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BEES FOR POLLINATION, CROP IMPROVEMENT AND AGRIBUSINESS-SOME BASIC FACTS

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ABSTRACT

The insects, particularly bees are the pollinators in flowering plants, leading to fruit and seed production. Pollination biology is facilitated by the rewards gained by the bees by way of nectar and pollen resulting in honey production. The structural patterns of the pollinating insect and of the flower they pasture on are so co-ordinated and co-evolved that the plant-insect mutualism is sustained to the benefit of the associated partners on the one hand and the humans on the other by way of producing natural products. Honey bees are the only insects making food for man. Honey is the ultimate major product, which is considered as the food of foods, the drink of drinks, and the drug of drugs, explaining the spectrum of applications of honey alone in human affairs. The value of pollination mechanism by the honey bees is put to use by employing the insect through apiary locationing in crop fields and orchards to increase fruit/seed production. There is immense new scope in promoting agribusiness through pollen-based honey standardization, honey drinks, mapping of bee pasture ecology and even development of apiary gardens with an equitable bee pasture, plant biodiversity, which together will be very encouraging in terms of ecology, economy and livelihood.

Key words: Bees, Social System, Pollination, Bee-keeping, Agri-business.

INTRODUCTION

Insects are the most diverse group of animals on the planet and include more than a million described species representing more than half of all known living organisms. Some insects damage crops by feeding on sap, leaves or fruits, a few bite humans and livestock, alive and dead, to feed on blood and some are capable of transmitting diseases to humans, pets and livestock. Many other insects are considered ecologically beneficial and a few provide direct economic benefit. They play a vital role in increasing crop productivity by way of pollination.

SYSTEMATICS AND STRUCTURAL FEATURES OF BEES

The important families of Hymenoptera are Apidae, Megachilide, Anthophoridae, Halictidae and Melittidae. The stinging group include important pollinators such as bees, wasps, hornets and ants. However, of all insects, the Apidae are the most important and are highly adapted for anthophily. Adults of all the species feed on nectar and pollen. The wild bees may be solitary, gregarious or social. The family Apidae consists of bumble bees, stingless bees and true honey bees. Scientific classification of honey bees is as follows

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Hymenoptera

Superfamily: Apoidea

Family: Apidae

Sub family: Apinae

Genus: *Apis*

The insects of the Orders Coleoptera, Diptera, Lepidoptera and Hymenoptera are very important pollinators of cultivated plants. Honey bees are involved not only in the pollination process but also in the production of honey,

based on which apiculture as an occupation and agribusiness have evolved. There are many newer avenues for knowledge generation and economic well being. The present treatise narrate some basic facts relating to bee based science and technology with notes on potential for new research and management in apiculture.

Honey bees (Genus: *Apis*), belong to super family Apoidea in the Order Hymenoptera. Occurring in almost all parts of the world except the polar region with its possible centre of origin in South and South East Asia (250 genera in 9 families). These bees are either solitary or lead a social life but all individuals share some common characteristics. Body of all bees is covered with branched hairs. Bees possess one pair of compound eyes and three numbers of ocelli facilitating good vision, chewing and lapping type of mouth parts with well adapted proboscis for nectar collection. There are pairs of legs differentially modified, first pair for antenna cleaning, second pair for wax picking and third pair for pollen collection. Nearly all bees feed on pollen and nectar and they tend the young ones in the cells with food for the developing individual. They represent only a small fraction of approximately 20,000 known species of bees.

SOCIAL SYSTEM OF HONEY BEES

Honey bees are social insects leading a colonial life. A honey bee colony has a fascination of its own and is admired for their industriousness, unity, self sacrifice, toleration, division of labour and spirit of social service. There are three castes in a colony: Queen, Workers and Drones. In a normal colony there is generally one queen, 10,000 to 30,000 workers and a few hundred drones.

Queen

The queen is the only perfectly developed female and is the mother of the colony capable of laying 750-1000 eggs per day. She mates with several drones in the air only once in her life time. She can lay fertilized or unfertilized eggs at her will. From the former, workers and sexual females or potential queens and from the latter drones are produced. The differentiation between the workers and the queen is not due to the quality as previously believed, but to the quantity of the food fed to the larvae. The partial starvation, from about the third day of the larvae that are reared in worker cells, results in their differential growth and they become workers and if they would have been lodged in the specially-constructed larger queen cells they developed into a queen. The queen is raised from a normal worker egg, but is fed with a larger amount of royal jelly, a protein-

rich secretion from hypo-pharyngeal glands on the heads of young workers. If not for being heavily fed with royal jelly, the queen larvae would have developed into a regular worker bee. All honey bee larvae are fed with some royal jelly for the first few days after hatching but only queen larvae are fed on it exclusively. As a result of the difference in diet, the queen will develop into a sexually mature female, unlike the worker bees.

Honey **bee queen** releases **pheromones** to regulate hive activities. The queen influences and controls the colony by the production and dissemination of a variety of pheromones or 'queen substances'. One of these chemicals suppresses the development of ovaries in all the female worker bees in the hive and prevents them from laying eggs.

Workers

The worker bees are imperfectly developed females. They are unable to reproduce but possess all the maternal instincts. They are responsible for the maintenance and welfare of the colony. A worker bee has no individual existence and throughout her life she labours for the welfare of the colony. A worker bee lives for 44 - 54 days. Division of labour is prominent in honey bee colony. Worker bees do all the activities in the colony according to their age in days: day 1-2 cleaning the cells; day 3-11 feed the worker larvae; day 6- 11 production of royal jelly for feeding the queen; day 12-17 wax production, comb building, sealing ripened honey, pollen packing, propolising, fanning; days 18 - 21 carrying water, serve as guard bees; days 22 - 54 foraging.

Drone

They are male bees and the only function of the male bee is to mate with the queen. They are bigger in size than the workers and can be identified by the darker colouration, big eyes and rounded abdominal tip. Drones are characterized by eyes that are twice the size of those of worker bees and queens. They have short tongue and do not collect food from flowers. Drones never exhibit typical worker bee behaviors such as nectar and pollen gathering, nursing or hive construction. They are devoid of sting, wax glands and scent glands. Drones are reared and tolerated during the breeding season when new queens are to be mated. They are driven out of the hive to die of starvation when not needed. After mating with the queen the drone bee dies.

Communication in bees

Bees communicate each other with the help of bee dances and pheromones. Foragers communicate their floral findings to the hive through two types of dances, round dances and waggle dances - the former for indicating nearby targets and the latter for indicating distant targets.

BEE FORMS - A PROFILE

There are four true *Apis* species *viz.*, Rock bee *Apis dorsata* Fab. , the little bee *Apis florea* Fab., Asian honeybee *Apis cerana indica* Fab., and European honey bee *Apis mellifera* Linn. and the stingless bee *Trigona iridipennis* available in India. The rich and diverse flora of our country/ State offers a congenial ecosystem/domicile for their existence. All these species can be exploited for pollination and crop improvement.

Rock bee (*Apis dorsata* