollen. Nectar-collecting honey bees are less effective pollinators than those collecting pollen because of their stance while working the florets. When locating onion seed fields, all attractive sources of pollen like sweetclover or safflower should be avoided. Production of hybrid onion seed has expanded greatly since 1940, and honey bees are regularly supplied for pollination.

Most tomato varieties are attractive to pollinators. Honey bees work the newer varieties and probably contribute to their pollination. Bee activity has proved beneficial to tomatoes grown in greenhouses. The development of hybrid tomatoes will require bee pollination.

Other vegetable seed crops that require visits by bees include most of the cruciferous plants such as cabbage, cauliflower, and radish, many legumes such as beans, and such other crops as peppers, asparagus, and celery. Where acreages of these crops are relatively small, wild pollinators or resident populations of honey bees may be adequate. However, many growers of these crops are insuring themselves against insufficient levels of pollinators by renting colonies of honey bees, especially where acreages are large or crops are competitive.

Cucurbits

Cantaloups produce hermaphrodite (female) and imperfect (male) flowers. Both produce nectar. Female flowers have both ovaries and pollen-bearing anthers. Male flowers bear anthers only. At least one pollen grain must reach the stigma for each seed produced. Honey bees are the main pollinators. If pollination is not adequate, no marketable fruit is harvested.

High bee populations are associated with more seeds per fruit and earlier, sweeter, larger, and more fruit (fig. 2). Dependable production of top quality fruit should not be left to chance.

Commercial recommendations call for one colony per acre. This should provide the equivalent of one bee for each 10 perfect flowers, or at least 12 bee visits per flower during the forenoon. If not, more colonies may be needed. In cooler areas bee visits are probably of value over a longer period; therefore, the number of colonies necessary will vary with the location of the field.

Some honey bees range far afield from their colony. Melon fields without a few bees present are rare. Visits by such bees can result in a high percentage of fruit set from the fewer flowers they visit. This may explain why some growers obtain moderate yields without purposely placing honey bee colonies in their fields. Such inadequate *chance* visitation usually results in a reduced yield, a later crop, and a high percentage of culls.

Watermelons and cucumbers have pollination requirements similar to cantaloup, and successful growers usually see that colonies are near the crop. The optimum pollinator populations or colonies per acre needed are undetermined.

Where watermelons are grown on large acreages, honey bee colonies are usually provided at the rate of one colony per acre. Recent work in Florida showed that this should supply the minimum of eight visits per flower necessary to set a commercial crop.

Doubtless many more colonies per acre are needed for cucumbers than watermelons. Many acres of cucumbers are grown in greenhouses in the Eastern States, and providing bees for them has become an important beekeeping specialty, with problems peculiar to keeping bees in confinement.

Squash and pumpkins, too, require bee transfer of pollen, but since these are native to America, several species of native bees as well as honey bees visit them. However, wild bees are usually inadequate where acreages are large, and again we must rely on the honey bee.

Many of the examples mentioned point up the deficiencies of pollination information on our crops. In many cases the importance of bees is recognized, but detailed information on the quantitative and biological aspects is either localized or completely lacking.

Practical Aspects of Current Practices

During the last few decades, honey bees in the United States have increasingly been used as an additional "tool" in the production of fruit and seed crops. As is necessary with all complicated tools, skills must be developed in their

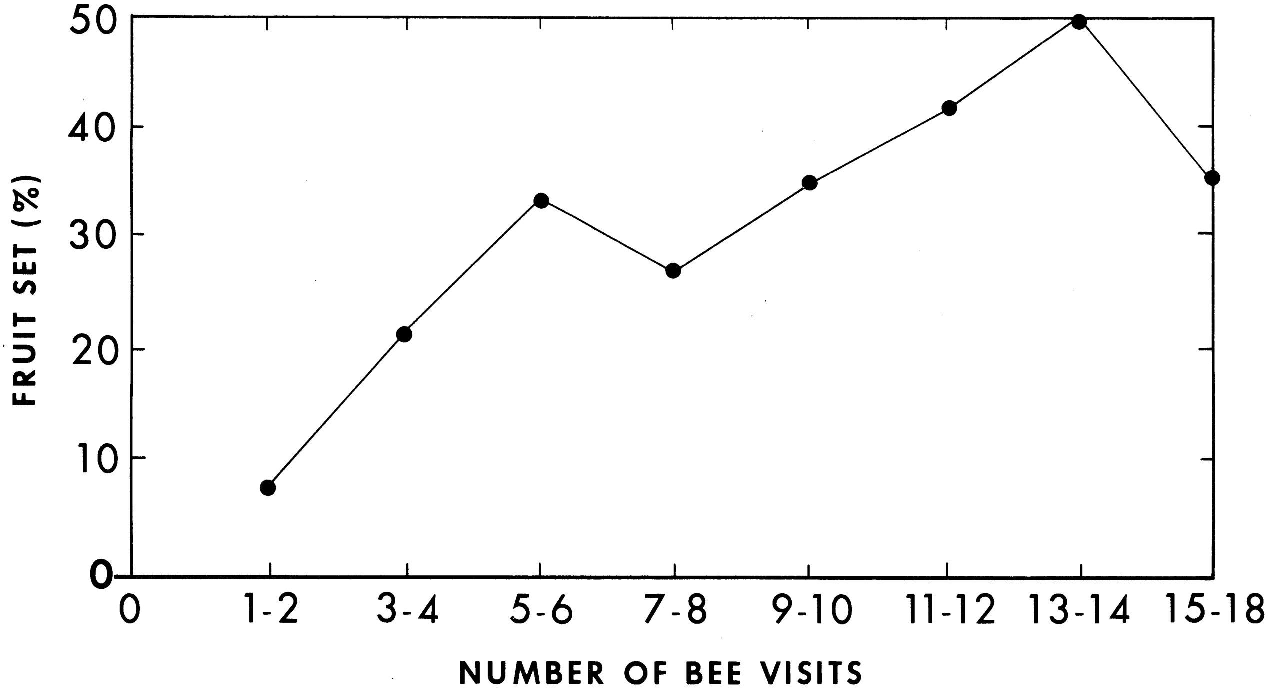

FIGURE 2.—Effect of bee visits on cantaloup fruit set, Yuma, Ariz., 1963.

use. We must learn what bees can do, their limitations, and the factors that affect their use. As a biological organism, the honey bee is much more susceptible to factors beyond our control than are most tools, and only recently have we even developed techniques for studying some of these factors.

Colony Standards

Information on the number of colonies per acre needed for many crops is lacking. Furthermore, apiculturists are aware that the colony is not a standard unit. Greater percentages of the colony population fly from "strong" colonies than from weak colonies and under more adverse conditions. Flight activity and pollen collection are correlated with the amount of brood rearing. Therefore, evaluations of colony strength or quality are based on population and brood.

Some beekeepers supply a one-story colony containing bees and brood on only five to seven frames. However, pollination colonies need to be populous and vigorous at the beginning of the flowering season and should occupy two or more standard Langstroth hive bodies and have 600 to 800 square inches of brood in all stages.

Timing

The best time to place the colonies in the field or orchard is not the same for all crops. For some crops, the colonies should be taken to the crop as soon as flowering starts so that the bees can pollinate the earlier flowers. However, for others, increased numbers of colonies should be moved into the field as flowering progresses.

Moving

The logistics of moving large numbers of colonies quickly and frequently for pollination service stimulated the invention of loading equipment and other new techniques. Colonies now are merely smoked, picked up by hand or hoist, and stacked with open entrances on large flat-bed trucks. They are roped down, usually covered with a wet burlap tarpaulin or plastic screen, and moved to their new location.

Water, Shade, and Windbreaks

Every effort should be made to provide a dependable water source as close as possible to the bees. Time spent carrying water or cooling hives is time lost to pollination. Air temperatures exceeding 90° to 100° F. greatly increase the need for water and can upset the normal work in the hive. Shade greatly reduces the heating effects of the sun. Water needs are reduced under shade, although not eliminated, and the bees can be more productive. Wherever possible, colonies should be placed under at least partial shade even in areas where high temperatures are not often a problem.

Colonies pollinating very early crops are vulnerable to chilling winds, which cut down flight activity. Windbreaks effectively reduce these detrimental effects. They also cut down on drifting of bees between colonies, which is frequently troublesome in windswept locations.

Costs, Contracts, and Middlemen

When beekeepers undertake pollination work, they encounter new business problems. When a grower pays for the use of bees, both he and the beekeeper assume responsibilities. Difficulties arise when responsibilities are not clearly stated in a written and binding contract. Paying for bees is a new concept to many growers, and sometimes they hesitate to accept the associated responsibilities.

Since some contracts include the possibility of a partial honey crop as part of the fee, the beekeeper manipulates the colonies for maximum honey production, which should be of secondary concern. Ideally, the pollination fee should allow the beekeeper to concentrate on pollination efficiency and ignore honey production. This should ultimately be most profitable to both grower and beekeeper.

In 1967, pollination fees range from $1 per colony, which scarcely pays for the cost of moving, to $15, which should compensate for a potential honey crop. Probably more colonies are rented for $4 to $5, and this is rarely enough to permit a beekeeper to ignore honey production.

Most successful pollination services are contracted through a third party. Business-oriented beekeepers, seed companies, commodity cooperatives, or enterprising individuals not connected in any other way with crops or bees are more likely to be successful "third-party contractors."

A pollination service, as such, can "sell" growers on the benefits of efficiently utilized bees, contract with beekeepers, coordinate the logistics of moving colonies, conduct an impartial inspection service, and in other ways protect the interests of both parties. In many ways the real future of pollination lies in the development of efficient "third-party contractors" to run pollination-service businesses.

A strong, prosperous, beekeeping industry is needed to supply the pollinators demanded by modern agriculture. Until beekeepers receive full value for the pollination services of their bees, they must rely on income from honey and wax production, and their problems in doing this are of importance to all agriculture.

The increasing use of honey bees as a tool in agricultural crop production has greatly augmented the value of the beekeeping industry to the economy of our country, and the dependence of agriculture on honey bees will continue to increase.

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BROOD DISEASES OF HONEY BEES

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Bee diseases result in losses amounting to millions of dollars annually. In 1963, various States spent an estimated $1 million in apiary inspection for American foulbrood. In the same year the value of colonies destroyed under State laws to control American foulbrood exceeded $470,000. European foulbrood, sacbrood, nosema disease, septicemia, paralysis, and other diseases and enemies are estimated to cause losses in excess of 10 times that of American foulbrood. In addition to these figures, bee diseases cause considerable losses, which are difficult to estimate, through reduced honey and beeswax production and crop pollination. It is apparent, therefore, that both beginning and advanced beekeepers should learn to recognize and control bee diseases.

A guide for diagnosing brood diseases of honey bees is given in table 1.

American Foulbrood

American foulbrood disease occurs throughout the world where honey bees are kept. About 5 percent of all colonies inspected in the United States are found to be infected.

Bacillus larvae White, the causative organism of American foulbrood, is a spore-forming bacterium. Workers, drones, and queens are equally susceptible to American foulbrood. Only spores are capable of inciting the disease. The spores are extremely resistant to heat and chemical agents.

A severely infected American foulbrood comb has a mottled appearance due to a mixture of healthy capped brood and diseased or empty cells formerly occupied by diseased brood. The cappings of diseased cells appear moist and darkened. The convex cappings found on cells of diseased larvae become concave as the disease progresses. Another symptom commonly associated with the disease is the punctured capping. Larvae are susceptible to American foulbrood only when they are less than 3 days of age. A healthy larva has a glistening, pearly white appearance. Normally it begins development curled on the base of the cell. As it grows, it elongates to the full length of the cell. It is in the elongated position that the larva or pupa dies. As the infection progresses, the larva or pupa changes to creamy brown and eventually becomes dark brown. The remains become ropy and can be drawn out as threads of an inch or more. Also a very characteristic odor develops at this stage described by some as "typical gluepot odor."

The remains of diseased brood finally dry out to form scales, which adhere strongly to the sides of

TABLE 1.—*Differentiating characters of brood diseases*

Characters to observe	American foulbrood	European foulbrood	Sacbrood
Appearance of brood comb.	Sealed brood; discolored, sunken, or punctured cappings.	Unsealed brood; some sealed brood in advanced cases, with discolored, sunken, or punctured cappings.	Sealed brood; scattered cells with punctured cappings, often with 2 holes.
Age of dead brood____	Usually older sealed larvae or young pupae; occasionally younger unsealed larvae.	Usually young unsealed larvae; occasionally older sealed larvae.	Usually older sealed larvae; occasionally young unsealed larvae or young pupae.
Color of dead brood___	Dull white, becoming, yellow, light brown, coffee brown to dark brown or almost black.	Dull white, becoming yellowish white to brown, dark brown, or almost black; often unevenly colored.	Grayish or straw colored, becoming brown, grayish black, or black; head end darker.
Consistency of dead brood.	Soft, nonsticky, becoming sticky to ropy.	Watery to pasty; rarely sticky or ropy.	Watery and granular; tough skin forms sac.
Odor of dead brood____	Slight to pronounced typical odor.	Slight to penetratingly sour.	None to slightly sour.
Scale characteristics___	Brittle; rough texture; lies flat on lower side of cell; adheres tightly to cell wall; head lying flat; fine, threadlike tongue of dead pupae adheres to opposite wall of cell.	Rubbery; smooth texture; usually twisted in cell; does not adhere tightly to cell wall.	Brittle; rough texture; lies flat on lower side of cell; does not adhere tightly to cell wall; head prominently curled up.

the cells. If death occurs in the pupal stage, the mouth parts may adhere as a fine thread to the opposite side of the cell. This is a positive symptom of American foulbrood disease (figs. 1 and 2).

The infection can be transmitted to a larva from nurse bees or from spores remaining in the bottom of the brood cell. Early detection of the disease is helpful in preventing further spread. A colony that is weakened by American foulbrood may be robbed, and the robber bees inadvertently carry honey containing spores of *B. larvae* to healthy colonies.

European Foulbrood

In some areas European foulbrood poses a more serious threat to beekeepers than American foulbrood. This disease is serious because it occurs most frequently at the time that colonies are building their peak populations.

The cause of this disease is *Streptococcus pluton* (White), a nonspore-forming bacterium. Other bacteria commonly associated with the disease are *Bacillus alvei* Cheshire & Cheyne and *Bacterium eurydice* White.

Superficial examination of diseased combs shows the same mottled effect and puncturing as seen in American foulbrood. In most cases death usually occurs in the larva stage. Workers, drones, and queens are equally susceptible to European foulbrood.

Larvae that die from European foulbrood are found in a variety of positions. Some are in a curled stage and others elongated. The normal pearly white appearance of a healthy larva changes to a dull white, then yellow, and finally brown. Ropiness and sour odor are caused by secondary invaders. The elasticity of the ropy material is less than that associated with American foulbrood. The tracheae appear as fine silvery tubes immediately below the skin, especially as the larvae turn brown. This symptom is highly characteristic of European foulbrood. Loosely adhering scales also differentiate this disease from American foulbrood (fig. 3).

European foulbrood can be transmitted by contaminated food, stores, and equipment. The disease is usually most serious in the spring and clears up during the summer when nectar and pollen are abundant. However, outbreaks of European foulbrood in the late summer are not unusual.

Sacbrood

Death of a colony by sacbrood is rare. However, because of the similarity to other diseases, the beekeeper should learn to distinguish sacbrood from the more serious diseases. The etiologic agent in sacbrood is a virus.

Larvae die of sacbrood in capped cells in the elongated position. As the disease progresses the larval skin forms a sac, which separates itself from the pupal skin. Between these two layers of skin is an accumulation of fluid. The outer skin toughens and as a result the larva can be picked up in its entirety without the release of the fluid.

The larva changes from pearly white to off-white, then brown, and finally almost black. The head end is usually the darkest. It usually curls up from the cell floor. A loosely adhering scale is formed from the larval remains. No odor is attributable to the sacbrood virus although heavily infected combs may have a yeastlike odor (fig. 4).

Like European foulbrood, sacbrood is most commonly found in the spring. No chemotherapeutic agent is effective against sacbrood. Fortunately colonies appear to recover spontaneously from the disease.

Other Brood Diseases

Chalk brood and stonebrood are both caused by fungi. Chalk brood is caused by *Ascosphaera apis* Olive & Spiltoir. This disease is characterized by the chalky white appearance of the larvae after death. To date there has been no report of this disease in the United States.

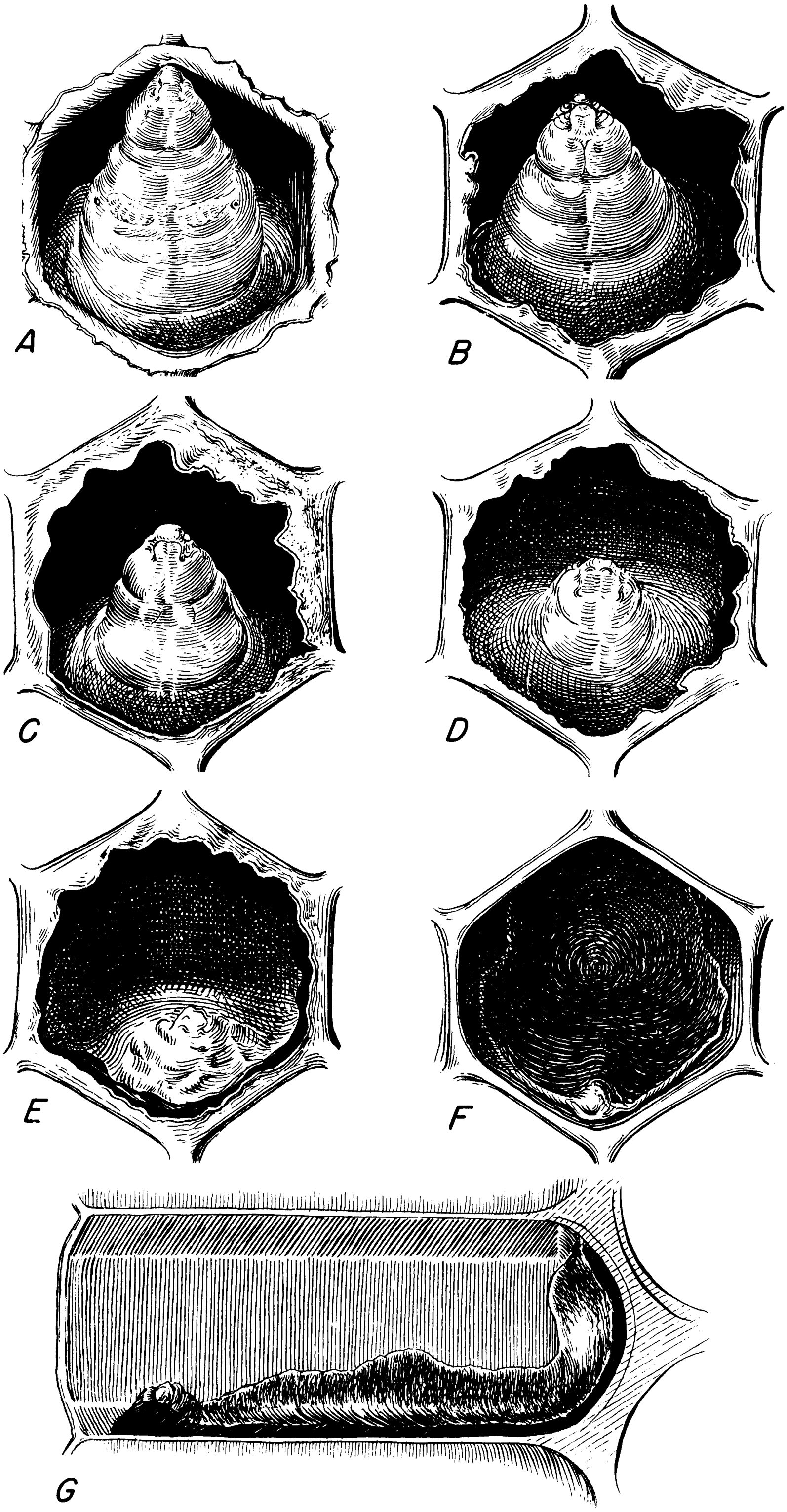
Aspergillus flavus Link is usually isolated from bees that have stonebrood. This disease is unusual in that it infects both brood and adults. Bees dying from this disease form mummies. The fruiting bodies of the fungus make the infected bee appear yellowish green or brown.

Purple brood is a nutritional disease of larvae and pupae. It is believed to be caused by nectar or pollen from *Cyrilla racemifloral* L., also called southern leatherwood, black titi, red titi, summer titi, and he-huckleberry. This problem exists only in the Southern States where southern leatherwood is found. Diseased larvae and pupae are purple.

Other conditions that mimic contagious diseases are chilled and starved brood. Chilled brood is usually attributed to insufficient bees to keep the brood area warm. The same cause can also result in starved brood. However, starved brood is generally caused by insufficient nectar. At times wax moth damage may cause brood to appear diseased.

Disease Prevention and Control

A beekeeper can spread bee diseases by transferring combs from colony to colony to equalize stores or numbers of bees. This practice can lead to serious consequences if disease is present. Records kept on the source of combs are helpful so that a beekeeper can trace a possible source of infection. Honey from colonies with American foulbrood should never be fed to healthy colonies.



DN-2219

FIGURE 1.—Honey bee larvae killed by American foulbrood, as seen in cells: *A*, Healthy larva at age when most of brood dies of American foulbrood; *B–F*, dead larvae in progressive stages of decomposition (remains shown in *F* is scale); *G*, longitudinal view of scale.

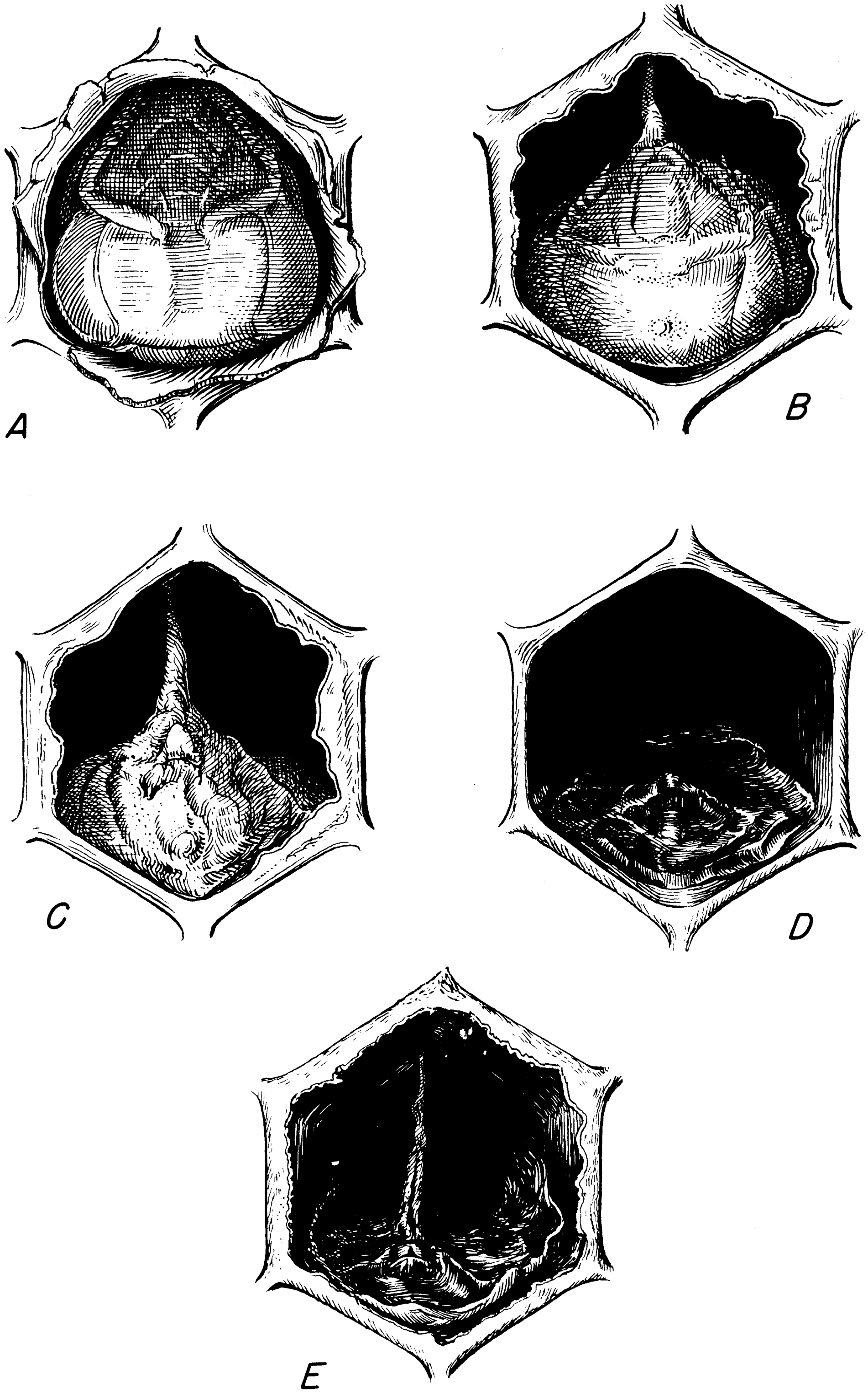


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FIGURE 2.—Honey bee pupae killed by American foulbrood, as seen in cells: *A–C,* Heads of pupae in progressive stages of melting down and decay; *D–E,* scales formed from drying of dead pupae. In *B, C,* and *E* tongue is shown adhering to roof of cell.

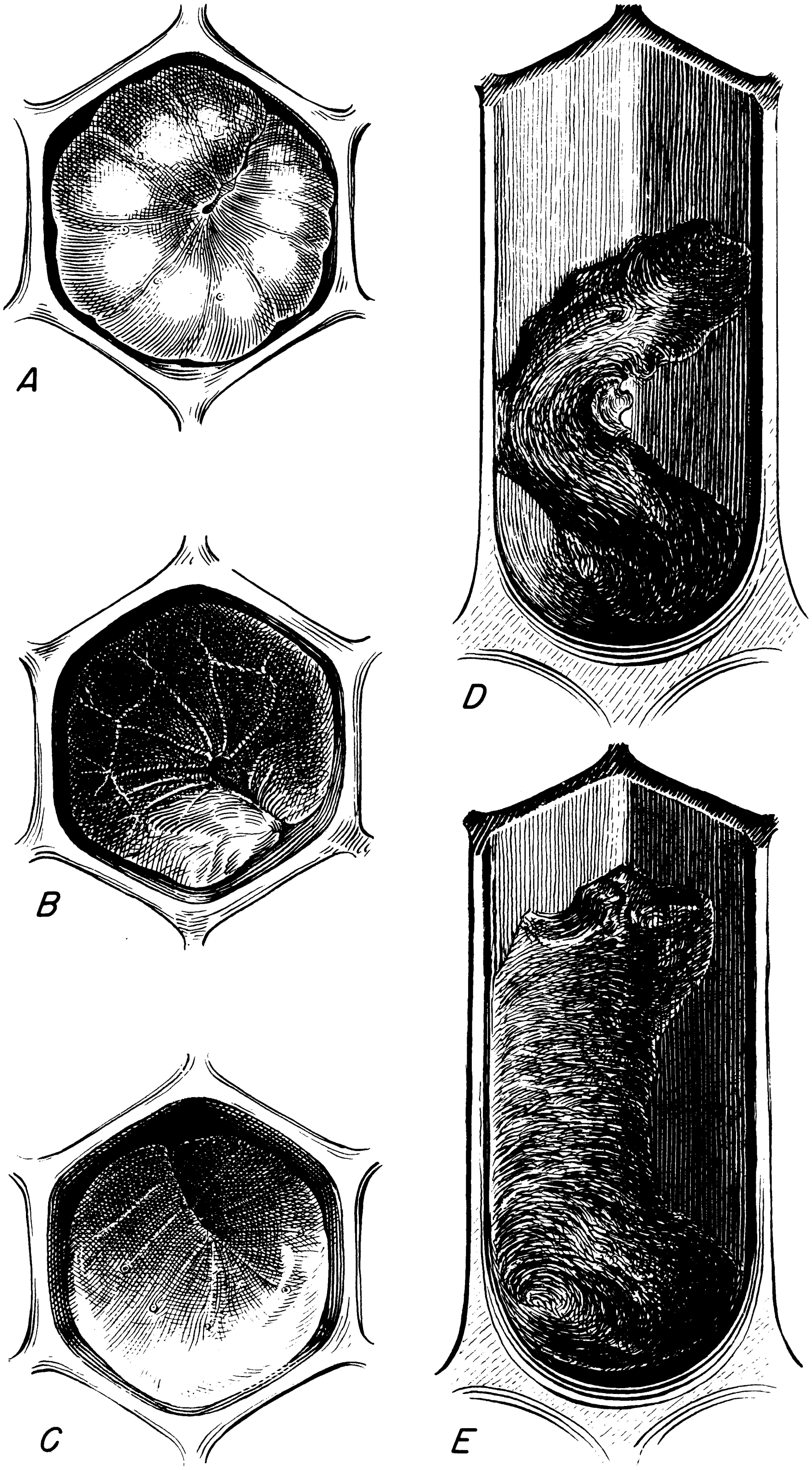

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FIGURE 3.—Honey bee larvae killed by European foulbrood, as seen in cells: *A*, Healthy larva at earliest age when brood dies of European foulbrood; *B*, scale formed by dried-down larva; *C*, one of several positions of sick larvae prior to death; *D–E*, longitudinal views of scales from larvae that were in lengthwise position prior to death.

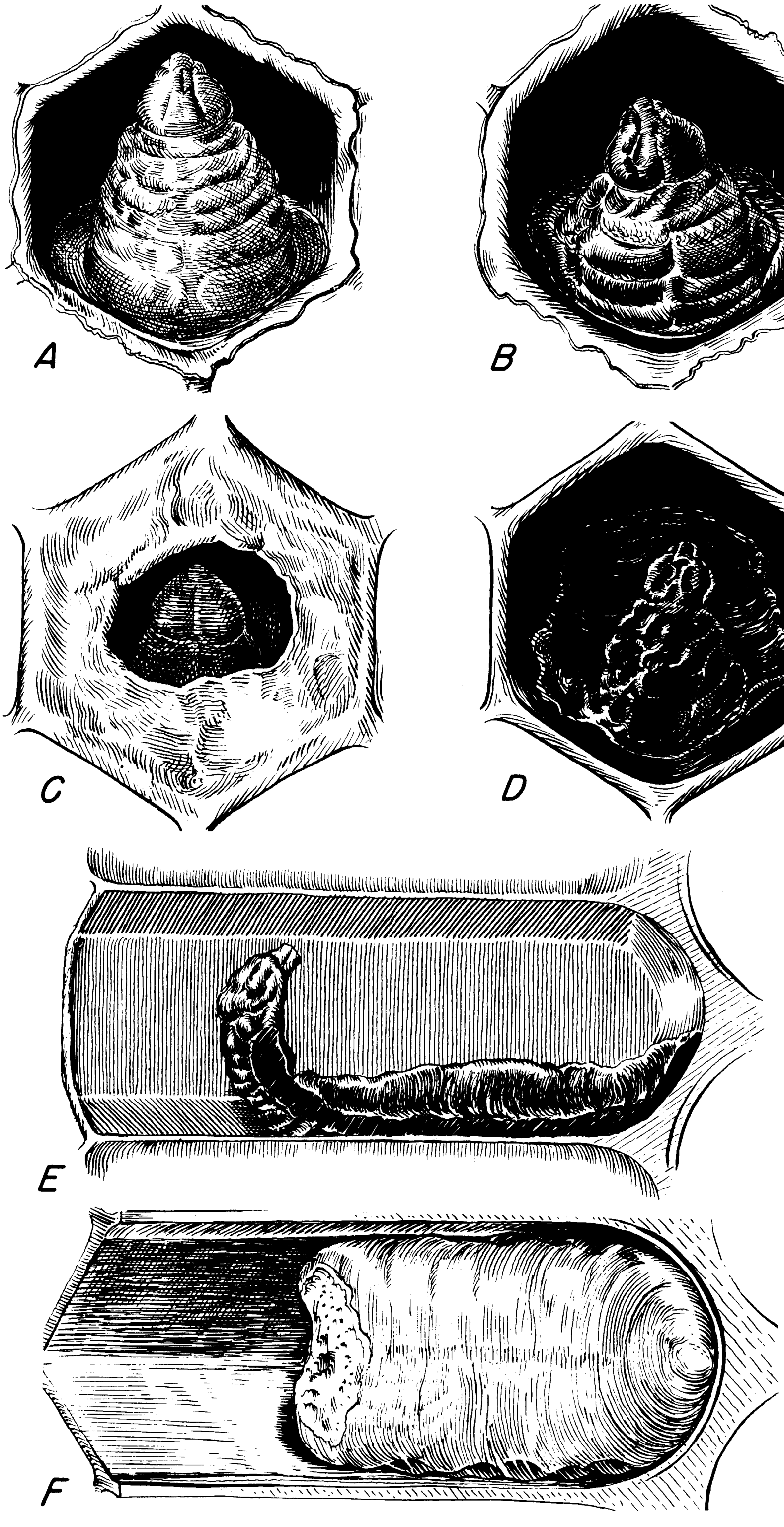

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FIGURE 4.—Honey bee larvae killed by sacbrood, as seen in cells: *A–B*, Larvae in different stages of decomposition; *C*, erect head of dead larva showing through opening made by bees in capping; *D–E*, views of scale; note how head remains erect; *F*, remains of larva, head of which has been gnawed away by bees.

Purchasing used bee equipment may be economical but can lead to serious disease problems. Infected honey, combs, hive bodies, or other equipment are important disseminators of bee diseases far beyond the flight range of the honey bees. Consequently, beekeepers should thoroughly inspect colonies or equipment before making the actual purchase. Even then, used hive equipment should be washed in hot soapy water or scorched before it is used. The wash water should be disposed of in such a way that it would be inaccessible to foraging bees. A common practice among beekeepers is the capturing of swarms. These should be isolated and inspected for disease before they are moved into a healthy apiary.

A beekeeper should always keep a clean, tidy apiary. Scrapings of comb and propolis should be placed in a sealed container. Honey should not be exposed. If sugar sirup is fed, it should not be allowed to run out the front entrance. These measures are important in the prevention of robbing of a diseased colony.

The U.S. Food and Drug Administration has approved labeling for Terramycin, sulfathiazole, and fumagillin as aids in the control of bee diseases. Terramycin has been used to control American and European foulbrood, whereas sulfathiazole is effective only on American foulbrood. Fumagillin has been used with limited success in controlling nosema disease. It is well to remember that the label carries specific instructions for the use of these materials for bee diseases. Therefore, these drugs can be used subject to State laws and regulations in the manner specified, but should never be used at a time or in such a way that would result in contamination of the marketable honey. Terramycin and sulfathiazole do not kill spores of *Bacillus larvae.* Consequently, some States require that the bees, contaminated combs, and honey of infected colonies be destroyed by burning. Beekeepers should consult their local apiary inspector for instructions on the disposal of diseased hives and the use of drugs.

Sending Samples for Laboratory Examination

If only a small amount of the brood or a few bees are affected or if the symptoms are unusual, a definite diagnosis in the apiary is sometimes difficult. Examination by laboratory methods is then necessary. Sometimes the diagnoses made in the apiary and verified in the laboratory are also desirable.

Diagnosis of the disease in the laboratory is a service made available to beekeepers and State apiary inspectors by the U.S. Department of Agriculture.

A sample of brood comb for laboratory examination should be 4 or 5 inches square and contain as much of the dead brood as possible. *No honey should be present,* and the comb should not be crushed. A sample of adult bees should consist of at least 200 sick or recently dead bees.

Mail the samples in a wooden or strong cardboard box. Do not use a tin, glass, or plastic container, and do not wrap the comb or bees in waxed paper or aluminum foil. Send all samples to the Bee Pathology Laboratory, Entomology Building A, Agricultural Research Center. Beltsville, Md. 20705. Your name and address should be plainly written on the box. If the sample is forwarded by an inspector, his name and address should also appear on the box.

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DISEASES AND PESTS OF ADULT HONEY BEES

By M. Diane Roberts, *parasitologist, Entomology Research Division, Agricultural Research Service* [1]

Nosema Disease

Nosema disease is a major disease of adult honey bees and can be found wherever bees are found. It is responsible for heavy economic losses in the beekeeping industry. The causative organism of the disease is a protozoan parasite, *Nosema apis* Zander. The disease is transmitted by ingestion of its spores, which germinate soon after reaching the ventriculus.

The external symptoms of nosema disease are not specific. Infected bees may have disjointed wings and swollen abdomens. The infected ventriculus may be swollen, soft, and grayish white. However, the disease may be present with no visible symptoms. A heavily infected colony may collect less food or rear less brood. The ovaries of an infected queen soon degenerate, and the result may be a queenless colony or supersedure.

The ventriculus and Malpighian tubules are the organs principally injured by the organism; however, it may spread to other tissues and organs. The infection greatly interferes with normal absorption of food. Workers, drones, and queens are affected.

Many questions remain unanswered concerning the life cycle of *N. apis*. This disease appears to have an annual cycle. The incidence of infection reaches a peak in the spring, gradually declines during the summer, and may display a small peak in the fall.

Diagnosis of nosema disease is based on the spores seen in a microscopic examination of the crushed ventriculus or midgut. Identification of spores in droppings of living bees is also valid and useful. The absence of spores does not insure that other stages are not present.

Acarine Disease

Although acarine disease has not been found in North America, it is a potential threat to American beekeeping. This disease is caused by a mite, *Acarapis woodi* (Rennie), which spends most of its life cycle in the anterior thoracic tracheae of the adult bee. Eggs are laid and hatched, and the mites mature within the tracheae. Mature female mites leave the tracheae and migrate to the body hairs to search for a new host. They transfer to the body hairs of a new host and enter its thoracic spiracles.

Symptoms of acarine disease include inability to fly, distended abdomens, disjointed wings, and dwindling colonies. The spread of the disease within the colony depends partly on the presence of newly emerged bees. The thoracic spiracles are protected by a fringe of hairs, which are soft and flexible on the young bee but soon harden to form a barrier against the entering mite. Therefore, bees that escape infestation during the first week of life do not become infected.

Positive diagnosis is possible only by dissection of the thorax and observation under a low-power microscope of the exposed tracheae. If healthy, the tracheae appear uniformly white or flesh colored; if heavily infested, they are blackened. Intermediate stages between noninfested and heavily infested can be recognized by a bronzing or streaking or both of the tracheae.

Septicemia

Septicemia is an infectious bacterial disease of the adult honey bee, in which the causative agent multiplies and spreads in the body cavity. The causal organism was first classified as *Bacillus apisepticus* Burnside and later reclassified as *Pseudomonas apiseptica* (Burnside). Other organisms, classified as *Serratia* sp., cause a septicemia-like disease in Switzerland.

The method by which these pathogenic bacteria reach the blood is not understood, but once in the blood they multiply rapidly and cause death of the bee in a short time.

The principal symptom of septicemia is the disintegration of the bee. The slightest handling soon after death causes the legs, wings, and other body parts to fall apart. Bees with septicemia have a characteristic foul odor. The blood of infected bees is often a milky color rather than clear or slightly opalescent as in healthy bees.

Septicemia can be diagnosed by the typical dismemberment of the bee's body soon after death. More positive diagnosis is made by microscopic examination of the hemolymph, where short rod-shaped bacteria indicate the presence of the causative organism.

No treatment is presently available.

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[1] In cooperation with Louisiana Agricultural Experiment Station.

Bee Paralysis

Bee paralysis is a name given to several maladies having similar symptoms. Suspected causes of paralysis are viruses, pollen and nectar from such plants as buttercup, rhododendron, laurel, and some species of lime, deficient pollen during brood rearing in the early spring, and consumption of stored fermented pollen.

Two morphologically different viruses, chronic bee paralysis virus (CBPV) and acute bee paralysis virus (ABPV), have been isolated from paralytic bees. CBPV kills the bees more slowly than does ABPV. Paralytic bees are feeble and shaky. Their legs and wings are slightly spread and their honey stomachs are abnormally distended with honey. In the chronically paralyzed bees, microscopic examination of hindgut tissue sections shows certain cell inclusions that do not occur in healthy or acutely paralyzed bees. The mouth parts of ABPV-infected bees are permanently extruded and disjointed, so that it is impossible for them to eat.

The virus is spread by infected nurse bees and by contaminated feces. ABPV can be transmitted through the egg or transovarially. Susceptibility to CBPV appears to be inherited from the queen.

Tentative diagnosis can be made on the basis of symptoms alone. Positive diagnosis requires histological examination. No treatment is known for bee paralysis; however, requeening sometimes eliminates the disease. In the United States, losses due to bee paralysis are considered relatively insignificant.

Other Adult Diseases

Amoeba disease is caused by *Vahlkampfia (Malpighamoeba) mellificae* Prell, a micro-organism that invades the Malpighian tubules. Parasites develop and multiply in the excretory cells lining the tubules, forming spherical cysts, which are passed in the excreta of the bee. Cysts are swallowed by other bees to begin another phase of growth and multiplication of the disease. Its symptoms and effect on the individual bee are similar to those of nosema disease.

The diagnosis of the disease depends on the discovery of the cysts under the microscope either in samples of bees or in their excreta.

In the United States, bee losses from this disease are relatively mild. Combs from diseased colonies can be made safe for use by fumigation with acetic acid.

Gregarines are protozoan parasites found in the digestive tract of adult honey bees. They occur in the United States, France, Italy, Switzerland, Canada, and South America. Gregarine spores are eliminated from the bee in the excreta and are ingested by new hosts in water or food. The pathological importance of this parasite has not been determined.

Wax Moth

The greater wax moth (*Galleria mellonella* (L.)) causes a substantial loss of combs, honey, and bee equipment. It is found almost everywhere bees are raised. Since it is most active at higher temperatures, its greatest damage occurs in the Southern United States.

Masses of small white eggs (fig. 1, *A*) are laid on combs or in cracks between hive parts. The larva (fig. 1, *B*) receives its nourishment from the impurities in the wax. In obtaining these impurities it ingests the wax itself and in so doing destroys the comb. Brood combs and combs containing pollen are attacked more readily than new combs or foundation.

When fully grown, the larva spins a rough silken cocoon, which is usually attached to some solid support, such as the frame or the inside of the hive. Frequently the larva cements the cocoon inside a cavity chewed in the wood. Frames chewed in this way are weakened and easily broken.

Within the cocoon the larva changes to the pupa and overwinters in the pupal stage. Under warm conditions adults may emerge at almost any time of year.

The adult female moth (fig. 1, *C*) is about ¾ inch long with a wingspan of 1 to 1¼ inches. The males are smaller and have a scalloped outer margin on the forewing.

The female begins to deposit eggs 4 to 10 days after emergence from the cocoon. The total number of eggs laid by a female varies, but is usually fewer than 300. The adults may live as long as 3 weeks.

The larva is most destructive to combs stored in dark, warm, poorly ventilated places. It sometimes attacks combs within the active hive. The damage consists of small tunnels and borings through the wax caps of the honey cells (fig. 2).

The most effective enemies of the greater wax moth are bees themselves. Bees in a strong colony will remove the moths and prevent damage. Therefore, beekeeping methods that help maintain strong colonies will help prevent wax moth damage. For protection, combs can be held in cold rooms or stacked in such a way that a strong draft of air flows over them.

The larvae of the lesser wax moth (*Achroia grisella* (F.)) cause damage to stored combs similar to that of the greater wax moth. The larvae of the Mediterranean flour moth (*Anagasta kuehniella* (Zeller)) feed on pollen in the hive and cause some damage by tunneling into the midrib and the brood cells. These two moths are controlled by the same methods used for the greater wax moth.

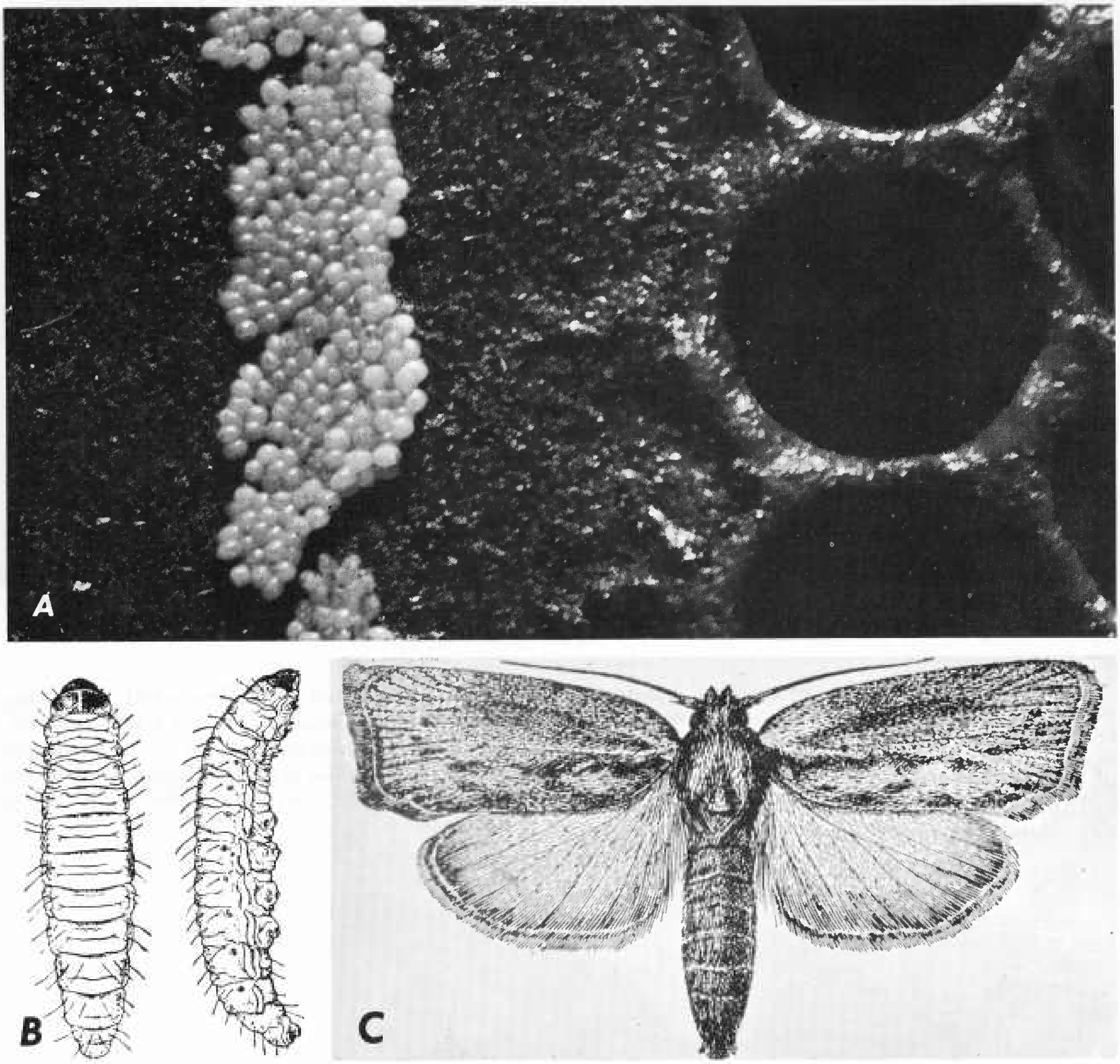

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FIGURE 1.—Greater wax moth: *A*, Eggs; *B*, larvae (left, dorsal; right, lateral); *C*, adult.

Other Pests

Ants sometimes invade the hive and disrupt the work of the colony, but generally they are more of a pest to the beekeeper. Termites can damage the hive parts placed on the soil. Other insects such as dragonflies, robber flies, praying mantises, ambush bugs, and certain wasps are natural enemies of the honey bee.

Skunks and bears cause extensive damage to apiaries in many parts of the country. A skunk has a tremendous appetite for bees and can severely weaken a colony. They may be controlled by trapping and poisoning. Bears eat bees, brood, and honey and destroy the hive in the process. Electric fences are helpful in discouraging such raids.

Mice may enter the hive in winter if the entrance is not reduced or protected by a mouse guard. They chew the combs and frames and construct their nest in the deserted area of the hive.

Birds, toads, and frogs are also minor pests of the honey bee.

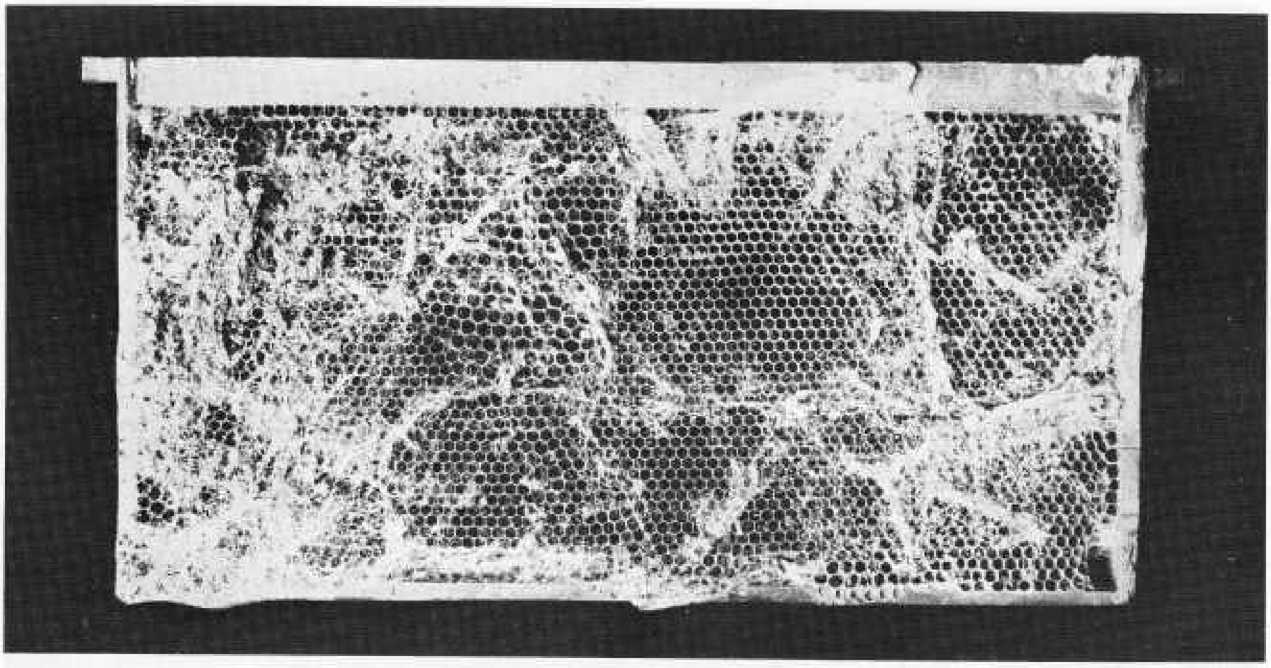

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FIGURE 2.—Brood comb infested with greater wax moth larvae.

External mites closely resembling *Acarapis woodi*, the cause of acarine disease, infest honey bees and are widely distributed in the United States. Apparently they have no adverse effect on their hosts.

The bee louse *Braula coeca* Nitzsch is occasionally found on worker bees and drones, but it mainly infests queen bees. The adult louse generally does little damage. It is not a true parasite, but feeds on the nectar or honey from the mouth parts of its host. The greatest damage is from the burrowing of the larvae in the cappings of honeycomb.

PESTICIDES

By Philip F. Torchio, *apiculturist, Entomology Research Division, Agricultural Research Service*[1]

One of the major problems faced by beekeepers in the United States and in most other countries with highly developed agriculture is the poisoning of bees by pesticides.

By nature, bees from a colony roam and visit flowers over an area of several square miles. The intensity of visitation in any one part of the area is determined by the relative attractiveness of the flowers. The extent of damage to the colony caused by a pesticide application is affected by the number of bees from the colony working in the treated area, the type of food (nectar and pollen) collected, the time of day the pesticide is applied, the method and number of applications, and the relative toxicity of the material to bees.

The damage can occur when the bee collects food from treated or drift-contaminated plants or by contact with the pesticide on the plant or in the air. The brood can be damaged if fed contaminated pollen.

Symptoms of Pesticide Poisoning

The following are some usual symptoms of pesticide poisoning. Not all of them are likely to be seen at any one time. Nor are they conclusive as pesticide poisoning, as they can also be the result of other causes. None of these symptoms indicate which material may have affected the bees.

(1) An excessive number of dead bees in front of the colony (fig. 1).

(2) An unusual number of dead colonies at one time, particularly if they contain honey.

(3) A depleted population when the colony should be strong.

(4) Sudden cessation of food storage.

(5) Dead or deserted brood, with honey in the hive.

(6) Dead bees on the floor of the hive during mild weather.

(7) A severe break in the brood rearing cycle.

(8) A cessation in flower visitation (of significance especially where pollination is desired).

(9) Bees crawling from the entrance to die nearby.

(10) Dead bees in the hive—on the tops of frames or on the bottom board.

(11) The absence of the usual "hum" of workers in the air.

BN-30058

Figure 1.—Dead bees at hive entrance—a symptom of pesticide poisoning.

(12) Incoming nectar- or pollen-laden bees attacked at the hive entrance by other bees.

(13) An unusual number of bees emerging from the entrance carrying dead bees. (The normal daily death rate inside the colony is about 100 bees.)

(14) Paralyzed, stupefied, or preening bees on weeds or other objects in the apiary.

Chemical Analysis of Bee Samples

Establishing proof of bee poisoning by chemical analysis is difficult even when the type of pesticide is known. Many pesticides break down rapidly when exposed to the elements. For a sample to be of any value to the analytical chemist, it should

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[1] In cooperation with Utah Agricultural Experiment Station.

be collected immediately after exposure and kept under deep-freeze conditions until analyzed.

There is no Federal laboratory equipped for routine analysis of bee samples for all pesticide residues. Some State experiment stations are equipped to determine certain residues. If analysis of a sample of bees is desired, the State experiment station or extension service should be consulted before the sample is submitted to determine whether an analysis can be made. Some commercial laboratories analyze for residues on a fee basis.

Determining Toxicity Levels of Pesticides

The problem of determining toxicity levels on honey bees in the laboratory and field has been studied for years by many Federal and State research workers. Hundreds of pesticide formulations have been tested in both dusts and sprays. These tests *have not been* conducted on low-volume or ultra-low-volume applications. Limited experience indicates that with these methods of application the hazard to bees increases with certain materials. Extra precautions should be taken until the hazard of pesticides applied by these new methods has been determined. The results of field and laboratory tests *using diluted* pesticides are incorporated in table 1.

Wild bees are also damaged not only by contaminated food but also by contaminated leaf material, florets, soil, and other articles used in nesting. Furthermore, pesticide residues in soil can remain toxic to ground-nesting bees for several years. Table 2 shows the comparative toxicity of 29 pesticides to the alkali bee and the leafcutting bee.

TABLE 1.—*Summary of toxicity and poisoning hazard of pesticides to honey bees* [1]

Pesticide [2]	Type [3]	Laboratory toxicity	Field application in dust			Field application in spray		
			Toxicity	Residual effect	Use class [4]	Toxicity	Residual effect	Use class [4]
Abate	P					Low	3 hours	II
aldrin	C	Very high	Very high		I	Very high		I
allethrin	B	Low						III
Aramite	M	do	Moderate		II–III	Low		III
azinphosethyl (Ethyl Guthion).	P	Very high				Very high	1 day +	I
azinphosmethyl (Guthion).	P	do				do	2–4 days	I
Banol	Ca					do	>7 hours	I
Bay 39007 (Baygon)	Ca	High				High	>1 day	I
Bay 39007 (Baygon G)	Ca		Low		III			
Bay 41831	P	Very high						I
Bidrin	P	do				Very high	5 hours–1 day+.	I
binapacryl (Morocide)	D	Low				Low	<2½ hours	III
Bomyl	P	Very high				Low–high	2 days	I
calcium arsenate	I	High	Very high	Long	I			I
carbaryl (Sevin)	Ca	Low–high	High	3 days+	I	Moderate–high.	7–12 days+	I
Carbaryl (Sevin G)	Ca		Low	<2 hours	III			
carbophenothion (Trithion).	P	Moderate	High	>1 day	I	High	<5 hours	II
chlorbenside (Mitox)	M	Low				Low	<2 hours	III
chlordane	C	Very high	High–very high.	2–3 days	I	High		I
chlorobenzilate	M	Moderate				Low		III
chloropropylate	M					do	<1 day	III
Chlorthion	P							I
Ciodrin	P	Very high						I
cryolite	I	High	High		I	High		I
DDT	C	Moderate	Moderate–high.	2–3 days	I–II	Moderate	1 day+	II
demeton (Systox)	P	Very high				do	<3 hours	II
diazinon	P	do	Very high	1 day+	I	Very high	1 day	I
dicapthon	P	do						I
dichlorvos (Vapona)	P	do				Very high	1 day+	I
dicofol (Kelthane)	M	Low				Low		III
dieldrin E	C	Very high				High	2 days	I
dieldrin G	C		Moderate	<2 hours	II			
dieldrin WP	C	Very high	Very high	8 days	I	Very high	5–7 days	I

See footnotes at end of table.

TABLE 1.—*Summary of toxicity and poisoning hazard of pesticides to honey bees* [1]—Continued

Pesticide [2]	Type [3]	Laboratory toxicity	Field application in dust			Field application in spray		
			Toxicity	Residual effect	Use class [4]	Toxicity	Residual effect	Use class [4]
Dilan	C	Low	Low–high	3 hours	II	Low–high	3 hours	II
dimethoate	P	Very high				Very high	1–2 days	I
dimetilan	Ca	Moderate				Low	3 hours	II
Dimite (DMC)	M	Low				do		III
dinitrobutylphenol (DNOSBP).	D	Very high				Very high	1 day+	I
dinitrocresol (DNOC)	D	High				do		I
dinocap (Karathane)	D	Low						III
dioxathion (Delnav)	P	do				Low–high	2 hours	II
disulfoton (Di-Syston)	P	Very high				Low	3 hours	II
Di-Syston G	P		Low	<2 hours	III			
DN–111	D	Low						III
endosulfan (Thiodan)	C	Moderate				Low	<5 hours	II
endrin	C	Very high				Moderate	<2 hours	II
EPN	P	do	High	1 day+	I	Very high		I
ethion	P	Low				Low–high	<2 hours	II
famphur (Famophos)	P	Very high						I
fenson	M					Low	<2 hours	III
fenthion (Baytex)	P	Very high				Very high	2–3 days+	I
Genite 923	M	Low	Moderate		II–III	Low	<2 hours	III
heptachlor	C	Very high				Very high		I
heptachlor G	C		Moderate	<2 hours	II			
Hooker HRS–16 (Pentac)	M					Low	<1 day	III
Imidan	P	Very high				Very high	1–4 days	I
isobenzan (Telodrin)	C	do				High	>2 hours	II
isodrin	C	Moderate						II
Isolan	Ca	High				Low	3 hours	II
isopropyl parathion	P	Low						III(?)
Kepone	C	do				Low	<1 day	III
Kepone bait	C		Low		III			
lead arsenate	I	Very high				Very high	Long	I
lime sulfur	I	Low				Moderate		III
lindane and benzene hexachloride (BHC).	C	Very high	Very high	2 days+	I	High		I
malathion	P	do	do	1 day+	I	Moderate–very high.	2 hours–2 days+.	I
malathion G	P		Low	None	II			
Matacil	Ca	High				Very high	>3 days	I
menazon	P					Moderate	<2 hours	II
methoxychlor	C	Low				do	<1 day	II
methyl demeton (Metasystox).	P	High				do	None	II
methyl parathion	P	Very high						I
Methyl Trithion	P	do				High	<1 day	I
mevinphos (Phosdrin)	P	do	Very high		I	Very high	2 hours–1 day.	I
mirex G	C		Low		III			III
Morestan	Co		do	None	III	Low	None	III
naled (Dibrom E)	P	Very high				Very high	3 hours	II
naled (Dibrom WP)	P		High	>7 hours	I	do	>3 hours	II
Naugatuck D–014 (Omite)	M					Low	<3 hours	III
Nemacide (V–C 13)	P	High				do	2 hours	II
Neotran	M	Low				do		III
nicotine sulfate	B	do	Low	Few hours	III			
Nissol	A					Low	3 hours	II
ovex	M	Low	Low–high		II–III	do		
oxydemetonmethyl (Metasystox R).	P	High				Moderate	None	II
paraoxon	P	Very high						I
parathion	P	do	Very high	1 day+	I	High	1 day+	I
Perthane	C	Moderate	Moderate	1 day+	II	Low	<1 day	II
phorate (Thimet E)	P	do				Very high	5 hours	II
phorate (Thimet G)	P		Moderate	<2 hours	II			
phosphamidon	P	Very high				Very high	2 hours–2 days.	I

Footnotes at end of table.

TABLE 1.—*Summary of toxicity and poisoning hazard of pesticides to honey bees* [1]—Continued

Pesticide [2]	Type [3]	Laboratory toxicity	Field application in dust			Field application in spray		
			Toxicity	Residual effect	Use class [4]	Toxicity	Residual effect	Use class [4]
Phostex	P	Moderate				High	2 hours	II
propyl thiopyrophosphate (NPD).	P	Very high				Low	2½ hours	II
Pyramat	Ca	do						I
pyrethrum	B	Low	Low	3 hours	III	Low		III
ronnel (Korlan)	P					Moderate	3 hours	II
rotenone	B	Low	Low–high	<1 day	II–III			
ryania	B	do				Moderate	>3 hours	II
schradan (OMPA)	P	Low–very high.				Low	1 day	III
sodium hexafluorosilicate bait.	I		Low		III			
Strobane	C	Low						III
sulfotepp	P	Very high						I
sulfur	I	Low			III	Low		III
Sulphenone	M	Moderate	Moderate		II–III	do		III
TDE (Rhothane)	C	do	do		II	Moderate		II
Temik G	Ca		Low	None	III			
tepp	P	Very high	Very high	<3 hours	II	Very high	3 hours	II
tetradifon (Tedion)	M	Low				Low	<2 hours	III
Tetram	P	do				Moderate		II
Thiocron	P	High				Low	3 hours	II
thioquinox (Eradex)	Co	Moderate						II
toxaphene	C	Low	Low–high	<1 day	I–II	Low	<1 day	II
trichlorfon (Dylox, Dipterex).	P	Low–high	High	>3 hours	I	Low–high	2–5 hours	II
Zectran	Ca	Very high				Very high	1–2 days	I
Zinophos	P	do						I

[1] Arrangement and much of data from Johansen, C. A., Summary of the Toxicity and Poisoning Hazard of Insecticides to Honey Bees, Gleanings Bee Cult. 94: 474–475, 1966.

[2] Chemical names given at end of section on Pesticides.

[3] A=acetamide, B=botanical or derivative, C=chlorinated hydrocarbon, Ca=carbamate, Co=carbonate, D=dinitro compound, I=inorganic compound, M=specific miticide, and P=organophosphorus compound.

[4] Classification of materials: I=hazardous to bees at any time, II=not hazardous if applied when bees are not foraging, III=not hazardous to bees at any time.

Laboratory tests of pesticide formulations on honey bees determine toxicity levels on individuals but do not indicate seriousness of damage to the field force and its pollinating or honey-production potential. The field testing of insecticides on the honey bee is especially difficult, because individuals visit fields briefly, the social organization normally prevents all members of the colony from being equally exposed to pesticides, and a part of the field force of any colony may be visiting areas outside the confines of the experiment. Any or all of these factors can drastically affect results. Furthermore, there is no accurate measurement of sublethal effects on a colony exposed to a pesticide application.

Techniques are used that determine (1) toxic effects of direct applications, by placing caged bees in the field as the field is being treated; (2) fuming effect, by placing additional caged bees in the field at hourly intervals after treatment until mortality ceases; and (3) residual effects on the field force, by counting floral visitors before and after exposure to treated and untreated areas for a particular period. In addition, the examination of colonies in treated and untreated areas and counting dead bees in front of hives before and after applications provide a basis for evaluating the effect of the material on the colony. The combined data obtained from these testing techniques provide for an intelligent estimate of pesticide effects on honey bees in the field.

Reduction in Bee Losses

Observation of the following precautions can significantly reduce bee losses from pesticide poisoning.

Grower Cooperation

The grower should use a pesticide only when needed. The benefit of the material should outweigh the harm it does to bees. The value of the bees as pollinators should be considered, as well as the effect of the pesticide on them. The effect of the pesticide on the pollinators of other crops in the area should also be considered. A pesticide

TABLE 2.—*Comparative toxicity of 29 pesticides to alkali bee and alfalfa leafcutting bee* [1]

Pesticide [2]	Alkali bee	Alfalfa leafcutting bee
Aramite	III	
Bidrin	I	I
carbaryl (Sevin)	I	I
carbophenothion (Trithion)	II	I
DDT	III	I
demeton (Systox)	III	III
diazinon	I	
dicofol (Kelthane)	III	III
dimethoate	I	I
dioxathion (Delnav)	----------	III
endosulfan (Thiodan)	I	I
endrin	II	I
EPN	I	
ethion	----------	I
malathion	II	I
menazon	----------	III
methoxychlor	III	
mevinphos (Phosdrin)	I	
naled (Dibrom)	II	II
oxydemetonmethyl (meta-Systox R)	III	
parathion	I	I
phosphamidon	I	I
Phostex	----------	III
ronnel (Korlan)	----------	I
schradan (OMPA)	----------	III
tepp	III	
tetradifon (Tedion)	III	
toxaphene	III	I
trichlorfon (Dylox, Dipterex)	----------	I

[1] Classification of materials: I=hazardous to bees at any time, II=not hazardous if applied when bees are not foraging, III=not hazardous to bees at any time.

[2] Chemical names given at end of section on Pesticides.

aiding one crop could seriously reduce production of another one in the area.

Select the right pesticide. All pesticides are not equally hazardous to bees. Some pesticides will kill an entire colony, some will weaken it, but still others are safe. Select the pesticide that is least hazardous to pollinators and that will control the harmful pests.

Apply granules or sprays rather than dust. Granules are, in general, harmless to bees. Sprays drift less than dusts.

Use ground equipment. Airplanes discharge pesticides at higher altitude and with greater turbulence than ground machines. This increases the likelihood that bees in flight will come in contact with the pesticide or that it will drift onto adjacent crops or into apiaries. Time the pesticide application. The safest time to apply pesticides is when bees are not working plants. Treat at night or at a time of day when bees are not in the field.

Avoid drift of the pesticide. Bees cluster on the hive entrance on hot days and nights where they can be exposed to drifting pesticides. Wait until the night is sufficiently cool for the bees to move inside. Colonies can be damaged by fumes of some pesticides, such as parathion, azinphosmethyl, malathion, and benzene hexachloride. Notify the beekeepers near areas to be treated so that they may move or otherwise protect the colonies. However, notification is not a release of responsibility.

Beekeeper Cooperation

Select safe bee locations. Place colonies away from agricultural areas if possible, away from fields routinely treated, or at least where they will not be subject to drift of the material from the treated field.

Identify the colonies. Post owner's name, address, and telephone number in a conspicuous place in the apiary. Let the nearby growers know where the bees are located so the beekeeper can be notified.

Know the pesticides. Be acquainted with pesticides likely to be used in the area and their potential hazard to bees.

Confine the bees when hazardous materials are applied. Beehives can be covered with plastic sheeting that will confine the bees and exclude pesticide sprays, dusts, or fumes. Since heat builds up rapidly under plastic exposed to the sun, confinement can only last for a few hours after dawn on warm days. This may be long enough to protect the bees from some materials.

Hives can also be covered with wet burlap for a day or more, even during the hottest weather, and the bees will not suffer from lack of air or water. The hives should be covered at night when all the bees are in the hives. During the day the burlap should be soaked with water at least once every hour.

Relocate the colonies if they are likely to be repeatedly exposed to hazardous pesticides.

Bees are valuable to the grower. Try to convince him of their value to him and of the importance of protecting them.

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Chemicals Referred to in Tables 1 and 2

Name used	*Chemical name*
Abate ®	*O,O*-dimethyl phosphorothioate *O,O*-diester with 4,4′-thiodiphenol
aldrin	not less than 95 percent of 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4-*endo-exo*-5,8-dimethanonaphthalene
allethrin	2-allyl-4-hydroxy-3-methyl-2-cyclopenten-1-one ester of 2,2-dimethyl-3-(2-methylpropenyl) + cyclopropanecarboxylic acid
Aramite ®	2-(*p-tert*-butylphenoxy)-1-methylethyl 2-chloroethyl sulfite
azinphosethyl (Ethyl Guthion ®)	*O,O*-diethyl phosphorodithioate *S*-ester with 3-(mercaptomethyl)-1,2,3-benzotriazin-4(3*H*)-one
azinphosmethyl (Guthion ®)	*O,O*-dimethyl phosphorodithioate *S*-ester with 3-(mercaptomethyl)-1,2,3-benzotriazin-4(3*H*)-one
Banol ®	6-chloro-3,4-xylyl methylcarbamate
Bay 39007 (Baygon ®)	*o*-isopropoxyphenyl methylcarbamate
Bay 41831	*O,O*-dimethyl *O*-4-nitro-*m*-tolyl phosphorothioate
benzene hexachloride	1,2,3,4,5,6-hexachlorocyclohexane, consisting of several isomers and containing a specified percentage of *gamma* isomer
Bidrin ®	3-hydroxy-*N,N*-dimethyl-*cis*-crotonamide dimethyl phosphate
binapacryl (Morocide ®)	2-*sec*-butyl-4,6-dinitrophenyl 3-methyl-2-butenoate
Bomyl ®	dimethyl 3-hydroxyglutaconate dimethyl phosphate
calcium arsenate	calcium arsenate
carbaryl (Sevin ®)	1-naphthyl methylcarbamate
carbophenothion (Trithion ®)	*S*-[[(*p*-chlorophenyl)thio]methyl] *O,O*-diethyl phosphorodithioate
chlorbenside (Mitox ®)	*p*-chlorobenzyl *p*-chlorophenyl sulfide
chlordane	1,2,4,5,6,7,8,8-octachloro-3a,4,7,7a-tetrahydro-4,7-methanoindane
chlorobenzilate	ethyl 4,4′-dichlorobenzilate
Chloropropylate ®	isopropyl 4,4′-dichlorobenzilate
Chlorthion ® (now unavailable)	*O*-(3-chloro-4-nitrophenyl) *O,O*-dimethyl phosphorothioate
Ciodrin ®	*alpha*-methylbenzyl 3-hydroxycrotonate dimethyl phosphate
cryolite	sodium hexafluoroaluminate
DDT	1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane
demeton (Systox ®)	mixture of *O,O*-diethyl *S*(and *O*)-[2-(ethylthio)ethyl] phosphorothioates
diazinon	*O,O*-diethyl *O*-(2-isopropyl-4-methyl-6-pyrimidinyl) phosphorothioate
dicapthon	*O*-(2-chloro-4-nitrophenyl) *O,O*-dimethyl phosphorothioate
dichlorvos (Vapona ®)	2,2-dichlorovinyl dimethyl phosphate
dicofol (Kelthane ®)	4,4′-dichloro-*alpha*-(trichloromethyl)benzhydrol
dieldrin	not less than 85 percent of 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-*endo-exo*-5,8-dimethanonaphthalene
Dilan ®	a mixture of 1 part of 1,1-bis(*p*-chlorophenyl)-2-nitropropane (Prolan ®) and 2 parts of 1,1-bis(*p*-chlorophenyl)-2-nitrobutane (Bulan ®)

Name used	*Chemical name*
dimethoate	*O,O*-dimethyl *S*-(*N*-methylcarbamoylmethyl) phosphorodithioate
dimetilan	1-dimethylcarbamoyl-5-methyl-3-pyrazolyl dimethylcarbamate
Dimite ® (DMC)	4,4′-dichloro-*alpha*-methylbenzhydrol
dinitrobutylphenol (DNOSBP)	2-*sec*-butyl-4,6-dinitrophenol
dinitrocresol (DNOC)	4,6-dinitro-*o*-cresol
dinocap (Karathane ®)	2-(1-methylheptyl)-4,6-dinitrophenyl crotonate
dioxathion (Delnav ®)	2,3-*p*-dioxanedithiol *S,S*-bis (*O,O*-diethyl phosphodithioate)
disulfoton (Di-Syston ®)	*O,O*-diethyl *S*-[2-(ethylthio)ethyl] phosphorodithioate
DN-111 ®	dicyclohexylamine salt of 2-cyclohexyl-4,6-dinitrophenol
endosulfan (Thiodan ®)	6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxathiepin 3-oxide
endrin	1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-*endo*-*endo*-5,8-dimethanonaphthalene
EPN	*O*-ethyl *O*-*p*-nitrophenyl phenylphosphonothioate
ethion	*O,O,O′,O′*-tetraethyl *S,S′*-methylenebisphosphorodithioate
famphur (Famophos)	*O,O*-dimethyl *O*-[*p*-(dimethylsulfamoyl)phenyl] phosphorothioate
fenson	*p*-chlorophenyl benzenesulfonate
fenthion (Baytex ®)	*O,O*-dimethyl *O*-[4-(methylthio)-*m*-tolyl] phosphorothioate
Genite 923 ®	2,4-dichlorophenyl benzenesulfonate
heptachlor	1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene
Hooker HRS-16 (Pentac)	decachlorobi-2,4-cyclopentadien-1-yl
Imidan ®	*O,O*-dimethyl *S*-phthalimidomethyl phosphorodithioate
isobensan (Telodrin ®)	1,3,4,5,6,7,8,8-octachloro-1,3,3a,4,7,7a-hexahydro-4,7-methanoisobenzofuran
isodrin	1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4-*endo*-*endo*-5,8-dimethanonaphthalene
Isolan ®	1-isopropyl-3-methylpyrazol-5-yl dimethylcarbamate
isopropyl parathion	*O,O*-diisopropyl *O*-*p*-nitrophenyl phosphorothioate
Kepone ®	decachlorooctahydro-1,3,4-metheno-2*H*-cyclobuta[*cd*]pentalen-2-one
lead arsenate	acid lead arsenate
lime sulfur	30 percent calcium polysulfide and various small amounts of calcium thiosulfate plus water and free sulfur
lindane	1,2,3,4,5,6-hexachlorocyclohexane, *gamma* isomer of not less than 99 percent purity
malathion	*O,O*-dimethyl dithiophosphate of diethyl mercaptosuccinate
Matacil ®	4-(dimethylamino)-*m*-tolyl methylcarbamate
menazon	*S*-[(4,6-diamino-*s*-triazin-2-yl)methyl] *O,O*-dimethyl phosphorodithioate
methoxychlor	1,1,1-trichloro-2,2-bis(*p*-methoxyphenyl)ethane
methyl demeton (Metasystox ®)	mixture of *O,O*-dimethyl *S*(and *O*)-[2-(ethylthio)ethyl] phosphorothioates
methyl parathion	*O,O*-dimethyl *O*-*p*-nitrophenyl phosphorothioate
Methyl Trithion ®	*S*-[[(*p*-chlorophenyl)thio]methyl] *O,O*-dimethyl phosphorodithioate
mevinphos (Phosdrin ®)	methyl 3-hydroxy-*alpha*-crotonate dimethyl phosphate
mirex	dodecachlorooctahydro-1,3,4-metheno-2*H*-cyclobuta[*cd*]pentalene
Morestan ®	6-methyl-2,3-quinoxalinedithiol cyclic *S,S*-dithiocarbonate
naled (Dibrom ®)	1,2-dibromo-2,2-dichloroethyl dimethyl phosphate
Naugatuck D-014 (Omite)	2-(*p*-*tert*-butylphenoxy)cyclohexyl 2-propynyl sulfite
Nemacide ®	*O*-2,4-dichlorophenyl *O,O*-diethyl phosphorothioate
Neotran ®	bis(*p*-chlorophenoxy)methane
nicotine sulfate	nicotine sulfate
Nissol	2-fluoro-*N*-methyl-*N*-1-naphthylacetamide
ovex	*p*-chlorophenyl *p*-chlorobenzenesulfonate
oxydemetonmethyl (meta-Systox R ®).	*S*-[2-(ethylsulfinyl)ethyl] *O,O*-dimethyl phosphorothioate
paraoxon	diethyl *p*-nitrophenyl phosphate
parathion	*O,O*-diethyl *O*-*p*-nitrophenyl phosphorothioate
Perthane®	a mixture of 1,1-dichloro-2,2-bis(*p*-ethylphenyl)ethane (95 percent) and related reaction products (5 percent)
phorate (Thimet ®)	*O,O*-diethyl *S*-[(ethylthio)methyl] phosphorodithioate

Name used	*Chemical name*
phosphamidon	2-chloro-2-diethylcarbamoyl-1-methylvinyl dimethyl phosphate
Phostex ®	a mixture of bis(dialkyloxyphosphinothioyl) disulfides (alkyl ratio 75 percent ethyl, 25 percent isopropyl)
propyl thiopyrophosphate (NPD ®).	propyl thiopyrophosphate
Pyramat ®	6-methyl-2-propyl-4-pyrimidinyl dimethylcarbamate
pyrethrum	----------
ronnel (Korlan ®)	*O,O*-dimethyl *O*-2,4,5-trichlorophenyl phosphorothioate
rotenone	1,2,12,12a-tetrahydro-2-isopropenyl-8,9-dimethoxy[1]benzopyrano [3,4-*b*]furo[2,3-*h*][1]benzopyran-6(6a*H*)-one
ryania	----------
schradan (OMPA)	octamethylpyrophosphoramide
sodium hexafluorosilicate bait	sodium hexafluorosilicate
Strobane ®	terpene polychlorinates (65 percent chlorine)
sulfotepp	*O,O,O,O*-tetraethyl dithiopyrophosphate
sulfur	sulfur
Sulphenone ®	*p*-chlorophenyl phenyl sulfone
TDE (Rhothane ®)	1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethane
Temik ®	2-methyl-2-(methylthio)propionaldehyde *O*-(methylcarbamoyl) oxime
tepp	ethyl pyrophosphate
tetradifon (Tedion ®)	*p*-chlorophenyl 2,4,5-trichlorophenyl sulfone
Tetram ®	*S*-[2-(diethylamino)ethyl] *O,O*-diethyl phosphorothioate hydrogen oxalate
Thiocron	*O,O*-dimethyl phosphorodithioate *S*-ester with 2-mercapto-*N*-(2-methoxyethyl)acetamide
thioquinox (Eradex ®)	2,3-quinoxalinedithiol cyclic trithiocarbonate
toxaphene	chlorinated camphene containing 67–69 percent chlorine
trichlorfon(Dylox®,Dipterex®)	dimethyl (2,2,2-trichloro-1-hydroxyethyl)phosphonate
Zectran ®	4-(dimethylamino)-3,5-xylyl methylcarbamate
Zinophos ®	*O,O*-diethyl *O*-2-pyrazinyl phosphorothioate

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE

HYMENOPTEROUS INSECT STINGS

By THOR LEHNERT, *apiculturist, Entomology Research Division, Agricultural Research Service*

The honey bee is the most common single species of stinging insect in the United States. Bees and the related wasps, hornets, yellow jackets, and ants usually do not sting unless stepped on, touched, or molested. They are usually not active at temperatures below 55° F. or on rainy days. The highest incidence of stings is in August. Yellow jackets, honey bees, and wasps are the worst offenders in that order. Yellow jackets cause more moderate and also more severe reactions than bees or wasps.

Bee Venom

The poison gland system of the bee consists of a small alkaline gland and a larger acid gland. The venom comes from these two glands. The stinger is made up of two lancets with sharp barbs pointing backward, similar to a harpoon. When a honey bee stings, its stinger is pulled from its body. Even after the stinger is separated from the bee, its muscular mechanism can continue to force its venom into the wound. Because venom continues to be injected by the stinging mechanism, the stinger should be removed immediately. Most people make the mistake of pulling it out with the thumb and index finger and thereby squeeze more venom into the wound. The stinger should be scraped or scratched out with a fingernail.

Other stinging Hymenoptera, such as yellow jackets, wasps, and hornets, retain their stingers.

Bee venom is a water-clear liquid with a sharp bitter taste and a distinct acid reaction. The specific gravity is 1.1313. The venom is easily soluble in water and acid, but almost insoluble in alcohol.

The three toxic effects of bee venom are neurotoxic (paralysis of the nervous system), hemorrhagic (increase of the permeability of the blood capillaries), and hemolytic (destruction of red blood cells).

Recent work reveals that bee venom is a very complicated substance with several active biochemical components. By 1956 at least eight active components plus several biological inactive components had been identified. The substances showing activity are histamine, melittin (a protein), a hyaluronidase, and phospholipase A.

The histamine recovered was shown not to be a major pharmacological factor in bee venom, although histamine is commonly known to be a powerful depressant, causing a rapid fall in blood pressure.

Melittin, a protein having a molecular weight of 33,000 to 35,000, is thought to be responsible for the general local toxicity of the venom. Melittin in high concentrations has also caused hemolysis of red blood cells.

Bee venom contains at least two enzymes—a hyaluronidase and phospholipase A. The hyaluronidase is believed to be the "spreading" factor. By breaking down the cell-cementing substance, hyaluronidase allows the toxic principles of bee venom to infiltrate the tissues.

Phospholipase A apparently has no general toxicity. However, through indirect action on the unsaturated fatty acids, it causes hemolysis of red blood cells. Phospholipase A also causes inactivation of thrombokinase, inhibits oxidative phosphorylation, and attacks enzymes involved with metabolic dehydrogenation. The pain experienced after being stung may well be the result of these last three actions.

For many years formic acid was erroneously believed to be the major component of venom produced by the honey bee, and this belief is still held by many. The action of venom is much more complex than the simple concept of direct action on the tissue by formic acid.

Sting Reactions

In most cases insect stings cause only a local reaction, with pain lasting for several minutes after penetration of the stinger. A redness and slight swelling at the sting site may also occur. Until recently some people believed severe symptoms and death from stinging insects were due to venom being introduced directly into a small blood vessel. Severe reactions are now considered to be due to sensitivity to bee protein not venom.

In about 2 percent of persons a hypersensitivity develops in which each additional sting produces a more severe reaction. Hypersensitivity may appear after a varying number of stings, usually each sting making the reaction progressively worse. Some develop sensitivity after one sting, whereas others after a series of normal reactions. In a few individuals hypersensitivity appears to be inborn. The first sting has resulted in death.

Symptoms in an allergic person usually appear within a few minutes after the sting, but may not appear for 24 hours. Local swelling may be excessive. A hivelike condition may break out over the body. There is a sensation of choking, difficult breathing, asthma, and the lips turn blue. Shocklike symptoms, vomiting, and loss of consciousness may follow in rapid succession.

Treatment and Precautions

Treatment is divided into three stages. (1) Immediate treatment for anaphylaxis is epinephrine 1:1,000, 0.3 cc. to 0.5 cc. given intramuscularly or by deep subcutaneous injection. (2) Second-stage treatment includes a sympathomimetic agent, such as metaraminol, 100 mg. in 500-cc. isotonic saline solution given intravenously, a tourniquet above the sting site if practical, antihistamine given intramuscularly, and corticosteroids. (3) Long-term care involves immunization with the appropriate insect antigen.

The long-term treatment undertaken to relieve the allergic condition to stings is known as desensitization. This treatment consists of a graduated series of injections of an extract made from the body of the offending type of insect. If the stinging insect is not identified, the sensitive person should be treated with an antigen composed of honey bee, hornet, paper wasp, and yellow jacket.

The degree of relief from allergic reactions is not the same for all persons after desensitizing treatments. The frequency of treatment also varies. In some cases one series of treatments is effective. In other cases the treatment must be repeated with booster injections once a month.

Another important point is that of cross-protection. The injection of stinging insect extract of one species will protect some persons against all stinging insects. Some will need a combination of extracts to achieve complete protection. This makes the procedure of desensitization an individual process.

Desensitization seems to be helpful to about three-fourths of persons with severe reactions, in that they report lessened reactions to subsequent stings. Desensitization should be considered by persons who have severe reactions.

Such persons should have an emergency kit available at all times. This kit should contain a tourniquet, ampoules of epinephrine 1:1,000, and an injectable antihistamine. Instructions on the use of remedies in the kit should be obtained from a physician.

Immunization of a sensitive person should always be carried out, since there is no way of completely avoiding stinging insects. However, one can take several precautions to prevent stings. For example, the type of clothing worn affects the probability of being stung. Beekeepers consider clothing color to be one of the most important factors. Light-colored clothes should be worn in preference to dark, rough, or woolly clothing. Suede or leather materials, particularly horsehide, seem to be especially irritating to bees. If around bees, women should wear some type of head covering to keep them out of their hair.

The odor of perspiration has little effect on bees. Certain hair oils and perfumes should be avoided because they seem to be irritating to honey bees, which when once attracted are likely to sting.

Bees will more quickly attack a moving object than an immobile object. This can easily be demonstrated by making fast jerky hand movements when working with a hive of bees. Striking, swatting, and swinging at bees will increase the chance of being stung.

No success has been attained in developing an effective repellent against stinging insects. Dimethyl phthalate, which has been very effective in repelling mosquitoes and biting flies, is not effective as a repellent against stinging insects.

Only a small percentage of the population suffers serious reactions from hymenopterous insect stings. However, when reactions other than local irritation and swelling do occur, a physician should be called for immediate treatment. He should be consulted for long-range protection with desensitizing shots.

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OBSERVATION BEEHIVE

By THOR LEHNERT, *apiculturist, Entomology Research Division, Agricultural Research Service*

The observation hive offers many useful possibilities to the beekeeper, teacher, and researcher.

All types of observation hives are in use today, ranging from single frame models to full-scale hives enclosed in glass. Although observation hives are available commercially from many of the bee supply houses, most people get more satisfaction from designing and building their own.

Several points must be considered when constructing the hive. A screened hole should be provided in the hive for adequate ventilation. A bee space of one-fourth to three-eighths inch between the frames and glass sidewalls, top, bottom, and ends of the hive will allow the bees to move around freely. If more space is provided, bees will quickly build burr comb on the glass and make observations difficult.

In figure 1 are given the design and list of materials necessary to construct the three-frame observation hive that is used at the Bee Disease Research Laboratory in Beltsville, Md.

The hive may be set up anywhere in the house except where the bees will get too hot, since they cannot tolerate extreme heat. The flight hole to the outside should be located so that they will leave the house above the heads of passers-by. The location of the hive should be well lighted so that activities of the bees can be observed. If a permanent outside exit cannot be provided, the hive must be taken outside every second or third day so the bees can fly. They should be allowed to fly from late afternoon to sundown. The hive can then be closed again and returned indoors.

The hive may be stocked with bees from a local beekeeper who can supply a queen, a frame of brood, a frame or two of honey, and worker bees. If bees are not available from a local source, a queen and 2-pound package may be bought from a package bee producer.

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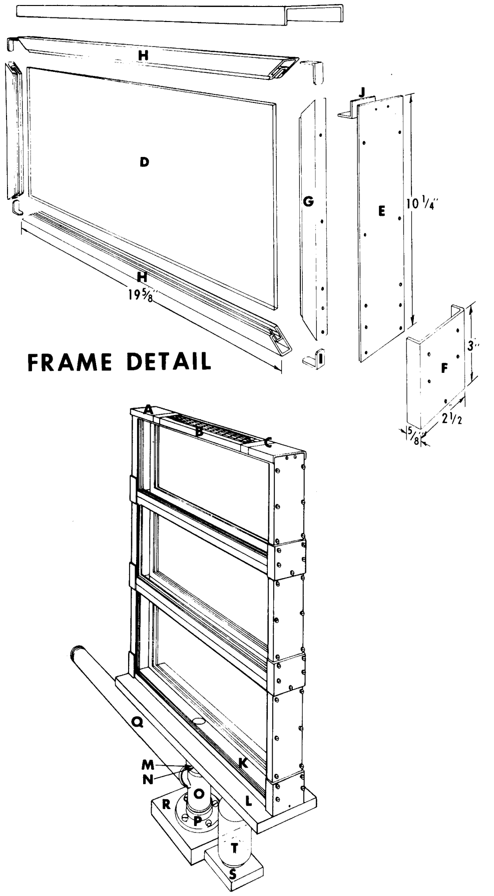

MATERIALS

TOP

A 1- 1/2″×2 7/16″×1/2″ CHANNEL, 20″ LONG
B CUT 1″× 8″ VENT AND COVER WITH HARDWARE CLOTH
C SECURE WITH MASKING TAPE

FRAME

D 2-18 1/2″×9 1/4″ DOUBLE-STRENGTH GLASS PANELS
E 2- 10 1/4″×2 1/2″× 1/16″ ALUMINUM SIDES
F 2-5/8″×2 1/2″×5/8″ STACKING CLIPS, 3″ LONG
G 4- 10 1/4″ SIDE RAILS (REYNOLDS WINDOW MOLD #30A)
H 4- 19 5/8″ TOP AND BOTTOM RAILS (REYNOLDS WINDOW MOLD #30A)
I 8- CORNER CLIPS
J 2- 3/4″ ×3/4″ ANGLE FRAME SUPPORTS 1 1/2″ LONG
(1/16″ ALUMINUM SHEET- RIVET TO SIDE PANELS)
20- 1/4″ SHEET METAL SCREWS

BASE

K 1- 19 3/4″×2 7/16″× 1 5/8″ WOODEN FRAME SUPPORT (CUT TO SHAPE)
L 1- 3/4″× 5 3/4″×20″ PLYWOOD BASE
(ASSEMBLE AND DRILL 1 1/4″ DIAMETER HOLE AT CENTER)
M 1- 4 1/2″ FLANGE (2″ PIPE)
N 1- 1 1/2″ NIPPLE (2″ PIPE,)
O 1- TEE (2″ PIPE)
P 1- 5 1/2″ FLANGE (WELD TO BOTTOM OF TEE)
7- 1″ WOOD SCREWS
Q 1- 2″ PIPE , LENGTH TO SUIT (18 SHOWN W/CAP)
R 1- 1 3/8″ ×7″×7″ WOOD BLOCK (CUT TO FIT)
S 1- 1″ × 6 1/2″×4″ WOOD BLOCK (CUT TO FIT)
T 1 - MASON JAR WITH FLANGED LID DRILLED WITH EIGHT 1/32″ HOLES

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FIGURE 1.—Design and list of materials for three-frame observation hive.

MANAGEMENT OF WILD BEES

By GEORGE E. BOHART, *apiculturist, Entomology Research Division, Agricultural Research Service* [1]

The term "wild bees" includes all bees except the three species of honey bees *Apis mellifera* L., *indica* Fabricius, and *cerana* Fabricius [2] managed by man. Generally bees are hymenopterous insects that provide their young with a diet of pollen and honey. They are characterized by the presence of plumose body hairs and usually by somewhat expanded hindlegs. Most species construct and provision nests, but perhaps 5 percent lay their eggs in nests constructed by other bees. Most bees are solitary (no cooperation between females and no contact between mother and adult offspring), but perhaps 10 percent display various degrees of social development. Many of the solitary species are neighborly and develop nesting aggregations numbering into the thousands or even millions.

According to C. D. Michener, there are at least 20,000 species of bees in the world. These are distributed among eight recognized families and perhaps 400 genera. In the United States there are seven families, about 100 genera, and between 3,000 and 4,000 species. In favorable locations only a few square miles may be inhabited by several hundred species.

Probably the high point in wild bee populations in the United States was reached about 1915, when hedgerows and unused fields provided ideal habitats and insecticides were rarely used. Today intensive land use, elimination of weeds, and widespread and frequent broadcasting of poisons are undoubtedly taking their toll. However, seed growers in some areas are protecting wild bees and propagating a few species for pollination. Furthermore, there is increasing emphasis nationally on the development of control measures that minimize the use of insecticides.

Pollination

Crops visited freely and pollinated efficiently by sufficient numbers of honey bees have no need for wild bees. However, under some circumstances either certain "problem" crops are not visited freely by honey bees or their visits do not usually bring about the thorough pollination desired. Some of these crops are efficiently pollinated by wild bees. If these bees can be managed, they may contribute greatly to the complete pollination of our crops.

Bumble Bees

Bumble bees (*Bombus*) (fig. 1) are important pollinators of many plants. However, their small colonies do not make them well suited for large-scale pollination.

Bumble bee colonies are obtained by placing domiciles in the field to attract queens or by inducing queens to establish colonies in domiciles kept in cages or greenhouses. The queens can forage and seek out the domiciles, or they can be confined to the domiciles until they start to nest (fig. 2).

In areas where bumble bees are abundant, attracting searching queens in the spring to domiciles placed in the field is often the most successful method of obtaining colonies. A colony established in this manner can be moved just before the first workers emerge. It should be placed on a post under a shelter and the entrance tube reduced to confine the queen. Honey should be placed in the honeypot when this is done.

Colonies of *Bombus terrestris* (L.) and *B. lapidarius* (L.) have produced as many as 1,000 bees, although never more than about one-third of this number is present at one time. The queens produced in such colonies may number as many as 300, but these are not very useful for pollination until the following year. For most species, 50 to 100 workers during the peak population are exceptionally high. Some rarely have more than 10 to 15. With such small colonies it is questionable whether bumble bees could be profitably maintained for pollination in the field, although interest in doing so persists.

A more practical result of bumble bee culture may be the accumulation of knowledge about these bees on which to base recommendations for their protection and increase. We know that a continuity of suitable forage is important, but we know little about how to provide suitable nesting conditions on a large scale or how to effect practical control of such enemies as *Psithyrus*, ants, wax moths, and rodents.

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[1] In cooperation with Utah Agricultural Experiment Station.

[2] Often known as *Apis indica japonica* Radoszkowski.

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FIGURE 1.—Species of bumble bees: *A, Bombus nevadensis* Cresson; *B, fervidus* (Fabricius); *C, huntii* Greene; *D, griseocollis* (De Geer).

Alfalfa Leafcutting Bee

The alfalfa leafcutting bee *Megachile rotundata* (Fabricius) was accidentally introduced into the Eastern United States in the 1930's and has since spread westward across the northern two-thirds of the country, reaching Utah and California in the early 1950's.

Alfalfa seed growers have been aware of the potential value of this bee since 1950 (fig. 3). Throughout the 1960's, growers in Utah, Idaho, Oregon, Washington, Alberta, Montana, South Dakota, and California have been following recommendations of experiment stations in their areas and also developing methods of their own for culturing it. Since it nests in many kinds of manmade structures, as well as holes in banks, pores in lava, and other natural cavities, it is not limited by soil conditions and is present in most farming areas within its range, at least in small numbers.

This bee is the smallest leafcutting bee in the United States (one-fourth to three-eighths inch long). Like most other leafcutters, it is charcoal gray and carries its pollen on the underside of the abdomen. Its preferred host range is limited, consisting primarily of small-flowered forage legumes, some mints, and a few crucifers. In the West, sweetclover is the principal host plant, competing with alfalfa. Unlike other leafcutting bees, the alfalfa leafcutting bee takes its leaf pieces from herbaceous plants (fig. 4), such as alfalfa, rather than shrub and tree leaves, but it occasionally damages gardens by cutting flower petals.

Depending somewhat on their size, the female bees choose $\frac{5}{32}$- and $\frac{7}{32}$-inch-diameter holes in

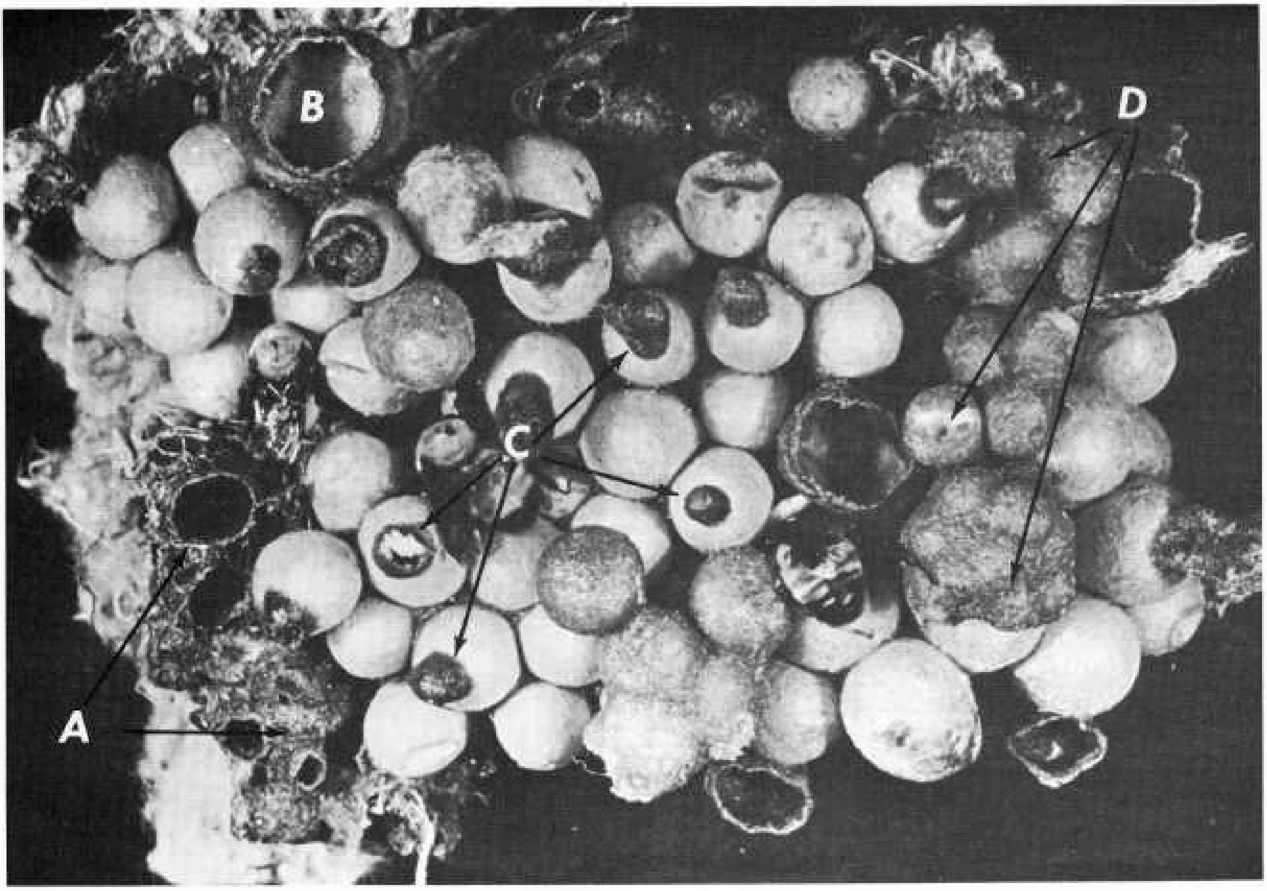

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FIGURE 2.—Nest of *Bombus morrisoni* Cresson: *A*, Honey pots; *B*, pollen tube; *C*, egg baskets on cocoons (one opened); *D*, young brood in wax cells.

which to nest. Since brood mortality is usually lower in the larger holes, many growers use only large holes. The best hole depth seems to be from 4 to 5 inches.

Nesting Materials

Of the three materials most commonly placed in the field for their use, alfalfa leafcutting bees usually prefer holes in wood to bundles of soda straws, and soda straws to stacks or rolls of corrugated cardboard. Holes cast in foam plastic (polyurethane) are also sold for leafcutter nests in the Northwest, but these are not yet well tested. These preferences are usually demonstrated when different nesting materials are combined near a natural nesting population. However, since newly emerged females tend to renest in the same kind of nest hole from which they emerged, the preferences observed may largely represent the type of nest inhabited by a natural population. It is not surprising that growers often have difficulty changing materials and hole sizes from one season to the next.

The most generally satisfactory nesting units devised so far are made of grooved boards stacked together (fig. 5). Planer blades are modified to cut a series of $\frac{3}{16}$-inch grooves in boards, which are then strapped tightly together. The principal advantages of the grooved units are clean holes, resulting from grooving with the grain, and the ease with which the units can be taken apart to clean out scavenger beetles and pollen-blocked holes.

Populations

One female per five square yards appears to be adequate for good pollination of alfalfa seed fields. If this figure is doubled to allow for the bees not actually foraging at any one time, 100,000 nesting females should be able to pollinate a 50-acre field. Since the bees tend to forage within a few hundred feet of their nests, they should be placed in shelters distributed throughout the field at about 500-foot intervals.

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FIGURE 3.—Alfalfa leafcutting bee "tripping" alfalfa florets.

Shelter Designs

The shelter should be oriented to receive the early morning sun but protect the nests from direct rays after about 10:00 a.m. It should afford some protection from wind and rain, provide good ventilation, and be conspicuous for the bees. It should accommodate at least 10,000 nesting bees, be placed at least 2½ feet above the ground, and be built so that covers or screens can be added for protection against pesticides or birds.

A box or cupboard supported on legs and protected by a shade board roof is generally satisfactory. It is also advisable to insulate the inner walls of the shelter and to paint the outside white or cover it on the top and the south and west sides with aluminum foil. At the back near the top, screened slots should be provided for ventilation. If birds are a problem, the open side of the shelter should be covered with rabbit wire. Cloth can be used to confine the bees for a few hours after insecticide applications, or until the temperature inside builds up to about 95° F. For longer protection, the shelter box can be placed in a cool, dark room.

Overwintering

By mid-September in most areas the nesting materials can be moved to an unheated room or cellar for overwintering and protection from mice. To prevent a buildup of scavenger beetles during storage and to guard against excessive temperature fluctuations, it is better to keep the nests (or cells taken from the nests) in cold-

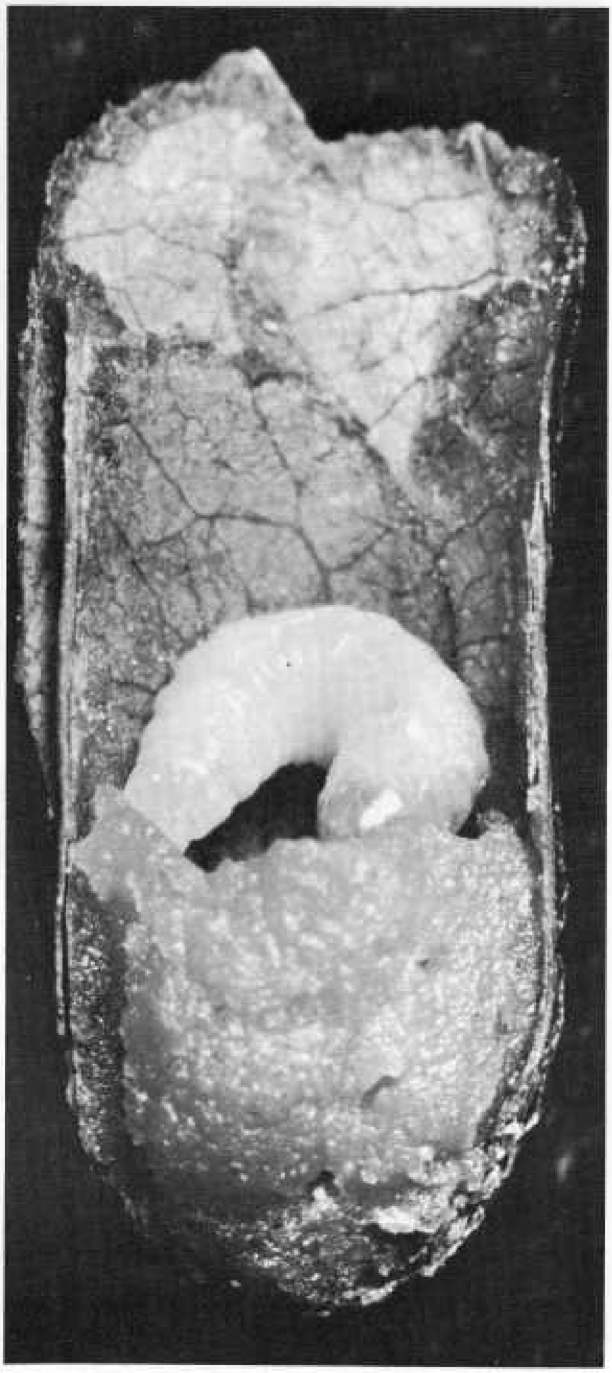

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FIGURE 4.—Cell of alfalfa leafcutting bee opened to show construction.

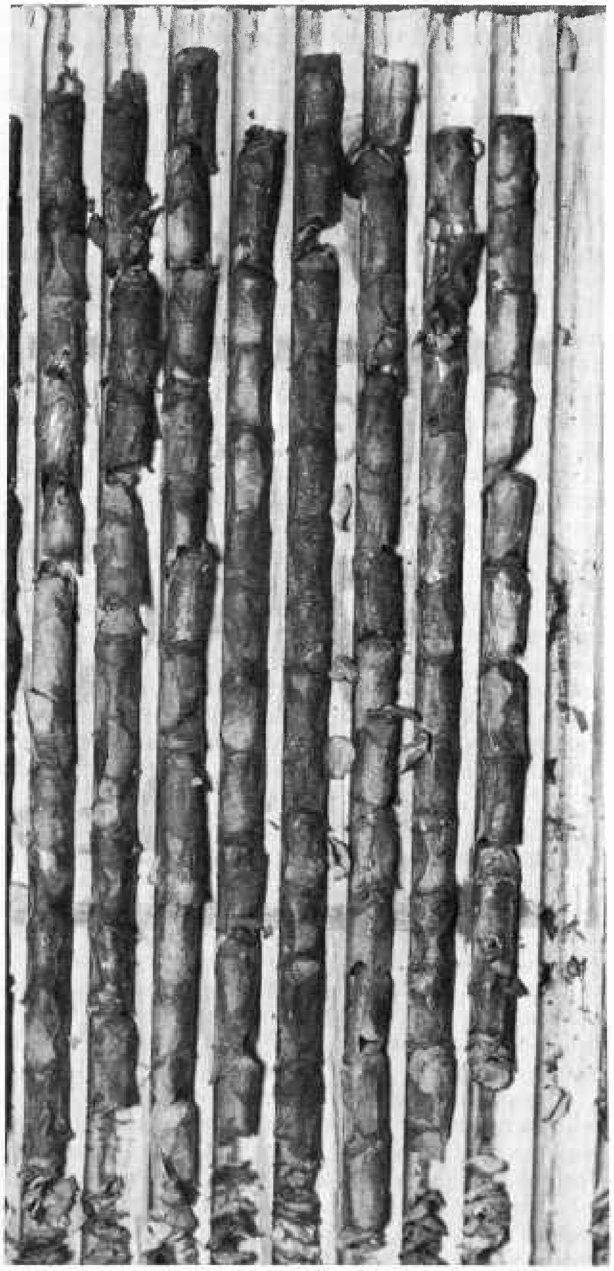

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FIGURE 5.—Cells of alfalfa leafcutting bee in grooved board unit (leaf pieces at lower right).

storage facilities at 30° to 40° F. Before nests brought from the field are placed in cold storage, they should be held at room temperature for about 12 days.

Incubation

Approximately 1 month before the bees are needed for pollination, the nests can be placed in their shelters in the field. Emergence time will vary by several weeks, depending on climatic conditions. For a more predictable emergence date, it is better to incubate the nests or loose cells at a nearly constant temperature between 86° and 90° F. until the males begin to emerge (usually about 15 days) before placing them in the field. Water should be added to the incubator to provide humidity.

To prevent bees from renesting in boxes with loose cells or in unwanted nesting materials, the nests or cells should be placed in a tight box with one or more long screen cones attached to one side. Bees trying to reenter the box will usually go to the base of the cones. Before placing loose cells in a shelter, it is important that the bees be ready to emerge. Otherwise the pupae are likely to desiccate. If the bees are being used for the first crop seed and the temperatures are rather low, the shelters should be oriented to the south until shade temperatures reach the high 80's.

Moving Adult Bees in Field

If the bees are moved after they begin nesting, they will return to their original location. If nothing but alfalfa remains, most of them will return to the new location, especially if it is marked by a large shelter to which they can orient. Several seed growers have successfully used large shelters mounted on trailers, which can be moved to areas needing additional pollination.

Protection From Parasites

The most serious parasite of the alfalfa leafcutting bee is a metallic-colored chalcid wasp with a long ovipositor (*Monodontomerus*). The female parasites lay eggs in the host cocoons during the nesting season and also in the spring before the bees emerge. The best time to control them is during incubation. Since the wasps emerge earlier than the bees under constant temperature incubation, a light can be placed over a tray of water in the incubator to attract and then drown them. Unless control measures are used during incubation, a light degree of parasitism in the fall may become almost total before the bees can emerge in the spring.

Protection From Scavenger Beetles

A species of grain beetle, *Tribolium madens* (Charpentier), and several species of carpet beetles (*Trogoderma*) infest leafcutter nests. Both groups of beetles can be baited from the nests and killed with DDT-treated pollen pellets taken from pollen traps on honey bee hives. The pellets can be placed under the nesting materials where the bees cannot contact them or in boards with shallow grooves or corrugated cardboard with flutes too narrow for the bees to enter. This method of control can be used during incubation or nesting and also during cold storage if the temperature is above 40° F. Studies in Alberta, Canada, indicate that carpet beetles can also be controlled during incubation by using the method described previously for chalcid wasp control.

Megachile concinna Smith

This species is closely related to the alfalfa leafcutting bee *Megachile rotundata* (Fabricius) and apparently arrived on the east coast of the United States at about the same time. It took a southerly route across the country, or possibly was independently introduced to Arizona, from which it spread to California. *M. concinna* differs from *M. rotundata* as follows: The adults cut leaves of shrubs and trees as well as herbaceous leaves and flower petals. It presumably has greater tolerance for high temperatures. It seems to prefer bamboo stems over straws or holes in wood. In Arizona its nests are infested with a small chalcid wasp (*Tetrastichus*), which seems to be a serious limiting factor.

Alkali Bee

The alkali bee *Nomia melanderi* Cockerell is found in scattered localities west of the eastern escarpment of the Rocky Mountains. In Nevada, Wyoming, Idaho, Utah, and the intermountain areas of Washington and Oregon it ranks with the alfalfa leafcutting bee in importance as an alfalfa pollinator. In Washington, Oregon, Idaho, and Nevada, seed growers have successfully established and maintained nesting sites for several years by following recommendations of their State experiment stations.

Alkali bees are nearly as large as honey bees and can be readily recognized by the pale-green or greenish-bronze highly polished bands across the rear part of their bodies. They are found principally in the larger valleys where poorly drained, alkaline areas are prevalent. They are abundant in some areas and totally absent in others. They may appear suddenly in large numbers in one season and disappear almost as quickly several years later.

The host range of alkali bees is rather limited. In the Delta area of Utah, only sweetclover (*Melilotus* spp.) and Russian-thistle (*Salsola kali* L.) offer serious competition to alfalfa, although a few other less abundant plants such as saltcedar (*Tamarix gallica* L.), morning-glory (*Convolvulus arvensis* L.), and various clovers are attractive. Common competitors in the area for honey bees present no attraction for alkali bees. These include greasewood (*Sarcobatus vermiculatus* (Hook.) Torr.), povertyweed (*Iva axillaris* Pursh), gumweed (*Grindelia squarrosa* (Pursh) Dunal), sunflower (*Helianthus annuus* L.), and rabbitbrush (*Chrysothamnus* spp.).

In Utah, Idaho, and Wyoming, adult males usually appear in the fields near the first of July. Females often do not appear in any large numbers until the middle or even the end of July. Males in the field are restless and stop only occasionally to feed on nectar from flowers. However, they do trip a high percentage of the flowers visited, and we have observed fields in which they have been the most important pollinators. Females work much more efficiently than males. The grower, in order to take full advantage of alkali bees, must time his bloom for late July or early August. Since there is a partial second generation, some adults may be found until September.

Alkali bees construct nest burrows in the soil from 6 to 10 inches deep (figs. 6 and 7). These bees are highly gregarious, but each female builds and provisions her own nest without help from her neighbors. A successful nest contains from 15 to 20 brood cells, in each of which is placed a ball of honey-moistened pollen and a single egg (fig. 8). As soon as the egg is laid, the mother bee seals the cell and has no further contact with her offspring. Most of the nests are constructed and provisioned during July and early August. The larva matures by late August and becomes a pupa during the following June or early July.

Characteristics of Ideal Nesting Site

An ideal nesting site is composed of a fine sandy loam, a well-drained surface, a constant underground supply of moisture extending upward to the surface, a bare or only sparsely vegetated surface, and a salty crust. This crust should not be thick or hard, and no fluffy dry layer should be under the crust.

A good nesting site may contain more than a million nests and remain populous for many years. However, after a few years, the population may decline or disappear altogether. The causes, except for untimely rains, are at least partially under the grower's control. Many farming practices that are ordinarily desirable, if done without regard for alkali bees, can sharply reduce seed yields by damaging the bees' nesting sites. Growers should remember that land occupied by an alkali bee site is worth many times the same acreage devoted to crop production.

Protection of Nesting Sites

Seed growers should find all the nesting sites within several miles of their fields and take whatever steps are needed to protect them. Usually nesting sites can be protected most effectively on a community basis, since the value of the bees

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FIGURE 6.—Female alkali bee at nest entrance.

extends beyond property lines, as does the effect of many farming practices, such as spraying and drainage. Most of the measures involve simple control over farming practices. Simply fencing off a nesting site does not necessarily protect it. This may permit excessive growth of vegetation, which removes soil moisture and shades the surface. Weeds can be eliminated by mowing or by spraying with herbicides. Skunks are readily controlled by baiting or trapping. Seed growers can organize and offer a bounty for skunks on an areawide basis.

A decline in nest density often results from a year-to-year buildup of fungus (*Aspergillus*) in the soil. By systematically removing about 20 percent of the nesting bed to a depth of about 10 inches each year and backfilling with fresh soil, it should be possible to maintain relatively "clean" beds. The removed soil can often be taken out as "plugs" with overwintering larvae and used or sold for stocking newly prepared beds.

Controlling the bee fly parasite *Heterostylum robustum* (Osten Sacken) is difficult (fig. 9). On newly established nesting sites the adult parasites are simply swatted by teams of "vigilantes." Some growers have found that "a penny a fly" is expensive but worthwhile. Blackbirds and other birds are also a serious problem in some areas. Scarecrows and firecracker devices soon lose their effectiveness.

Building and Maintaining Nesting Sites

Where a hardpan layer exists a foot or more under the soil surface, a natural nesting site can often be built by gently crowning the area and providing it with water in a series of blind, parallel irrigation ditches close enough for moisture to seep to the surface from one ditch to the next. If the water is run through draintiles laid above the hardpan and the tile has open joints covered by gravel, a better site is likely to result.

Where a natural hardpan is not present or is insufficiently impervious, plastic film can be substituted. To construct sites with plastic film, a 3½-foot-deep excavation should be prepared with a level bottom and 1-to-1 or 2-to-1 slope on the walls. The entire excavation should be lined with 0.008-inch polyethylene or 0.006-inch vinyl film overlaid with 4 to 6 inches of soil

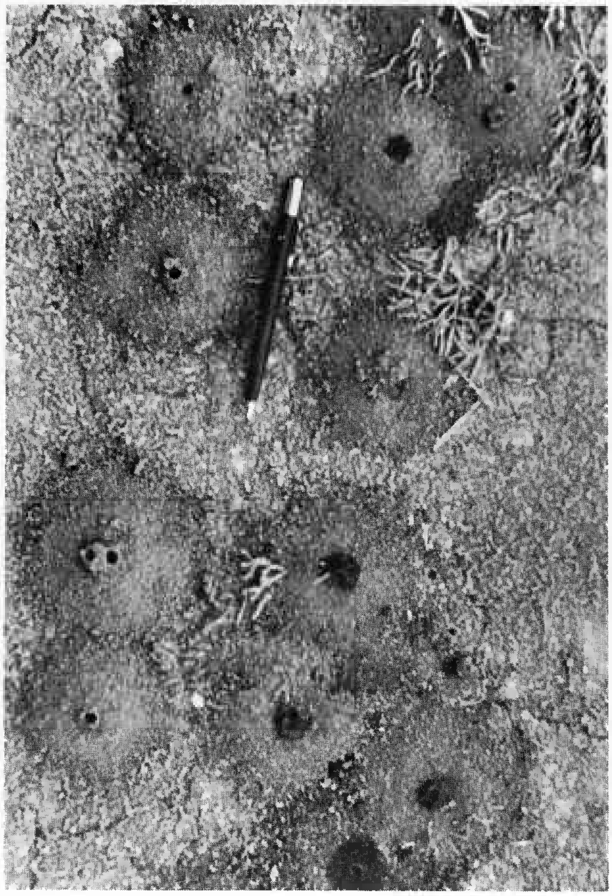

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FIGURE 7.—Nest mounds (tumuli) of alkali bees.

for protection. If the excavation is larger than the sheets of film, adjacent pieces can be overlapped on berms about 1 foot high placed where needed. This procedure creates two or more water-holding compartments. A 6- to 8-inch layer of clean gravel should be spread over the protecting soil. Some site builders lay a grid of draintile in the gravel layer to insure rapid and uniform distribution of water. At 3- or 4-foot intervals, footwide holes should be dug into the gravel and filled with soil to serve as wicks. The gravel layer should then be covered with an inch or two of straw or with plastic screen to keep dirt from plugging the gravel. One-foot-wide strips of plastic film a foot apart can also be used. The excavation should then be filled with fine sandy loam until the surface is strongly crowned. At each end of the site or of its compartments a large diameter pipe or tile should extend from above the soil surface to several inches deep in the gravel layer. The gravel should be mounded around the base of the tile. If a grid of draintile has been laid in the gravel, the standpipe should connect with it.

Water should be run into the pipes until moisture appears uniformly across the surface of the site. Where the soil is low in salt (sodium chloride), it is necessary to add stock salt at the rate of a pound per square foot to help draw moisture to the surface. The salt can be raked into the top few inches as crystals or dissolved in water and sprinkled on the surface. More salt may be required, but it is easier to add it than to remove an excess. The soil should be moist when added to the site. The moisture should be kept up to the surface in the site during the entire nesting season. Sometimes only one watering is required before the bees are active.

The size of the site depends on the acreage of alfalfa to be pollinated and the resources of the grower. Since it is unlikely that a surplus of wild pollinators will ever be developed in artificial sites, the best recommendation is to continue building and expanding them as time and resources permit. It would be advantageous for groups of farmers to pool their equipment and labor to build sites on an areawide basis.

Newly created sites can be colonized by installing blocks of undisturbed soil removed from existing sites in the spring. Steel cylinders about 1 foot long made from 12- to 18-inch well casing can be sharpened on one end and welded to a protective rim on the other. The cylinder should be cut down one side and provided with clamps to hold it together. It can be driven into a densely populated part of the site with a mallet or preferably with the hydraulic drawbar of a tractor. It can then be pried loose against an existing trench and the soil plug released from it by opening the clamps. The plug can be protected from breakage by wrapping it in bottle-wrap cardboard held in place with bands made from truck or tractor inner tubes. Another way to obtain good soil blocks is to saw them out with a chain saw or a disk saw attached to a tractor. The sawed blocks can be pried loose with cardboard cartons slipped over them.

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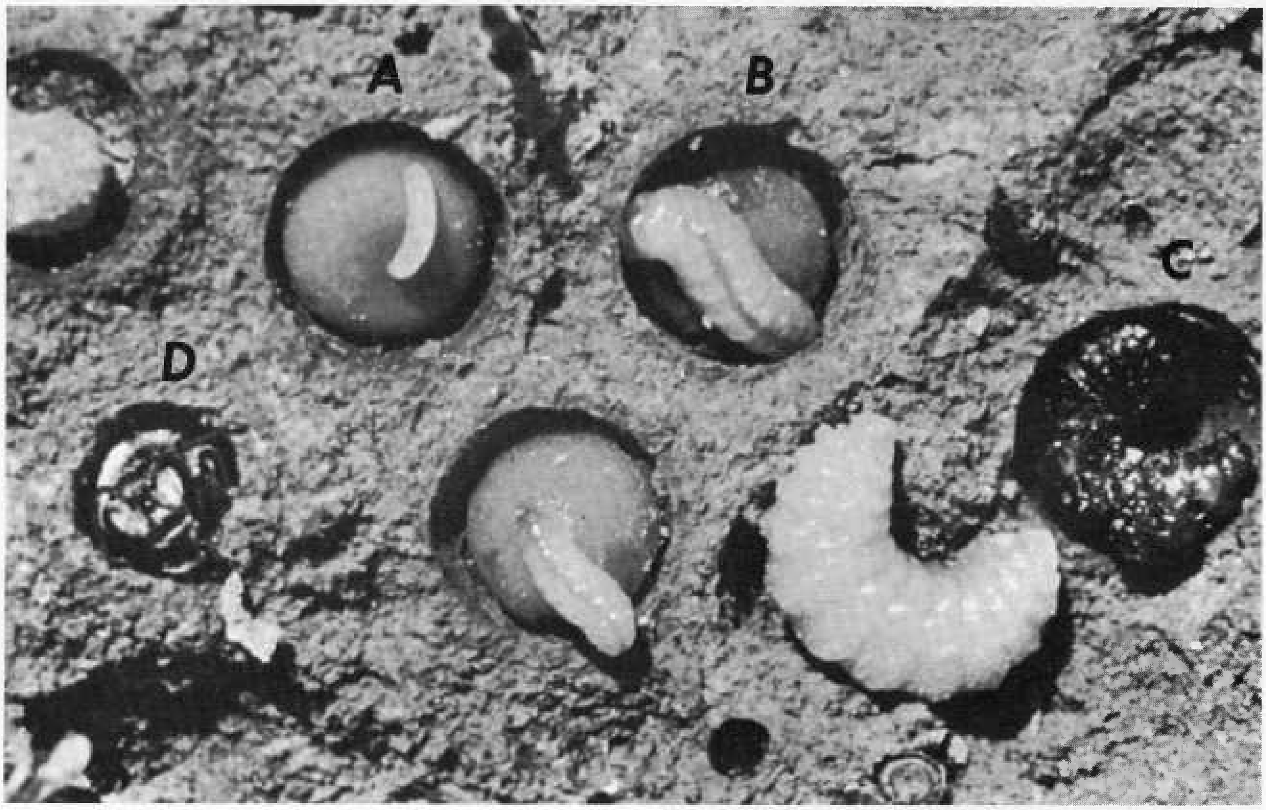

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Figure 8.—Alkali bee nest (horizontal section at cell level): *A*, Egg on pollen ball; *B*, growing larva; *C*, diseased larva; *D*, adult in main burrow.

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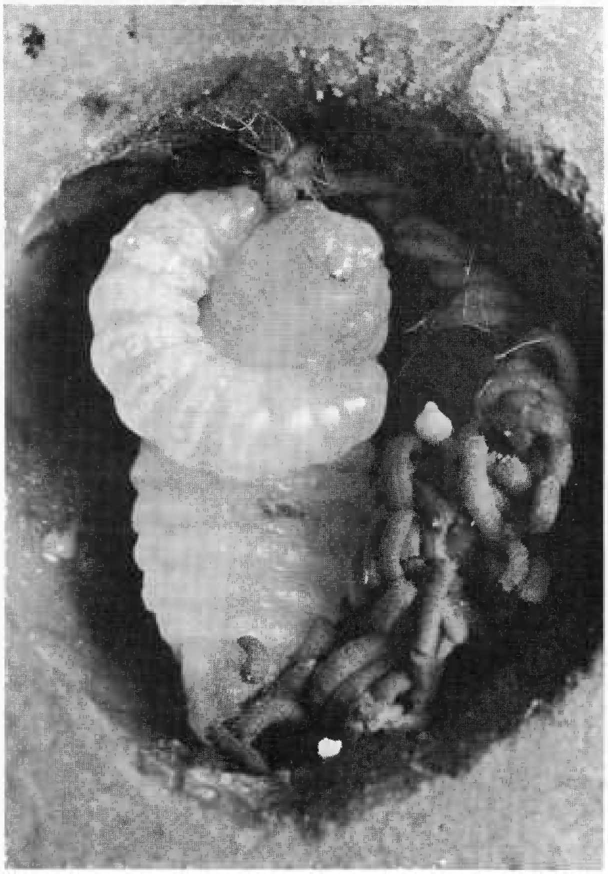

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FIGURE 9.—Third-instar larva of bee fly parasite feeding on alkali bee prepupa. (Artificial cell—fecal pellets not in natural position.)

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FEDERAL AND STATE BEE LAWS AND REGULATIONS

By A. S. MICHAEL, *Assistant Chief, Apiculture Research Branch, Entomology Research Division, Agricultural Research Service*

The Federal Government has no laws or regulations pertaining to honey bees or beekeeping within the United States. However, on August 31, 1922, Congress passed a law, popularly known as the Honeybee Act, restricting the importation of living adult honey bees into the United States. This act was amended in 1947 and again in 1962. This last amendment, Public Law 87–539, dated July 19, 1962, resulted in the establishment of the following regulations covering all living adults of the genus *Apis:*

> The importation into the United States of adult honey bees is prohibited and all adult honey bees offered for entry shall be destroyed if not immediately exported, with the following exceptions.
>
> No disease dangerous to adult honey bees exists in Canada other than those already present in the United States and adequate precautions have been taken to prevent the importation of adult honey bees into Canada from countries where such dangerous diseases are known to exist. Therefore, the unrestricted importation of adult honey bees from Canada by any person is authorized.
>
> Importation of adult honey bees from any country other than Canada shall be conditioned upon a determination that no such diseases dangerous to adult honey bees exist in the country in question and that adequate precautions have been taken by that country to prevent the importation or entry of adult honey bees from countries where such dangerous diseases exist. The determination shall be based upon adequate investigations by the Agricultural Research Service of the United States Department of Agriculture. In the absence of substantial evidence that diseases dangerous to adult honey bees do not exist in the country in question or that adequate precautions have been taken by the country in question to prevent the importation or entry of adult honey bees from countries where such dangerous diseases exist, importation is prohibited. If under the conditions existing in areas surrounding the country in question, adequate precautions cannot be taken by such country to prevent the entry of adult honey bees from countries where diseases dangerous to adult honey bees exist, importation is prohibited.
>
> The Agricultural Research Service, United States Department of Agriculture, may import into the United States from any country adult honey bees for experimental or scientific purposes.

The first apiary inspection law in the United States was established in San Bernardino County, Calif., in 1877. By 1883, a statewide law was passed by the California legislature, and by 1906, 12 States had laws relating to foulbrood. At present, almost all States have laws regulating honey bees and beekeeping.

State laws and regulations relating to honey bees and beekeeping are designed primarily to control bee diseases. Therefore, they usually attempt to regulate movement and entry of bees, issuances of permits and certificates, apiary location control and quarantine, inspection, and methods of treating diseased colonies. These laws and regulations are summarized in tables 1 and 2. Table 1 is a compilation of the bee laws for intrastate regulation; table 2 is a compilation of bee laws regulating interstate movement of bees and used bee equipment in the United States.

As will be noted from these tables, there is a lack of uniformity in State bee laws and regulations, but considerable agreement on specific points of law. Most of the States require registration of apiaries, permits for movement of bees and equipment interstate, certificates of inspection, right of entry of the inspector, movable-frame hives, quarantine of diseased apiaries, notification of the owner upon finding disease, prohibition of sale or transfer of diseased material, and use of penalties in the form of fines or jail or both. Although the destruction of American foulbrood diseased colonies is included in most State laws, table 1 shows that most States also allow the use of drugs for control or preventive treatment of this disease.

The key figure in the enforcement of bee laws and regulations is the apiary inspector. He may have the entire State, a county, or a community under his jurisdiction. His efforts are directed toward locating American foulbrood and eliminating sources of it whenever found.

The effectiveness of bee laws and regulations is based on the compliance of the beekeepers. In the final analysis, responsibility for disease control remains with the beekeeper, who should routinely examine colonies for disease as a regular part of his management program and take the necessary steps when disease is found.

Copies of State apiary laws and regulations are available from the various State departments of agriculture. State apiary inspectors can also be consulted in care of their State department of agriculture.

TABLE 1.—*Summary of U.S. intrastate bee laws and regulations, 1967* [1]

Item	Alabama	Alaska	Arizona	Arkansas	California	Colorado	Connecticut	Delaware	Florida	Georgia	Hawaii	Idaho	Illinois	Indiana	Iowa	Kansas	Kentucky	Louisiana	Maine	Maryland	Massachusetts	Michigan	Minnesota	Mississippi	Missouri
REQUIRED																									
Registration—apiary	X	----	X	X	X	----	X	X	X	X	----	X	----	----	----	X	X	----	X	X	----	X	X	----	
Registration—queen apiary	----	----	----	----	----	----	----	X	X	X	----	----	----	----	----	----	----	----	----	----	----	X	----	----	
Identification—apiary	X	----	X	----	X	X	----	----	X	----	----	X	----	----	----	----	----	----	----	X	----	----	----	----	
Permit—movement bees and equipment	X	----	X	X	----	----	X	----	X	X	----	X	X	----	X	X	X	X	----	X	----	X	X	X	
Certificate—inspection	----	----	X	X	X	----	X	X	X	X	----	----	X	----	----	X	X	X	X	----	X	----	X	X	
Inspection—apiaries	X	----	X	X	X	X	X	X	X	X	----	X	X	X	X	X	X	X	X	X	X	X	X	X	
Inspection—honey houses	----	----	----	----	----	X	----	----	X	----	----	----	----	----	----	----	----	----	----	X	----	X	X	----	
Entry—right of inspector	X	----	X	X	X	X	X	X	X	----	----	X	X	----	X	X	X	X	X	X	X	X	X	----	
Hives—movable-frame	X	----	X	----	X	X	----	X	X	----	----	X	----	----	X	X	X	----	----	X	X	X	X	----	
Declaration of disease	----	----	----	X	----	X	----	X	----	----	----	----	----	----	----	----	----	----	X	----	----	----	----	----	
Quarantine—diseased apiaries	X	----	X	----	X	X	X	X	X	X	----	X	----	----	----	X	X	X	----	X	----	X	X	X	
Notification—of owner	X	----	X	X	X	X	X	X	X	----	----	X	X	----	X	X	----	----	----	X	X	X	----	----	
Destruction—AFB [2] diseased colonies	X	----	X	X	X	X	----	X	X	X	----	X	X	X	----	X	X	X	----	X	----	X	----	X	
Disinfection—person, clothing, appliances by inspector	----	----	----	X	----	X	----	X	----	----	----	X	----	----	----	----	----	----	----	----	----	X	X	----	
Tax	----	----	----	----	----	----	----	----	----	----	----	X	----	----	X	X	----	----	----	----	----	----	----	----	
Fees	X	----	----	----	X	----	X	----	----	X	----	----	----	----	----	X	X	----	X	----	----	X	X	----	
Penalties:																									
Fines	X	----	----	X	X	X	X	X	X	X	----	----	X	----	X	X	X	X	X	----	X	X	----	----	
Jail	X	----	----	----	X	----	----	----	X	X	----	----	----	----	X	----	X	X	----	----	----	X	----	----	
PROHIBITED																									
Concealment of disease	----	----	----	----	X	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	X	----	----	
Exposure of diseased material	----	----	X	X	X	----	----	X	X	----	----	----	----	----	----	----	----	----	----	X	----	X	----	X	
Sale or transfer of diseased material	----	----	----	----	X	X	X	X	X	----	----	X	X	----	X	----	----	X	X	X	X	X	X	X	
PERMITTED																									
Appeal	X	----	----	----	X	----	----	X	----	----	----	----	X	----	----	----	----	----	----	----	----	X	----	----	
Wax salvage plants	----	----	----	----	X	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	
Drug treatment—control	X	----	----	----	----	X	X	----	----	----	----	X	----	X	X	X	----	----	X	X	X	----	X	----	
Drug treatment—preventive	----	----	X	----	----	X	----	----	X	----	X	----	X	X	X	X	X	----	X	X	X	X	X	X	

See footnotes at end of table.

TABLE 1.—*Summary of U.S. intrastate bee laws and regulations, 1967* [1]—Continued

Item	Montana	Nebraska	Nevada	New Hampshire	New Jersey	New Mexico	New York	North Carolina	North Dakota	Ohio	Oklahoma	Oregon	Pennsylvania	Rhode Island	South Carolina	South Dakota	Tennessee	Texas	Utah	Vermont	Virginia	Washington	West Virginia	Wisconsin	Wyoming
REQUIRED																									
Registration—apiary	X	X	X	----	----	X	X	----	X	X	X	X	----	X	----	X	X	----	X	----	----	X	----	----	X
Registration—queen apiary	----	X	X	----	----	----	----	----	----	X	----	----	----	X	----	----	----	----	----	----	----	X	----	----	
Identification—apiary	X	X	X	----	----	X	----	----	----	X	----	X	----	----	----	----	----	----	----	----	----	X	----	----	
Permit—movement bees and equipment	X	X	X	----	----	----	X	X	----	X	----	X	----	X	X	X	X	----	X	----	X	----	X	X	
Certificate—inspection	----	X	----	----	X	X	----	X	X	X	X	X	X	----	----	X	X	----	X	----	X	----	----	----	X
Inspection—apiaries	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	----	X	X	X
Inspection—honey houses	X	X	----	----	----	----	----	----	X	----	X	----	----	----	----	X	X	----	X	----	X	----	----	X	X
Entry—right of inspector	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	----	X	X	X	X	----	X	X
Hives—movable-frame	X	X	X	X	X	X	X	X	X	X	----	X	X	X	----	X	X	----	X	----	X	X	----	X	X
Declaration of disease	----	X	----	----	----	----	X	----	----	----	----	----	----	----	----	----	X	----	X	----	X	----	X	X	X
Quarantine—diseased apiaries	X	X	X	X	X	X	X	X	----	X	X	X	X	----	X	X	X	----	X	----	X	X	----	X	
Notification—of owner	X	X	X	X	X	X	X	----	X	----	X	X	X	X	----	X	X	----	X	----	X	X	X	----	X
Destruction—AFB [2] diseased colonies	X	X	X	X	X	X	X	X	X	X	X	X	X	X	----	X	X	X	X	X	X	X	X	X	X
Disinfection—person, clothing, appliances by inspector	----	----	X	----	----	----	----	----	X	----	X	----	X	X	----	X	X	----	X	X	X	X	----	----	X
Tax	----	X	X	----	----	X	----	----	----	----	----	----	X	----	----	----	X	----	----	----	----	----	----	X	
Fees	X	X	X	----	----	X	----	----	X	X	----	X	----	----	----	X	----	----	X	----	----	----	----	----	
Penalties:																									
Fines	X	X	----	X	X	X	X	----	X	X	----	X	X	X	X	X	X	----	----	X	X	X	X	----	X
Jail	X	X	----	X	----	X	----	----	X	----	----	X	X	----	X	----	----	----	----	----	X	----	----	----	
PROHIBITED																									
Concealment of disease	----	X	X	----	X	X	X	----	----	----	----	----	X	----	----	----	X	----	X	----	----	----	----	----	X
Exposure of diseased material	----	X	X	----	----	----	X	X	X	----	X	X	----	X	X	X	X	----	----	----	----	----	----	X	X
Sale or transfer of diseased material	X	X	X	----	X	----	X	X	X	X	X	X	X	X	X	X	X	----	X	X	X	X	X	X	
PERMITTED																									
Appeal	X	----	----	----	----	----	X	----	----	X	----	X	X	----	----	----	----	----	----	----	X	----	----	----	
Wax salvage plants	----	X	----	----	----	----	----	----	----	----	----	----	X	----	----	----	----	----	X	----	----	----	----	----	
Drug treatment—control	----	----	----	X	----	X	----	----	X	----	----	----	X	X	----	----	X	X	----	X	----	----	X	X	(3)
Drug treatment—preventive	X	X	X	X	----	----	X	----	----	X	X	X	X	X	----	----	X	X	----	----	X	X	X	X	X

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[1] Based on information supplied by various State departments of agriculture. [2] American foulbrood. [3] European foulbrood only.

TABLE 2.—*Summary of U.S. quarantine requirements for interstate movement of bees and used beekeeping equipment, 1967* [1]

Item	Alabama	Alaska	Arizona	Arkansas	California	Colorado	Connecticut	Delaware	Florida	Georgia	Hawaii	Idaho	Illinois	Indiana	Iowa	Kansas	Kentucky	Louisiana [2]	Maine	Maryland	Massachusetts	Michigan	Minnesota	Mississippi	Missouri
BEES ON COMB AND USED BEEKEEPING EQUIPMENT																									
Prohibited entry	X																	X				X			
Permit required			X	X		X			X	X	X	P		X		X	X						X	X	
Disease-free history 2 years									X	D														X	
Locations controlled												X				X							X		
Certificate with application			G	H		F_1			F	F	F_1	F_1		F		F_1							F_1	F	
Certificate to accompany load					G		X	F_1					F_1		X				F_1	F_1	F_1				
Time limit for certificate inspection [3]			90		V	60			30	30			60			180	30		60		60		60	60	
Permit in lieu of certificate								R	R				X		X										
Inspection stamp on hives																									
Advance location filing [3]			X	X					10			10		X		X							30		
Notification upon arrival [3]			M		3	X																			
Postentry quarantine [3]				U							Q														
Entry fee [4]				X								X				X							X		
Special requirements for used equipment	C										O					X									
Certificate required for honey																									
PACKAGE BEES																									
Certificate required [3]	60		O	L	S		L	L	S	X	L	X				X	X		L	O	O	X		X	
Cage food restriction					A							I					X							A	
QUEEN BEES																									
Certificate required [3]	60		O	L			L	L	S	X	L	X				X	X		L	O	O	X		X	
Cage food restriction					A							I					X							A	

Footnotes at end of table.

TABLE 2.—*Summary of U.S. quarantine requirements for interstate movement of bees and used beekeeping equipment, 1967* [1]—Continued

Item	Montana	Nebraska	Nevada	New Hampshire	New Jersey	New Mexico	New York	North Carolina	North Dakota	Ohio	Oklahoma	Oregon	Pennsylvania	Rhode Island	South Carolina	South Dakota	Tennessee	Texas	Utah	Vermont	Virginia	Washington	West Viginia	Wisconsin	Wyoming
BEES ON COMB AND USED BEEKEEPING EQUIPMENT																									
Prohibited entry		Z						X																	
Permit required		N	P					X	X	X			X			X	X				X	X		X	X
Disease-free history 2 years		3 yrs.	1 pct.													X									
Locations controlled		X	X													X									
Certificate with application		F						X	F_1	X						X	F_1				F_1				X
Certificate to accompany load	F_1	X	F_1Y	F_1	F_1	F_1Y	GY		F_1	F	F	F_1	F_1	F_1	F_1	G	X	F_1Y	F_1Y	F_1	F_1	F_1Y	F_1	F_1	X
Time limit for certificate inspection [3]		60	60			90	60		90			60	30		60	60	60	60	30						V
Permit in lieu of certificate					R																				
Inspection stamp on hives	K												X			X									X
Advance location filing [3]		60	X			X												10		1					
Notification upon arrival [3]			X			X			X	10		5	X				X					3		5	
Postentry quarantine [3]	90		X										X									30			
Entry fee [4]	X		X													X									X
Special requirements for used equipment															T		X							E	
Certificate required for honey																							F		
PACKAGE BEES																									
Certificate required [3]	X		30Y	F_1	O	L	X	60	90	X		L				X	X		L	X	X	X	F_1	L	L
Cage food restriction			B					X		X															A
QUEEN BEES																									
Certificate required [3]	X		30Y	F	O	L	X	60	90	X		L	X			X	X		L	X	X	X	F_1	L	L
Cage food restriction			B					X		X							X					B	B		B

See footnotes on page 124.

[1] Based on Summary of Quarantine Requirements for Interstate Movement of Bees and Used Beekeeping Equipment in the United States and Canada, January 1966, by H. Len Foote, Calif. Dept. Agr., plus additional information supplied by various State departments of agriculture. Letters in table indicate following information:

(A) "No honey" affidavit signed by shipper.
(B) Honey used in food must be boiled 30 minutes.
(C) Limited to clean package cages or honey containers for shipment out of State.
(D) Not eligible if drugs used to treat AFB (American foulbrood).
(E) Permit only.
(F) Show apiary free of disease; F_1 shipment free of disease.
(G) Statement of findings showing AFB destroyed.
(H) Beekeeper must file sworn affidavit of inspection.
(I) Inspector must certify honey boiled 30 minutes.
(K) Advance notice giving shipment date and marking.
(L) Same as for bees on comb.
(M) Permit surrendered at border inspection station and release obtained.
(N) Nucs (brood in every comb) only; disqualified for 30 days if disease found in apiary; barred for previous bee law conviction.
(O) No restrictions.
(P) Pollination only 6-month limit; colony strength standards enforced.
(Q) Unspecified period.
(R) Beekeeper must file report of inspection.
(S) Season issued.
(T) Equipment must be disinfected (Nevada: Treatment must be certified).
(U) Unloaded at border for inspection.
(V) Variable. California: Season issued; certificate from cold area showing inspection after Aug. 1 valid until following Apr. 1. Wyoming: Sept. 16–Mar. 31, no time limit; Apr. 1–June 15, 30 days; June 15–Sept. 15, 10 days.
(X) Yes—unspecified.
(Y) Copy of certificate must be sent in advance.
(Z) Prohibited entry except for nuclei, which must have brood in every comb.

[2] Package bees and queens from apiary free of American foulbrood for 1 year; certifying inspection within 60 days.

[3] Numbers refer to days.

[4] Entry fees: Arkansas, 25¢ per colony; Idaho, 25¢ per colony; Kansas, 10¢ per colony or $1 per application (minimum); Minnesota, $1.50 per apiary plus $1.50 per colony; Montana, inspection cost @ $10 per diem plus travel and $5 certification fee; Nevada, 25¢ per colony; South Dakota, 50¢ per colony; Wyoming, 25¢ per colony.

FEDERAL AND STATE APICULTURE ACTIVITIES

By S. E. McGregor, *Chief, Apiculture Research Branch, Entomology Research Division, Agricultural Research Service*

Federal Research

Research on honey bees by the U.S. Department of Agriculture was initiated in 1885 and has been continuous since 1891. It is presently under the direction of the Entomology Research Division, Agricultural Research Service, with headquarters at Plant Industry Station, Beltsville, Md. This agency often acts as technical adviser to bee-related industries and is a source of scientific and popular publications on bees. The research studies conducted in six field laboratories are as follows:

Arizona, *University of Arizona,*[1] *Tucson.*—Pollination of various crops, bee nutrition and physiology, bee behavior, and effect of pesticides on bees; cooperative study between Entomology Research Division and Agricultural Engineering Research Division on mechanization of beekeeping methods and equipment.

Louisiana, *Louisiana State University,*[1] *Baton Rouge.*—Bee breeding and bee genetics, nosema disease, nectar and pollen plants, and whiteclover pollination.

Maryland, *Agricultural Research Center, U.S. Department of Agriculture, Beltsville.*—Bee diseases, their control, and relationship of bee nutrition to bee diseases; disease diagnostic service for beekeeping industry and Bee Culture Branch of National Agricultural Library located here (see p. 128).

Utah, *Utah State University,*[1] *Logan.*—Commercial use of wild bees as pollinators, effect of pesticides on both honey bees and wild bees, and honey bee pollination.

Wisconsin, *University of Wisconsin,*[1] *Madison.*—Productive management of colonies for high yields, use of two-queen colonies, bee disease control, queen rearing, feeding of pollen supplements; cooperative study between Entomology Research Division and Agricultural Engineering Research Division on honey handling and processing.

Wyoming, *University of Wyoming,*[1] *Laramie.*—Bee diseases in open colonies, mode of transmission of bee diseases within and between colonies, disease resistance, and bee poisoning.

The U.S. Department of Agriculture also supports research on bees in the form of grants or cooperative agreements (about 3 years) at State universities. These institutions and studies are as follows:

University of Arizona, Tucson.—Innate and acquired immunity in honey bees.

University of Illinois, Urbana.—Behavioral study of effect of hormonal secretions of queen honey bee (*Apis mellifera* L.) on industriousness of worker honey bees.

Michigan State University, East Lansing.—Honey bee pollination requirements of hybrid cucumbers.

Ohio State University, Columbus.—Pathogenesis and diagnosis of nosema disease in *Apis mellifera* L.

Utah State University, Logan.—Glands in bees, their topography, innervation, morphology, histology, and physiology.

Research is also supported abroad with Public Law 480 funds, popularly known as P.L. 480 or the Food for Peace Program. This research includes the following studies:

Egypt.—Biology, ecology, and utilization of insects other than honey bees in pollination of agricultural crops.

India.—Biology, ecology, and utilization of insects other than honey bees in pollination of agricultural crops.

Italy.—Acarine disease of honey bees.

Poland.—Distance of mating flights of honey bee queens and drones, necessary isolation of mating stations to prevent mismatings, and biology and utilization of diploid drone honey bees.

The agencies of the U.S. Department of Agriculture concerned in some way with bees, honey, or wax and their areas of interest are as follows:

Agricultural Research Service, *Agricultural Engineering Research Division, Farm Electrification Research Branch.*—Mechanization of beekeeping and bee equipment, honey processing, and handling (see pp. 37–51); *Entomology Research Division, Agriculture Research Branch.*—Bee research investigations; *Pesticide Chemicals Research Branch.*—Determines toxicity of pesticides to bees under laboratory conditions; *Plant Pest Control Division, Pesticide Safety and Monitoring.*—Monitoring long-term effect of pesticides on bees; *Plant Quarantine Division, Program Development and Service Staff, Technical Services.*—Enforces Federal Honey Bee Act, which restricts entry of adult honey bees to prevent introduction and spread of certain bee diseases (see p. 119).

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[1] Cooperator.

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Agricultural Stabilization and Conservation Service, *Sugar Policy Staff.*—Focal point in formulation and recommendation on honey price support program; *Policy and Program Appraisal Division, Price Program Development Staff.*—Prepares price support and other national programs for honey (see p. 136); *Farmer Programs Division, Price Support Branch.*—Writes program regulations and provisions under which county ASC committees administer program; *Procurement and Sales Division.*—Supervises taking title to unredeemed honey under Commodity Credit Corporation price support loan, and processing, sales, and other disposition of such honey as may be necessary; *Minneapolis (Minn.) ASCS Commodity Office.*—Responsible for acquiring title to price supported honey and for its storage and disposition.

Consumer and Marketing Service, *Fruit and Vegetable Division, Market News Branch.*—Prepares monthly Honey Market News report; *Processed Products Standardization and Inspection Branch.*—Grade standards and inspection of honey; *Specialty Crops Branch.*—Honey Marketing Aids (see p. 134).

Federal Extension Service, *Agricultural Science, Technology and Management Division.*—Extension entomologist advises State entomologists on apiculture matters.

Foreign Agricultural Service, *General Sales, Export Sales and Pricing, Tobacco, Peanuts, Naval Stores, and Honey.*—Foreign sales of surplus products; *Commodity Programs, Sugar and Tropical Products Division, Commodity and Products Analysis Branch.*—Production and world supply of honey (see p. 143).

National Agricultural Library, *Field and Special Services, Division of Field Services, Bee Culture Branch* (see p. 128).

Statistical Reporting Service, *Agricultural Estimates Division, Livestock, Dairy and Poultry Branch.*—Statistics on bees and honey (see p. 139).

State Research

The States with one or more full-time apiculturists and their areas of research are as follows:

California, *University of California, Davis.*—Breeding and genetics of honey bees, mechanism of bee behavior, pollination, and bee mites; *Riverside.*—Laboratory and seasonal field tests on effect of pesticides on bees; *Santa Barbara.*—Communication in honey bees.

Florida, *University of Florida, Gainesville.*—Pollination, pollen substitutes, and bee disease control; *Vineland.*—Watermelon pollination by honey bees.

Georgia, *Coastal Plain Experiment Station, Tifton.*—Controlling pests of honey bee and miscellaneous bee problems.

Illinois, *University of Illinois, Urbana.*—Bee behavior and value of bees in crop pollination.

Maryland, *University of Maryland, College Park.*—Nutrition and caste determination in honey bees.

New Jersey, *Rutgers—The State University, New Brunswick.*—Blueberry pollination and bee diseases.

New York, *Cornell University, Ithaca.*—Bee behavior, pollination, pesticides, and honey.

Ohio, *Ohio State University, Columbus.*—Genetics of American foulbrood resistance in honey bees.

Oregon, *Oregon State University, Corvallis.*—Bee behavior and pollination.

Pennsylvania, *Pennsylvania State University, University Park.*—Bee venom and bee diseases.

Washington, *Washington State University, Pullman.*—Pollination and effects of pesticides on bees.

Occasional research, as situations arise, is conducted on bees in the following States:

Alaska, *University of Alaska, College.*—Improving efficiency of Alaska's insect pollinators.

Arizona, *University of Arizona, Tucson.*—Pollen substitutes.

Arkansas, *University of Arkansas, Fayetteville.*—Honey and pollen plants.

Idaho, *University of Idaho, Moscow.*—Pollination of vegetable seed crops.

Indiana, *Purdue University, Lafayette.*—Bee behavior in flight room.

Massachusetts, *University of Massachusetts, Amherst.*—Effect of pesticides on honey bees.

Michigan, *Michigan State University, East Lansing.*—Pollination.

Minnesota, *University of Minnesota, St. Paul.*—Bee nutrition and methods of bee management.

Rhode Island, *University of Rhode Island, Kingston.*—Bee diseases.

Utah, *Utah State University, Logan.*—Bee anatomy, pesticides, wild bees, and pollination.

Wisconsin, *University of Wisconsin, Madison.*—Biology of bumble bees, pollination, and bee-management studies.

One or more courses in beekeeping are taught in universities or colleges in Alabama, Arizona, Arkansas, California, Colorado, Florida, Illinois, Kansas, Louisiana, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Jersey, New York, North Carolina, North Dakota, Ohio, Pennsylvania, South Carolina, South Dakota, Utah, Virginia, and Wisconsin.

California, Florida, Ohio, and Pennsylvania have full-time extension bee specialists. Part-time extension work by apiculturists is conducted in

Illinois, Maryland, Michigan, Minnesota, New Jersey, and New York. Attention in varying degrees is given to apiculture by extension entomologists in other States. The Federal Extension Service employs one extension entomologist, who devotes part time to apiculture (see p. 126).

Almost every State has some form of apiary inspection service (see p. 119).

COLLECTIONS OF BEE LITERATURE

By JULIA S. MERRILL,[1] *librarian, Bee Culture Branch, National Agricultural Library*

The United States is fortunate to possess a good share of the bee literature of the world. The best known collections in the United States are at the U.S. Department of Agriculture, Cornell University, and the Universities of California, Minnesota, and Wisconsin. Canada has a sizable collection at the University of Guelph in Ontario.

U.S. Department of Agriculture

The Bee Culture Branch of the Department's National Agricultural Library at Beltsville, Md., has one of the largest collections of bee literature in the United States. It was started in the 1920's by James I. Hambleton of the former U.S. Bureau of Entomology.

This library now has about 6,500 bound volumes, over 2,000 scientific reprints, and about 500 translations. It currently receives 121 periodicals relating to beekeeping, 79 of which are in foreign languages. In addition to current books and periodicals relating to fundamental or applied research, this library has several volumes of historic value. Most of the older books added in recent years have been obtained through gift or exchange. The library receives $1,000 annually for the purchase of books and periodicals. Additional funds are sometimes made available.

To facilitate reference service and literature searches, an annotated card index of selected references from the world's literature on apiculture and closely related subjects was started in the 1920's. This Beekeeping Bibliography, as it is familiarly known, is currently maintained as a joint project of the Bee Culture Branch of the National Agricultural Library and the Entomology Research Division, Agricultural Research Service. References are added monthly, and copies are sent to the apiculture field laboratories of the Department of Agriculture in Tucson, Ariz., Baton Rouge, La., Logan, Utah, Madison, Wis., and Laramie, Wyo.

With this index, information on almost any subject relating to bees can be located. For instance, there are over 2,200 references on the role of the honey bee in plant pollination, 1,300 cards on the toxicity of insecticides to bees, and numerous references on such diversified subjects as bee anatomy, behavior, genetics, diseases, honey, beeswax, venom, colony management, and State and Federal laws relating to bees.

In addition to the bee literature, references for inclusion in the Beekeeping Bibliography are obtained from medical, biological, agricultural, and other nonbeekeeping books and periodicals. Abstract journals are covered as well as the Bibliography of Agriculture and Pesticides Documentation Bulletin, which are monthly publications of the National Agricultural Library. Each reference is filed by author and subject under one or more of the 28 major classifications and over 200 subheadings. Special bibliographies are prepared on request for Department of Agriculture personnel and for others as time permits.

The Bee Culture Branch has a translator. Translations from Dutch, French, German, Russian, and Spanish are prepared. The original remains in the library, and a copy is sent to each apiculture laboratory of the Department. Copies are also sent to the National Agricultural Library, Washington, D.C., and the Clearing House for Federal Scientific and Technical Information, Springfield, Va. Translations are exchanged with the Department of Apiculture, University of Guelph, Ontario, Canada; the Apiculture Section, Canada Department of Agriculture, Ottawa; and the Bee Research Association, an international organization for the furtherance of bee science, Gerrards Cross, Buckinghampshire, England. No list of translations is available, but each is noted in the Department's Bibliography of Agriculture.

Though the essential function of this library is to serve the U.S. Department of Agriculture bee research staff, anyone is welcome to use the library. Publications may be borrowed on interlibrary loan, but no individual loans are made to other than Department personnel. Photoprint and microfilm copies of articles or translations may be ordered from the Photoduplication Section, National Agricultural Library, U.S. Department of Agriculture, Washington, D.C. 20250. Photoprints cost $1 for each four pages, or fraction,

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[1] Grateful acknowledgment is made to the following people for supplying statistical and historical information: J. Richard Blanchard, librarian, University of California, Davis; Mrs. Evelyn L. Gish, entomology librarian, University of Minnesota, Minneapolis; Emory M. Pittenger, agricultural librarian, University of Wisconsin, Madison; Whiton Powell, librarian, Albert R. Mann Library, Cornell University, Ithaca, N.Y.; and Gordon F. Townsend, Head, Department of Apiculture, University of Guelpb, Ontario, Canada.

from a single book or article, and microfilm costs $1 for each 30 pages, or fraction.

Cornell University

The Phillips Memorial Beekeeping Library at Cornell University, Ithaca, N.Y., has valuable and beautifully bound books acquired by the late Everett F. Phillips when he was in charge of apiculture research at the U.S. Department of Agriculture and while he was Professor of Apiculture at Cornell University. Included in this collection are such items as the original patent granted to Lorenzo Lorraine Langstroth, "the father of modern beekeeping," for his movable-frame hive, his diary and letters written in his own hand, and original manuscripts of several editions of Moses Quinby's Mysteries of Beekeeping Explained. These, along with manuscripts of Dr. Phillips' own books and 1,000 more volumes printed before 1900, are kept in locked cases on a balcony overlooking the reference room of the Albert R. Mann Library at Cornell University. The bee periodicals, books, and pamphlets published in the 20th century are shelved with the general collection in the stacks.

The budget for sustaining the Phillips collection currently amounts to $700. This is the income from an endowment fund derived partly by gifts from beekeepers and partly from the Dyce Honey Crystallization process patent. The patent was given to Cornell University by its owner, Elton J. Dyce, now retired, who was Dr. Phillips' successor.

University of California

The University of California at Davis has 1,630 books and bound periodicals on bees, 66 of which are rare volumes. It currently receives 32 foreign and seven American bee journals. Noteworthy is the John S. Harbison manuscript collection dating from 1857 to 1912. Harbison was one of the first beekeepers to import bees into California. This collection includes his records of these shipments from New York to Sacramento by boat, freight receipts, records of other business transactions, and patent grants.

University of Minnesota

The collection of bee literature at the University of Minnesota in Minneapolis was begun about 1900 by Father Jager, a Catholic priest. The Division of Beekeeping, of which he was head, was then a one-man department. In 1928, the Division was consolidated with the Department of Entomology and Economic Zoology, and Father Jager's books were cataloged for the Entomology Library. Approximately 850 bee books are now on hand, 150 of which are kept under lock and key because of their age or because they are out of print. Over 600 bound periodicals, representing 55 beekeeping titles, are on file, and six American and 18 foreign bee journals are currently received. The beekeeping collection at this library contains an extensive group of books from eastern Europe. No actual count has been made, but such countries as Austria, Czechoslovakia, and Russia are well represented.

University of Wisconsin

The C. C. Miller Memorial Beekeeping Library at the University of Wisconsin in Madison was started in 1923, 3 years after the death of Charles C. Miller, as a memorial to that nationally known beekeeper, teacher, investigator, and writer. In 1922, his admirers presented to the regents of this university a fund of $1,957, the income of which was to be used for the maintenance of a beekeeping library. The current income amounts to about $250 per year and is used only to augment the library, not for maintenance or other library expenses.

In this library is the Walker Collection, which was obtained with funds given by the late Sigurd L. Odegard of Madison. The nucleus of this collection was a group of late 19th century books owned by Alfred Neighbour, an English bee appliance manufacturer and author. Upon his death in 1890, they were bought by H. J. O. Walker of Devon, England. Colonel Walker went to great length to add to this collection every important item on bees up until 1930, when he gave up the project and sold the collection.

From the time the books arrived for the Miller Library until his retirement in 1948, H. F. Wilson of the Department of Economic Entomology was custodian. Under his guidance the collection grew to what it is today. As early as 1930, a conservative estimate of its value was $12,000. For much of the material, Professor Wilson used his own money. He kept records of money received from beekeepers who donated a 10-pound pail of honey, or its equivalent in cash, each year for a fund he sponsored to buy books. These records are preserved as a part of the collection.

The Miller Library is housed in a special locked area of the Agricultural Library of the University of Wisconsin. It consists now of approximately 5,500 volumes, most of them beautifully bound, gold tooled, and in excellent condition. Section 4 of the agreement between the University and the Committee of the C. C. Miller Memorial Beekeeping Library, dated September 16, 1922, states: "In the case of rare books or journals, the University of Wisconsin agrees to retain two copies of such books or journals to secure the Library in case of loss of one copy. This shall apply to books or journals published in the United

States more than 50 years previous to the time they are received, or to books and journals published in foreign countries more than 20 years previous to their receipt." Within the scope of this definition, 2,000 volumes are considered rare. Over 50 bee periodicals are received currently, three-fourths of which are foreign.

The Miller Library has a historical collection of note, which may be used by anyone with the permission of the librarian. Journals and rare books are not loaned, but copies of most items are available.

University of Guelph

The University of Guelph, Ontario, Canada, has a collection of bee literature. It consists of approximately 1,700 books, several of which are of historical value; 800 volumes of bound and current periodicals, 46 of which are currently subscribed to; and over 5,000 beekeeping reprints and translations. These are housed in the Apiculture Building at the University and are available to interested persons for consultation. Interlibrary loan service may be arranged through the main library of the University of Guelph.

The extensive reprint collection serves as the "American Branch" of the Bee Research Association Library. Reprints are available for loan to American members of the Bee Research Association at no cost other than the return postage.

A full-time employee is responsible for maintaining the Guelph collection. The funds for salary and books are included in the overall budget for the Apiculture Department. Also a trust fund is available for book purchase, and additional money can be allocated for special purchases.

Though there is duplication among the literature collections mentioned here, items in each are unique. No serious effort has been made to obtain a "Union List" of the holdings of all the significant collections of bee literature on this continent, but this might be a goal for the future. Such a project, when completed, would be of inestimable value to apiculture students, research personnel, and libraries throughout the world.

NONGOVERNMENT BEEKEEPING ORGANIZATIONS

By J. D. Hitchcock, *apiculturist, Entomology Research Division, Agricultural Research Service*

National Organizations

The first national organization of beekeepers in the United States was the American Bee Association established at a convention in Cleveland, Ohio, in 1860, but it was soon disrupted by the Civil War. In 1871, two beekeepers' organizations, both having the Rev. L. L. Langstroth as their president, merged at a meeting, also in Cleveland, to form the North American Bee Keepers' Society. Some type of national organization, including the American Honey Producer's League (1924–42), has been in existence continuously since then, although the name has been changed eight times.

The present national organization of honey producers essentially began with the National Federation of State Beekeepers' Associations in 1943. The present name, *American Beekeeping Federation*, was first applied in 1949, and the organization was incorporated in 1954. Annual meetings have been held every year since 1871, except during 1 or 2 war years. Membership in the national organization exceeded 5,000 in 1911, but dropped to less than 200 during World War I. In 1965, there were 1,372 members in the federation. Its purpose is to promote the common interests and general welfare of the beekeeping industry. The first national publication was the Beekeepers' Review, published in 1912. The present bimonthly publication is the Federation News Letter, now in its 24th year.

Some of the outstanding accomplishments of the national beekeepers' organization are as follows:

1879: Persuaded the U.S. Post Office to permit sending queen bees through the mails.

1906: Lobbied for congressional passage of the Pure Food and Drug Act, to prevent adulteration of honey.

1922: Lobbied for congressional passage of the Honeybee Act, which prohibited importation of adult honey bees into North America, in order to prevent introduction of acarine disease.

1924: Published a treatise on the law pertaining to the honey bee.

1936: Urged establishment of a Federal bee research laboratory in the whiteclover region, resulting in the North Central States laboratory, now the Bee Management Investigations laboratory at Madison, Wis.

1949: Obtained a Federal Honey Price Support Program (see pp.136–138).

1953: Adopted a honey house sanitation schedule.

1954: Obtained congressional appropriations for research on pollination and on mechanization of beekeeping equipment.

1959: Sponsored a national honey queen contest to be held annually, based on beauty and personality, the winning girl then traveling across the Nation on a honey promotion tour.

The federation through its Honey and Pollen Plants Committee has sponsored eight pollination conferences as follows: 1945 and 1946: Atlantic, Iowa; 1947: Amherst, Mass.; 1948: Lincoln, Nebr.; 1949: Seattle, Wash.; 1950: Tucson, Ariz.; 1951: Ardmore, Okla.; 1965: College Station, Tex.

The federation has also cooperated with the U.S. Department of Agriculture in exhibiting honey at various international food fairs in foreign countries, such as those at Hamburg, Germany, in 1961; Brussels, Belgium, in 1962; Amsterdam, Netherlands, in 1963; and London, England, in 1965. Such promotion helps the honey export trade. It has also sponsored national honey shows in the United States annually since 1953.

The *American Bee Breeders' Association* is a national organization of queen breeders, formed in 1948 at a meeting in Meridian, Miss. Its primary objective is to improve the quality of honey bees in use in this country. It also has established standards so that its members can advertise under the association's emblem as a sign of reliability. It has about 70 members.

The *American Honey Institute* was organized in 1928. Its purpose is to promote the use of honey. To achieve this it has often cooperated with other industries for the mutual promotion of honey with other foods. Its headquarters were first in Indianapolis, Ind., then transferred to Madison, Wis., in 1932, and to Chicago, Ill., in 1965. In addition to thousands of leaflets, booklets, streamers, and other articles giving honey recipes tested in its own kitchen, the institute has published three books: Old Favorite Honey Recipes (1941), New Favorite Honey Recipes (1947), and More Favorite Honey Recipes (1956). It has maintained close contact with leading home economists and thus has increased distribution of its honey recipes. Attractive photographs and eye-catching color pictures form an important part of its advertising campaign. In addition to a number of sustaining organizations, headed by the Honey Industry Council of America, many individual beekeepers contribute toward its finances.

The *Apiary Inspectors of America* held national meetings at various times, at least as early as 1906, when E. F. Phillips presided at a meeting in San Antonio, Tex. However, their present organization began in 1928, under the leadership of R. L. Parker of Kansas, at a meeting of the American Honey Producers' League—then the national beekeepers' organization—in Sioux City, Iowa. The purposes of this organization are (1) to promote better beekeeping conditions through uniform, effective laws and methods for the suppression of bee diseases and (2) to seek mutual cooperation between apiary inspection officials of different States. Most State laws apply to American foulbrood and require certification that bee colonies are free of disease before they can be moved across State lines, as in migratory beekeeping. There were 36 members in 1966. The organization publishes proceedings of its annual meetings.

The *Bee Industries Association* is a national organization of manufacturers of beekeeping supplies and equipment. It was started in 1941 and has about a dozen member firms. Its purpose is to try to standardize beekeeping equipment and to promote the welfare of the beekeeping industry. Outstanding services include its intercession in Washington for high priority materials for the beekeeping trade during World War II and lending substantial financial aid to beekeeping groups.

The *Honey Industry Council of America* was established in 1953. It coordinates the overall plans of the beekeeping industry as a whole. Its Check-Off Plan, whereby both producers and processors allocate a certain amount of money per unit volume of honey, provides funds used to advertise honey and promote research.

The national *Honey Packers' and Dealers' Association* was organized in about 1950 and reorganized in 1953. Its members are primarily large-scale honey processors. Its purpose is to improve methods of processing and packaging honey and to increase its sale.

The *Royal Jelly Research Foundation* was organized in 1958 at a meeting of 27 royal jelly producers and dealers in Valdosta, Ga. Its purpose is to support research on the nutritional and therapeutic properties of royal jelly.

Some Regional Organizations

The *Eastern Apicultural Society* was founded at the University of Maryland in 1955, and incorporated in 1962. It was an outgrowth of associations of beekeepers from Connecticut, Massachusetts, and Rhode Island. It now includes associations in Connecticut, Delaware, Kentucky, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, and Ontario, Canada. All members in these associations, over 2,600 in 1966, are considered members of the Eastern Apicultural Society.

The *Northwest Beekeepers' Association*, primarily beekeepers of Idaho, Oregon, and Washington State, has had biennial conferences since 1957. These are usually attended by about 50 to 100 beekeepers and, like the Eastern Apicultural Society, it obtains nationally prominent speakers from both industry and science.

Similarly beekeepers from Arkansas, Colorado, Iowa, Kansas, Missouri, Nebraska, and Oklahoma have joined in annual *Seven States Beekeepers* regional meetings since 1962.

The *Southern States Beekeepers' Federation* was organized at a meeting in Texarkana, Ark., in 1928. It now has about 600 members from about 20 States. Since its purpose is to promote southern beekeeping, it is involved primarily with problems of the package-shipping and queen-rearing phases of the beekeeping industry. It has supported research on such problems at universities in Mississippi and Louisiana. The organization is affiliated with the American Beekeeping Federation.

The *Tidewater Beekeepers' Association*, comprised of beekeepers from the Southeastern Atlantic Seaboard States, was organized in 1939.

Another example of several adjacent States getting together for beekeepers meetings is the *Four States' Beekeepers* of Iowa, Minnesota, Nebraska, and South Dakota (1952).

Representative State and Local Organizations

The *California Bee Breeders, Inc.*, was organized in 1933 to promote the production of high quality queens and package bees in California. It has about 50 members.

The *California Honey Advisory Board* is a unique State organization operating under the California Department of Agriculture. It was organized in 1952. Its purpose is to promote the use of honey by research and advertising. It appears to be doing on a State scale what the American Honey Institute does on a national scale. It has its own recipe-testing kitchen. It also supports research programs at various branches of the University of California. It prints numerous honey recipe leaflets and other educational information about honey. These are provided free of charge to the State's honey producers and packers for distribution with their honey sales. It has published three honey recipe booklets, Honey's Nifty Fifty Recipes (1958), The Best From the West With Honey (1962), and Honey: It's Good Everyway Every Day (1965).

There are *State Beekeepers' Associations* in almost every State in the United States. The oldest is in Michigan established in 1865. At least 15 other States organized beekeepers' associations before 1900, including California, Colorado, Connecticut, Illinois, Kentucky, Maine, Minnesota, New York, Ohio, Tennessee, Texas, Vermont, Washington, and Wisconsin. Perhaps the most recent is in Nevada organized in 1959. Most State associations hold annual meetings during the winter. Several also hold summer picnic meetings. Most associations distribute some type of newsletter to their members.

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HONEY MARKETING AIDS

By J. S. MILLER, *marketing specialist, Fruit and Vegetable Division, Consumer and Marketing Service*

The Consumer and Marketing Service (C&MS) serves as the focal point for honey marketing activities of the U.S. Department of Agriculture. This agency frequently serves as liaison between the honey industry and the various other agencies of the Department. C&MS provides important marketing aids for use of the honey industry.

Current Marketing Information

Marketing of honey is nationwide since production occurs in all States. It is estimated that approximately one-half of each year's honey production is sold by the producer direct to consumers through roadside stands, by house-to-house selling, through mail-order sales, or from the producer's home. Some of these sales are made by the small or part-time producers, who have no real means of determining a true market price for their product. Often such sales are made on hearsay rather than on factual information.

C&MS has for many years published Honey Market News to make current marketing information available to producers and others interested. This unbiased monthly report is national in scope. It contains factual information on supply, demand, market prices, beeswax, colony and honey plant conditions, and crop production material on a State and national basis.

Various means are used to obtain the information included in the monthly report. Data on producer and packer sales of honey in the various size containers are obtained directly from the individuals or firms. Each month a questionnaire listing specific information needed is mailed from Washington, D.C., to approximately 300 members of the industry. Information voluntarily furnished by these contacts is summarized in the market report each month. Additional market information is obtained from wholesale dealers in many of the large cities throughout the United States by trained C&MS market news reporters.

Honey import and export data are included in the monthly report to help provide a complete picture of the supply situation. Likewise, foreign honey crop reports, furnished by the Department's Foreign Agricultural Service, are included to give some insight on the world honey market.

Quality Standardization

Quality standardization provides a means of uniformly classing quality of the honey being marketed. Furthermore, it is important since consumers prefer to buy on a quality basis. The U.S. Department of Agriculture has issued quality grade standards for extracted and comb honey. Use of the standards is not compulsory. They are designed to provide a convenient basis for sales, for establishing quality control programs, and for determining loan values. The standards also serve as a basis for inspection of honey by C&MS and as a quality guide for processors.

There are four designated U.S. grade levels for extracted honey: U.S. grade A or U.S. Fancy, U.S. grade B or U.S. Choice, U.S. grade C or U.S. Standard, and U.S. grade D or Substandard. Quality factors considered in ascertaining the grade of extracted honey are flavor, absence of defects, clarity, and moisture. Honey color is classed by means of the Department's permanent glass color standards or by the Pfund honey color grader.

U.S. standards also have been developed for the grades and types of comb honey. Grades for comb-section honey are U.S. Fancy, U.S. No. 1, U.S. No. 1 Mixed Color, U.S. No. 2, and Unclassified. Grades for shallow frame comb, wrapped cut-comb, and chunk or bulk comb honey packed in tin or glass are U.S. Fancy, U.S. No. 1, and Unclassified. Quality factors used in determining grades are appearance of cappings, presence of pollen grains, uniformity of honey, attachment of comb to section, absence of granulation, presence of honeydew, and weight.

C&MS offers inspection services to the honey industry on a fee-for-service basis. Such services include certification of grades, which helps the industry assure consumers of a clean and wholesome product. Four general types of inspection service are available: *Lot Inspection*—examination of a number of containers sampled from specific lots; *Continuous Inspection*—one or more inspectors assigned to a processing plant to observe and check operations continuously; *Plant Inspection-Pack Certification*—similar to continuous inspection, except that the inspector is not required to be present at all times; *Unofficially Submitted Samples*—inspection of samples submitted by applicant to determine quality, condition, and grade.

Plentiful Foods Program

The C&MS Plentiful Foods Program is a part of the broad policy of the U.S. Department of Agriculture to provide food distributors and consumers with information on food supplies and prices. Its purpose is to expand the market for foods that are in peak seasonal supply or are otherwise plentiful.

It is essentially a program to enlist concerted action by the Nation's grocers and food-service establishments to focus consumer attention on "plentifuls." This is done through stimulating creative merchandising, with simultaneous publicity in the press and on radio and television. The trade elements are alerted to current plentiful foods through a monthly periodical, the Plentiful Foods List, and through other special bulletins and personal contact by field personnel. The material is aimed at the grocery trade and all important feeding operations, including restaurants, industrial and institutional feeders, and schools participating in the National School Lunch Program.

Information about plentiful foods also is supplied regularly to mass media, especially to food editors, and to persons doing educational work in home economics and nutrition.

C&MS program specialists select the foods each month for designation as "plentiful," basing their selections on the Department's crop reporting and outlook services.

Surplus Removal

When supplies outrun demand and farm prices fall drastically, C&MS can sometimes help out with surplus removal programs. These programs serve to widen the market for farm products by encouraging domestic consumption, exports, or development of new outlets and uses. They are carried out under authority of section 32 of Public Law 320. "Section 32 programs" help to stabilize prices for farmers and make it possible to find useful outlets for many surplus farm commodities that might otherwise be wasted. Products purchased are used to improve the diets of school children and needy persons.

Inquiries and requests for information concerning any of these marketing aids or for inspection service and copies of the standards for grades of honey may be addressed to Fruit and Vegetable Division, Consumer and Marketing Service, U.S. Department of Agriculture, Washington, D.C. 20250, or to field offices of the agency.

HONEY PRICE SUPPORT PROGRAM

By HARRY A. SULLIVAN, *agricultural economist, Policy and Program Appraisal Division, Agricultural Stabilization and Conservation Service*

Price support programs for agricultural commodities were undertaken as a result of the depression of the 1930's. For some years, price support operations were restricted to what were called the "basic" commodities (corn, cotton, peanuts, rice, tobacco, and wheat), but gradually other commodities were added.

Factors Leading to Honey Price Support Program

Sugar rationing during World War II and the requests by the Government to increase the production of honey led to a large increase in colony numbers and a proportionate increase in honey production. With the end of sugar rationing, prices for honey dropped close to prewar levels. Due to the depressed economic situation facing them, representatives of the beekeeping industry requested assistance from Congress. In taking note of the industry's request, the House Committee on Agriculture had this to say:

> Since the close of the war, the price of honey has dropped to the point where beekeepers are finding it impossible to obtain their costs of production. It appears obvious to the committee that, if these vitally important insects are to be maintained in sufficient numbers to pollinate our crops, the beekeeping industry must have immediate assistance. Until the time comes when beekeepers can receive an adequate return from pollination services, the committee believes that a price support program for honey, as provided in this bill, is the only answer to this problem.

Honey Price Support Legislation

The Agricultural Act of 1949 required that honey, along with several other commodities under the heading "Designated Nonbasic Agricultural Commodities," be supported at a level between 60 and 90 percent of parity. In determining the actual level of support within the prescribed limits, the Secretary of Agriculture is directed to consider the following factors:

(1) Supply in relation to demand.

(2) Price levels at which other commodities are being supported.

(3) Availability of funds.

(4) Perishability of honey.

(5) Importance of honey to agriculture and the national economy.

(6) Ability to dispose of stocks acquired through price support operations.

(7) The need for offsetting temporary losses of export markets.

(8) The ability and willingness of producers to keep supply in line with demand.

Parity prices are a measure of the price levels needed to give agricultural commodities a purchasing power with respect to articles that farmers buy, equivalent to the purchasing power of those agricultural commodities in a base period. The technique used to determine parity prices for agricultural commodities has been outlined by Congress. The parity price calculations and determinations are made by the Statistical Reporting Service of the U.S. Department of Agriculture.

Operating Features of Price Support Program

The price of honey is presently supported through a farm-storage loan or purchase program or both. Loans at the applicable price support rate on farm-stored honey are made available to beekeepers during the crop year on any or all of the honey produced during that year. By providing immediate cash for his crop, this allows the beekeeper to hold his honey and to market it later during the crop year when he thinks it is most advantageous to him. However, if the market prices fail to rise above the support price, he may cancel his loan by delivering honey of value equal to the loan value at the end of the year unless arrangements for earlier delivery have been made.

If the beekeeper has not made use of the loan feature of the program for a part or all of his production, he can then use the purchase option. This means that the Commodity Credit Corporation (CCC) stands ready to buy at the applicable support price any of his production he wishes to sell and which is not already obligated to CCC as loan collateral.

The beekeeper, along with producers of other price-supported commodities, obtains loans or payment from a CCC purchase of his honey at his Agricultural Stabilization and Conservation Service county office. The U.S. Department of Agriculture carries out price support operations through the Agricultural Stabilization and Conservation Service (ASCS), which has field offices in each of the more than 3,000 counties in the country. The county office also issues delivery instructions as to time and location for honey deliveries being made to CCC.

Other Provisions of Loan and Purchase Program

Quality and Quantity Determination

For loan purposes, the beekeeper's statement is accepted as to the quality of the honey offered as collateral. He then receives 90 percent of the value (price support rate times quantity) of the loan honey. When honey is actually acquired by CCC through purchase or loan repayment, quantity is determined by the actual weight of honey delivered. Quality determination for this purpose is made by the Processed Products Standardization and Inspection Branch, Fruit and Vegetable Division, Consumer and Marketing Service, in accordance with U.S. standards for grades of extracted honey based on samples drawn by ASCS representatives supervising delivery. CCC bears the cost of this quality and color determination.

Color and Area Differential Structure

Honey is supported on the basis of color and class with an East-West area differential also applied. The color and class, along with the area differential for the 1966 crop, are illustrated as follows:

Class and color	*West (cents per pound)*	*East (cents per pound)*
Table honey:		
White and light	12. 0	12. 9
Extra light amber	11. 0	11. 9
Light amber	10. 0	10. 9
Other table honey	8. 0	8. 9
Nontable honey	8. 0	8. 9

The national average support rate on a 60-pound and larger container basis is 11.4 cents per pound for the 1966 crop.

Fees and Charges

A producer pays a nonrefundable loan fee of $4 for each loan disbursed. He pays a delivery charge of 1 cent per hundredweight on the quantity of honey delivered to CCC. The producer also pays all charges relative to insurance premiums, storage, and handling.

Early Support Program

The Department first decided that mandatory honey price support could be most widely and effectively assured by working through existing marketing machinery. Under the 1950 program, packers of honey signed contracts with the Department, under which they agreed to pay beekeepers 9 cents per pound delivered to their packing plants for all the honey acquired from them that met the requirements of the program. These requirements were especially concerned with the cleanliness of the honey, its moisture content, and the flavor.

The Department, in turn, agreed to accept from the contracting packer all the honey the packer offered and to pay the support price, plus established charges for handling, storage, and any processing requested by the Department.

In the 1951 season a similar program was operated, except a price support differential was introduced related to the degree of acceptability of honey for table use. The differential was 1.1 cents per pound between honeys of "general national acceptability" and "limited acceptability" for table use, reflecting to a degree the difference in market value for variations in this regard.

The type of price support program in operation during these first 2 years was not giving universal satisfaction. The 1952 season saw the producer (i.e., beekeeper) loan and purchase agreement type of program developed, which is now in use for honey and for most of the other agricultural commodities.

Summary of Price Support Activity

As indicated in table 1, activity under the price support program has been relatively modest, with small quantities put under loan and even

TABLE 1.—*Honey: Price support activity, 1950–66*

Year	Price support rate	Support as percent of parity	Quantity placed under loan		Quantity acquired by CCC
			Amount	As percent of production	
	Cents	*Percent*	*Million pounds*	*Percent*	*Million pounds*
1950	9. 0	60	(1)	--------	7. 4
1951	10. 0	60	(1)	--------	17. 8
1952	11. 4	70	9. 3	3. 4	7. 0
1953	10. 5	70	3. 1	1. 4	. 5
1954	10. 2	70	1. 5	. 7	0
1955	9. 9	70	1. 9	. 8	0
1956	9. 7	70	1. 6	. 7	0
1957	9. 7	70	2. 9	1. 2	. 1
1958	9. 6	70	5. 6	2. 1	2. 0
1959	8. 3	60	1. 3	. 5	0
1960	8. 6	60	1. 1	. 4	0
1961	11. 2	75	4. 2	1. 5	1. 1
1962	11. 2	71	3. 4	1. 2	0
1963	11. 2	67	3. 2	1. 1	0
1964	11. 2	65	9. 6	3. 4	2. 2
1965	11. 2	63	17. 3	6. 2	3. 3
1966	11. 4	61	(2)	(2)	(2)

[1] Direct Packer Purchase Program.

[2] Data not available.

smaller quantities acquired by CCC. The honey acquired by CCC has been disposed of primarily through the National School Lunch Program. The greatest activity in terms of CCC acquisition or loan placement took place in the initial 3 years after implementation of the program and in the 1964 and 1965 crop years. This pattern would seem to indicate that the honey industry's greatest need for this type of program had been in these two periods. However, there seems to be a general consensus that the price support program has provided the honey market with a significant degree of stability during the period it has been in operation.

STATISTICS ON BEES AND HONEY

By E. B. Hannawald, *Chief, Livestock, Dairy and Poultry Branch, Agricultural Estimates Division, Statistical Reporting Service*

Statistics concerning bees and honey were first issued by the U.S. Department of Agriculture in 1940. Its Statistical Reporting Service, through its Crop Reporting Board, issues three reports each year. The first report, in July, carries an estimate of the number of colonies on hand and the condition of nectar plants and colonies. The second, in October, includes preliminary estimates of the number of colonies, yield per colony, and production of honey. This report also shows producers' stocks of honey for sale as of September 15. The last report, in January, estimates the number of colonies, yield per colony, and total production for the previous year. The report also carries wholesale and retail prices received by producers for all honey, comb honey, chunk honey, and extracted honey; producers' stocks of honey as of December 15; and beeswax production and price. Estimates are made for each State; U.S. estimates are the sum of the State estimates (tables 1 and 2).

Number of Colonies

The first estimates in 1940 were based on studies of the Census of Agriculture enumerations, State inspection records, estimates by State apiary inspectors and entomologists, and reports from commercial honey buyers and packers. Since then the yearly change in the number of colonies has been based primarily on surveys and State inspection records. No questions regarding

Table 1.—*Honey: Number of colonies, production, value, and stocks, United States, 1940–66* [1]

Year	Number of colonies	Yield per colony	Honey production	Price per pound	Total value	Stocks on hand Dec. 15 for sale
	Thousands	*Pounds*	*Thousand pounds*	*Cents*	*Thousands*	*Thousand pounds*
1940	4,350	47.3	205,767	6.1	$12,584	(2)
1941	4,477	49.6	221,959	7.2	15,973	(2)
1942	4,893	36.3	177,672	13.8	24,481	40,512
1943	4,887	38.9	189,867	16.8	31,740	31,361
1944	5,217	36.2	188,917	17.7	33,433	26,237
1945	5,460	42.7	233,070	18.6	43,339	27,133
1946	5,787	36.9	213,814	24.4	52,137	10,787
1947	5,916	38.6	228,582	24.9	56,878	62,408
1948	5,721	36.0	206,185	17.9	36,852	70,774
1949	5,578	40.6	226,334	15.0	34,064	82,893
1950	5,601	41.5	232,431	15.3	35,615	83,119
1951	5,546	46.4	257,522	16.0	41,234	71,284
1952	5,493	49.5	272,011	16.2	44,063	77,047
1953	5,520	40.5	223,770	16.5	36,997	53,210
1954	5,451	39.7	216,419	17.0	36,737	40,965
1955	5,252	48.6	255,222	14.8	45,424	58,618
1956	5,195	41.2	214,035	19.0	40,621	49,489
1957	5,199	46.4	241,218	18.7	45,049	64,024
1958	5,152	50.6	260,522	17.4	45,216	71,084
1959	5,109	46.3	236,578	17.0	40,135	59,969
1960	5,005	48.5	242,802	17.9	43,500	52,206
1961	4,992	51.3	255,868	18.0	46,072	68,119
1962	4,900	50.9	249,608	17.4	43,494	55,933
1963	4,849	55.0	266,778	18.0	48,096	55,082
1964	4,840	51.9	251,188	18.6	46,638	65,776
1965	4,783	51.1	244,549	17.8	43,475	58,327
1966	4,770	51.8	246,972	17.4	42,927	56,854

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[1] Excludes Hawaii 1940–54 for all items and 1956 and 1957 for Dec. 15 stocks.

[2] Data not available.

TABLE 2.—*Beeswax: Production and value, United States, 1942–66*[1]

Year	Production	Price per pound	Total value
	Thousand pounds	*Cents*	*Thousands*
1942	3, 344	40. 3	$1, 343
1943	3, 743	41. 4	1, 551
1944	3, 921	41. 5	1, 627
1945	4, 543	41. 3	1, 888
1946	4, 381	44. 4	1, 947
1947	4, 500	43. 8	1, 969
1948	4, 041	43. 2	1, 746
1949	4, 139	37. 6	1, 554
1950	4, 261	42. 8	1, 824
1951	4, 692	50. 4	2, 368
1952	4, 812	43. 1	2, 075
1953	4, 081	41. 0	1, 673
1954	4, 011	44. 1	1, 764
1955	4, 620	51. 2	2, 367
1956	4, 096	54. 6	2, 237
1957	4, 452	57. 0	2, 537
1958	4, 695	46. 0	2, 159
1959	4, 215	44. 4	1, 872
1960	4, 372	44. 0	1, 922
1961	4, 720	44. 1	2, 080
1962	4, 805	44. 1	2, 117
1963	4, 828	44. 2	2, 133
1964	4, 672	44. 3	2, 070
1965	4, 749	44. 9	2, 132
1966	4, 728	46. 6	2, 202

[1] Excludes Hawaii 1942–54.

the number of colonies of bees have been asked on the census enumeration since 1950.

Questionnaires are sent to producers for each survey. Each questionnaire asks the number of colonies on hand at the beginning of the honey flow. The questionnaires are tabulated by size groups based on the number of colonies. Normally the size groups used are 1–9 colonies, 10–39, and 40 or more. In States with large commercial producers, a further breakdown of the large group is made.

The July inquiry asks for the number of colonies on hand a year earlier as well as the current number. These two questions provide an indication of the annual change in the number of colonies. This indication is referred to as the C/H (current/historic) percentage. The current number reported on the July returns is also matched with the number reported on the July inquiry a year earlier for the same producers. This provides an indication of change from the previous year, called C/C (current/current).

Indications from each size group on these two measurements are combined by weighting each size group indication by percentages that reflect the amount of the colonies in the universe in each size group. Each of these weighted indications for a series of years is plotted as the independent variable on charts, whereas the dependent variable is the Crop Reporting Board's percentage change in number of colonies from the preceding year. (For an example, see figure 1.) From these indications a percentage change from the previous year is adopted, which is multiplied by the estimated number of colonies for the previous year. This product is the estimated number of colonies for the current year. In some States, data on numbers of inspected colonies are available. Such records are considered in making the estimates.

The estimate of number of colonies is again reviewed for the October and December surveys and revised in December if necessary. Most consideration is given to the July survey, since the estimate relates to the number of colonies on hand at the beginning of the honey flow, and this date is the closest to the beginning of the flow.

The estimate of colony numbers can also be revised the following year in July and December. When revisions are made, they are based on State inspection records and other data not earlier available.

Honey Production

The first or preliminary estimate of the yield of honey per colony is made in October. This estimate is based on the amount of honey that producers have already taken and expect to take from the hives.

A final estimate is made in January, when producers are asked the amount of honey that was taken from the hives during the past year. The total pounds of honey, as reported by producers returning questionnaires, are divided by the sample number of colonies to obtain an average yield per colony. The yields for each size group are then weighted together to compute a State average. The weighting is particularly important because yield per colony increases markedly as the number of colonies increases. As colonies increase, management tends to improve; large producers move colonies from one location to another to obtain higher yields.

The reported yields are plotted on a chart with Board final yields. The chart is then used to determine the yield per colony. This derived yield per colony is multiplied by the Board estimate of number of colonies to obtain the estimate of total honey production.

Stocks of Honey

Stocks of producers' honey for sale are estimated and published in the October and January reports. A percentage indication of honey stocks on hand is derived from the sample by dividing the reported stocks by the reported

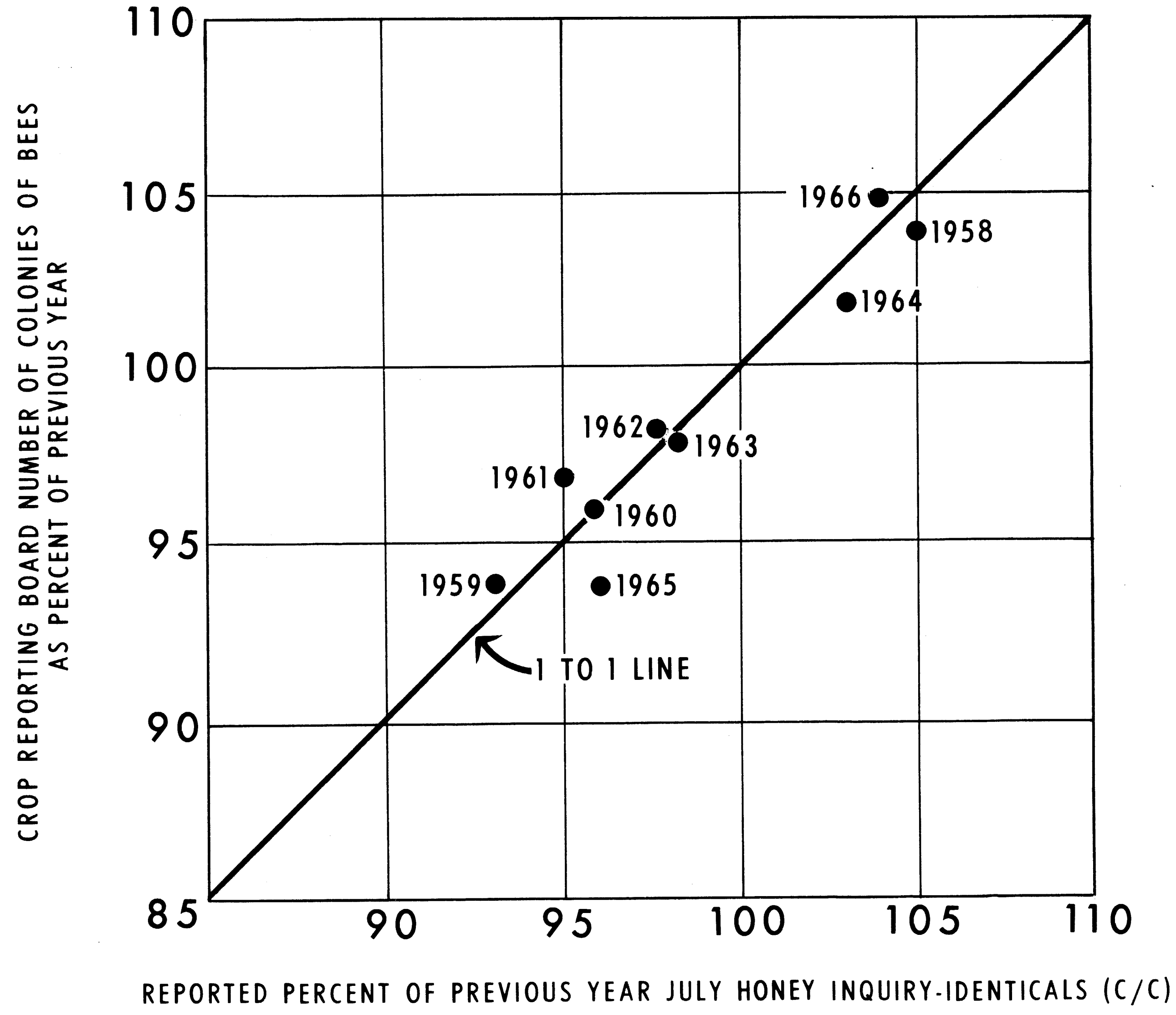

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FIGURE 1.—Colonies of bees, Iowa: Official estimates of number of colonies of bees as percentages of previous year's estimates in relation to percentage relation between number reported on same farm in current year to number reported in previous year on successive July honey surveys.

total honey produced. After the percentage of honey on hand for sale is determined for each size group, a weighted percentage is obtained. This weighted percentage is then expanded into a stocks estimate by multiplying it by the total honey production for the year.

Beeswax Production

An estimate is made in January of the amount of beeswax produced during the previous year. The estimate is based on the pounds of beeswax in relation to honey production. A percentage indication of beeswax output is derived from the sample by dividing the reported pounds of beeswax by the reported total honey production. The percentage is then expanded into an estimate of beeswax production by multiplying the total honey production for the year by this percentage.

Prices

Detailed estimates of prices received by producers for honey were first published by the Department in 1940. The questionnaire has since been changed several times to furnish the more comprehensive price data needed as price support legislation for honey became law. In 1948, the questionnaire was changed to provide a breakdown of both wholesale and retail sales of extracted honey, by size of containers most commonly sold. Sizes included were 60-pound, 5-pound, 1-pound, and "other" containers. In 1959, questions on prices and quantity of wholesale sales in 55-gallon drums were added.

The price estimate of all honey sold, published in January, is obtained by combining prices for each size container sold, both wholesale and retail. Estimated quantities of honey sold, by categories for each State, are used in this process to obtain a price for all honey. The quantities used as weights are derived from pounds of honey sold in each category as reported on the questionnaire and from other available sales data. The weights also are used to compute regional and U.S. average prices for wholesale and retail sales of extracted, comb, chunk, or bulk honey and for all honey.

WORLD PRODUCTION AND TRADE IN HONEY

By LESLIE C. HURT, *Acting Chief, Commodity and Products Analysis Branch, Sugar and Tropical Products Division, Foreign Agricultural Service*

Honey is produced in all States of the United States and in all continents of the world. World production of honey, excluding mainland China, is currently about 900 million pounds. All continents contribute to this total. North America is by far the largest producer, whereas only small amounts are produced in Africa. The United States accounts for about one-third of total world production. The U.S.S.R. ranks second in production, with about 200 million pounds. Other sizable producers are Argentina, Mexico, Canada, Australia, France, Turkey, Spain, and West Germany. Smaller producers include Brazil, Chile, New Zealand, Italy, and Japan. The production trend is upward throughout the world.

World trade in honey also is generally upward and amounts to about 150 million pounds annually. The largest exporters in recent years have been Mexico, Argentina, Australia, and in some years the United States. In recent years, Europe has often accounted for about 95 percent of all world imports. West Germany imports about 65 percent of the world total. Major suppliers in 1965 continued to be Argentina and Mexico, followed by mainland China in terms of quantity and the United States in terms of value. Several European countries import less than 10 million pounds of honey annually.

Of the largest exporters, Mexico in recent years has been shipping the biggest proportion of its production. Much of this is shipped to West Germany, but a substantial amount has also been shipped to the United States. Argentina and Australia for several years have exported over half of their crops. Canada exports a much smaller amount both in total volume and as a percentage of production. However, the Canadian market has had substantial growth in the last few years. The bulk of the sales is made to the United Kingdom, and the trend has been to smaller containers, predominantly the 1-pound variety.

Ranking second in imports in 1965, despite its leading position in world production, was the United States. Although a large share of U.S. imports of honey is for baking and manufacturing industries, there are also imports for specialty purposes. Exports from the United States since World War II have substantially exceeded imports in most years. During 1946–65, imports averaged 9.2 million pounds, whereas exports averaged 14.4 million pounds. The level of exports was highest during the 1950's; however, 1963 exports of 25.1 million pounds reflected the all-time record production. Practically all exports have been to European countries, with West Germany the leading buyer and France usually second.

World per capita consumption of honey is at a rather low level. In the United States it amounts to about 1.5 pounds and has not varied much in recent years. Argentina in 1965 furnished a good example of what can be done by promoting consumption. Local consumption rose to 35 million pounds, triple that of the previous year. The success of this promotion is referred to as "The Argentine Miracle," and illustrates the dormant potential for honey consumption.

GLOSSARY

Abdomen: Segmented posterior part of bee containing heart, honey stomach, intestines, reproductive organs, and sting.

***Acarapis woodi* (Rennie):** Scientific name of acarine mite, which infests tracheae of bees.

Acarine disease: Disease caused by acarine mite.

Alighting board: Extended entrance of beehive on which incoming bees land.

American foulbrood (AFB): Contagious disease of bee larvae caused by *Bacillus larvae* White.

Antennae: Slender jointed feelers, which bear certain sense organs, on head of insects.

Anther: Part of plant that develops and contains pollen.

Apiarist: Beekeeper.

Apiary: Group of bee colonies.

Apiculture: Science of beekeeping.

Apis: Genus to which honey bees belong.

***Apis dorsata* Fabricius:** Scientific name for giant bee of India; largest of all honey bees.

Artificial cell cup: (*See* Cell cup.)

Artificial insemination: Instrumental impregnation of confined queen bee with sperm.

***Bacillus larvae* White:** Bacterial organism causing American foulbrood.

Balling a queen: Clustering around unacceptable queen by worker bees to form a tight ball; usually queen dies or is killed in this way.

Bee bread: Stored pollen in comb.

Bee dance: Movement of bee on comb as means of communication; usually same movement is repeated over and over.

Bee escape: Device to let bees pass in only one direction; usually inserted between combs of honey and brood nest when removal of bees from honey is desired.

Bee gum: Usually hollow log hive; occasionally refers to any beehive.

Beehive: Domicile prepared for colony of honey bees.

Bee louse: Relatively harmless insect that gets on honey bees, but larvae can damage honeycomb; scientific name is *Braula coeca* Nitzsch.

Bee metamorphosis: Stages in development of honey bee from egg to adult.

Stage	*Period (days)* *Queen*	 *Worker*	 *Drone*
Egg	3	3	3
Larva	8	10	13
Pupa	4	8	8
Emerge as adult	15	21	24

Bee moth: (*See* Wax moth.)

Bee paralysis: Condition of bee, sometimes caused by virus, that prevents it from flying or performing other functions normally.

Bee plants: Vegetation visited by bees for nectar or pollen.

Bee space: Amount of space acceptable to bees, neither too narrow nor too wide; discovered by great American beekeeper Langstroth.

Beeswax: Wax secreted from glands on underside of bee abdomen; molded to form honeycomb and can be melted into solid block.

Bee tree: Hollow tree in which bees live.

Bee veil: Screen or net worn over head and face for protection from bee stings.

Bee venom: Poison injected by bee sting.

Bee yard: (*See* Apiary.)

Bottom board: Floor of beehive.

Brace comb: Section of comb built between and attached to other combs.

***Braula coeca* Nitzsch:** (*See* Bee louse.)

Breathing pores: (*See* Spiracles.)

Brood: Immature or developing stages of bees; includes eggs, larvae (unsealed brood), and pupae (sealed brood).

Brood chamber: Section of hive in which brood is reared and food may be stored.

Brood comb: Wax comb from brood chamber of hive containing brood.

Brood nest: Area of hive where bees are densely clustered and brood is reared.

Brood rearing: Raising bees.

Bumble bee: Large hairy bee in genus *Bombus*.

Burr comb: Comb built out from wood frame or comb, but usually unattached on one end.

Cap: Covering of cell.

Capped brood: (*See* Sealed brood.)

Capped honey: Honey stored in sealed cells.

Carniolan bee: Gentle grayish-black bee originally from Carniolan Mountains in or near Austria.

Caucasian bee: Gentle black bee originally from Caucasus area of Russia; noted for its heavy propolizing characteristic.

Cell: Single unit of space in comb in which honey is stored or bee can be raised; worker cells are about 25 cells per square inch of comb, drone cells are about 18 per square inch.

Cell cup: Queen cell base and part of sides; artificial cell cups are about as wide as deep.

Chilled brood: Immature stages in life of bee that have been exposed to cold too long.

Chunk comb honey: Type of honey pack in which piece of honeycomb is placed in container of liquid honey or wrapped "dry" in plastic container.

Circadian rhythm: Biological rhythm with period length of about 1 day.

Clarified honey: Honey that has been heated, then filtered to remove all wax or other particles.

Cleansing flight: Flight bees take after days of confinement, during which they void their feces.

Clipped queen: Queen whose wing (or wings) has been clipped for identification purposes.

Cluster: Collection of bees in colony gathered into limited area.

Colony: Social community of several thousand worker bees, usually containing queen with or without drones.

Comb: (*See* Honeycomb.)

Comb foundation: Thin sheet of beeswax impressed by mill to form bases of cells; some foundation is also made of plastic and metal.

Comb honey: Edible comb containing honey; usually all cells are filled with honey and sealed by bees with beeswax.

Commercial beekeeper: One who operates sufficiently large number of colonies so that his entire time is devoted to beekeeping.

Cross-pollination: Transfer of pollen from anther of one plant to stigma of different plant or clone of same species.

Crystallization: (*See* Granulated honey.)

Cut-comb honey: Comb honey cut into appropriate sizes and packed in plastic.

Demaree: Method of swarm control, by which queen is separated from most of brood; devised by man of that name.

Dequeen: Remove queen from colony.

Dextrin: Soluble carbohydrate of poor nutritive value to bee.

Dextrose: Also known as glucose; one of principal sugars of honey.

Diastase: Enzyme that aids in converting starch to sugar.

Division board: Flat board used to separate two colonies or colony into two parts.

Division board feeder: Feeder to hold sirup; usually size of frame in hive.

Drawn comb: Foundation covered with completed cells.

Drifting bees: Tendency of bees to shift from their own colony to adjacent ones.

Drone: Male bee.

Drone brood: Area of brood in hive consisting of drone larvae or pupae.

Drone comb: Comb having cells measuring about four to the inch and in which drones are reared.

Drone egg: Unimpregnated egg.

Drone layer: Queen that lays only infertile eggs.

Dwindling: Rapid or unusual depletion of hive population.

Dysentery: Unusual watery discharge of bee feces, often associated with nosema disease.

Emerging brood: Young bees first coming out of their cells.

Enzyme: Material produced by both man and animals that acts on another material to change it without changing itself.

Escape board: Board with one or more bee escapes on it to permit bees to pass one way.

European foulbrood: Infectious disease of larval brood, caused by *Streptococcus pluton* (White).

Excluder: (*See* Queen excluder.)

Extracted honey: Honey extracted from comb.

Extractor: Machine that rotates honeycombs at sufficient speed to remove honey from them.

Feces: Bee droppings or excreta.

Fecundate: To inseminate or implant sperm into female.

Fertilize: To make fertile, as by implanting sperm into ova.

Field bees: Bees 2½ to 3 weeks old that collect food for hive.

Flash heater: Device for heating and cooling honey within few minutes.

Food chamber: Hive body containing honey-filled combs on which bees are expected to live.

Foulbrood: Common name of two brood diseases; usually applied to American foulbrood.

Foundation: (*See* Comb foundation.)

Frame: Wood case for holding honeycomb.

Fructose: (*See* Levulose.)

Fumagillin: Antibiotic given bees to control nosema disease.

***Galleria mellonella* (L.):** Scientific name of greater wax moth.

Giant bee: (*See Apis dorsata* Fabricius.)

Glucose: (*See* Dextrose.)

Grafting: Transfer of larvae from worker cells into queen cells.

Granulated honey: Crystallized or candied honey.

Gynandromorph: Bee having both male and female characters.

Half-depth super: Super only half as deep as standard 10-frame Langstroth super.

Heterosis: Greater vigor displayed by crossbred animals.

Hive: Man-constructed home for bees.

Hive tool: Metal tool for prying supers or frames apart.

Hobbyist beekeeper: One who keeps bees for pleasure or occasional income.

Hoffman frame: Self-spacing wood frame of type customarily used in Langstroth hives.

Honey: Sweet viscous fluid elaborated by bees from nectar obtained from plant nectaries, chiefly floral.

Honey bee: Genus *Apis*, family Apidae, order Hymenoptera.

Honeycomb: Comb built by honey bees with hexagonal back-to-back cells on median midrib.

Honeydew: Sweet secretion from aphids and scale insects.

Honey extractor: (*See* Extractor.)

Honey flow: Period when bees are collecting nectar from plants in plentiful amounts.

Honey house: Building in which honey is extracted and handled.

Honey pump: Pump for transferring liquid honey from one container to another.

Honey stomach: Area inside bee abdomen between esophagus and true stomach.

Honey sump: Temporary honey-holding area with baffles; tends to hold back sizable pieces of wax and comb.

Hormone: Substance produced in small quantity in one part of body (usually in gland of internal secretion) and transported to other parts, where it exerts its action.

Hymenoptera: Order to which all bees belong, as well as ants, wasps, and certain parasites.

Introducing cage: Small wooden and wire cage used to ship queens and also to release them quietly into cluster.

Invertase: Enzyme produced by bee that speeds inversion of sucrose to glucose and fructose.

Italian bees: Bees originally from Italy; most popular race in United States.

Jumbo hive: Hive 2¼ inches deeper than standard Langstroth hive.

Langstroth frame: 9⅛- by 17⅝-inch frame.

Langstroth hive: Hive with movable frames; each frame usually 9⅛ by 17⅝ inches.

Larva: Stage in life of bee between egg and pupa; "grub" stage.

Laying worker: Worker bee that lays eggs after colony has been queenless for many days.

Legume: One of Leguminosae, or plants such as clover, alfalfa, peas, or beans.

Levulose: Fructose or fruit sugar; one of sugars, with glucose, into which sucrose is changed.

Mandibles: Jaws of insects.

Mating flight: Flight taken by virgin queen when she mates with drone in air.

Metamorphosis: Changes of insect from egg to adult.

Migratory beekeeping: Movement of apiaries from one area to another to take advantage of honey flows from different crops.

Mite: (*See Acarapis woodi* (Rennie).)

Movable frame: Frame bees are not inclined to attach to hive because it allows proper bee space around it.

Nectar: Sweet exudate from nectaries of plants.

Nectaries: Special cells on plants from which nectar exudes.

Nosema disease: Disease of bees caused by protozoan spore-forming parasite, *Nosema apis* Zander.

Nucleus (nuclei): Miniature hives.

Nurse bees: Young worker bees that feed larvae.

Observation hive: Hive with glass sides so bees can be observed.

Ocellus (ocelli): Simple eye(s) of bees.

Package bees: Screen wire and wood container with 2 or 3 pounds of live bees.

Parafoulbrood: Relatively rare bee disease similar to European foulbrood; caused by bacterium *Bacillus para-alvei* Burnside.

Paralysis: (*See* Bee paralysis.)

Parthenogenesis: Production of offspring from virgin female.

Pheromone: Chemicals secreted by animals to convey information to or affect behavior of other animals of same species.

Pistil: Part of flower extending from ovary to stigma.

Play flight: Short orientation flight taken by young bees, usually by large numbers at one time and during warm part of day.

Pollen: Dustlike material produced in flower and necessary on stigma of female flower for seed production; also collected in pellets on hindlegs of bees.

Pollen basket: Area on hindleg of bee adapted for carrying pellet of pollen.

Pollen cake: Cake of sugar, water, and pollen or pollen substitute for bee feed.

Pollen substitute: Mixture of water, sugar, and other material, such as soy flour, brewer's yeast, and egg yolk, used for bee feed.

Pollen supplement: Mixture, usually of six parts (by weight) pollen, 18 parts soy flour, 16 parts water, and 32 parts sugar.

Pollen trap: Device installed over colony entrance that scrapes pollen from legs of entering bees.

Pollination: Transfer of pollen from male to female element of flower.

Pollinator: Agent that transfers pollen.

Pollinizer: Plant that furnishes pollen for another.

Proboscis: Tongue of bee.

Propolis: Resinous material of plants collected and utilized by bees within hive to close small openings or cover objectionable objects within hive.

Pupa: Stage in life of developing bee after larva and before maturity.

Queen: Sexually developed female bee.

Queen cell: Cell in which queen develops.

Queen excluder: Device that lets workers pass through but restricts queen.

Queenless: Without queen.

Queen rearing: Producing queens.

Queenright: With queen.

Queen substance: Material produced from glands in head of queen; has strong effect on colony behavior.

Ripe honey: Honey from which bees have evaporated sufficient moisture so that it contains no more than 18.6 percent water.

Robbing: Bees of one hive taking honey from another.

Royal jelly: Food secreted by worker bees and placed in queen cells for larval food.

Sacbrood: Minor disease of bees caused by filterable virus.

Sealed brood: Brood in pupal stage with cells sealed.

Self-pollination: Transfer of pollen from male to female element within same flower.

Septicemia: Usually minor disease of adult bees caused by *Pseudomonas apiseptica* (Burnside).

Shallow super: Super less than $9\frac{9}{16}$ inches deep.

Shipping cage: Screen and wood container used to ship bees.

Skep: Beehive made of straw.

Smoker: Device used to blow smoke on bees to reduce stinging.

Solar wax extractor: Glass-covered box in which wax combs are melted by sun's rays and wax is recovered in cake form.

Spermatheca: Small saclike area in queen in which sperms are stored.

Spermatozoan: Male reproductive cell.

Spiracles: External openings of tracheae.

Stamen: Male part of flower on which pollen-producing anthers are borne.

Stigma: Receptive part of style where pollen germinates.

Sting: Modified ovipositor of female Hymenoptera developed into organ of defense.

***Streptococcus pluton* (White):** Causative agent of European foulbrood.

Sucrose: Cane sugar; main solid ingredient of nectar before inversion into other sugars.

Super: Extra division of hive above brood nest area.

Supersedure: Replacement of one queen by another while first is still alive.

Swarm: Natural division of colony of bees.

Tarsus: Fifth segment of bee leg.

Thorax: Middle part of bee.

Tracheae: Breathing tubes of insects.

Tumuli: Nest mounds.

Uncapping knife: Knife used to remove honey cell caps so honey can be extracted.

Unite: Combine one colony with another.

Unsealed brood: Brood in egg and larval stages only.

Virgin queen: Unmated queen.

Wax glands: Glands on underside of bee abdomen from which wax is secreted after bee has been gorged with food.

Wax moth: Lepidopterous insect whose larvae destroy wax combs.

Wild bees: Any insects that provision their nests with pollen, but do not store surplus edible honey.

Winter cluster: Closely packed colony of bees in winter.

Wired foundation: Foundation with strengthening wires embedded in it.

Wired frames: Frames with wires holding sheets of foundation in place.

Worker bee: Sexually undeveloped female bee.

Worker comb: Honeycomb with about 25 cells per square inch.

Worker egg: Fertilized bee egg.

U.S. GOVERNMENT PRINTING OFFICE: 1967—O261-907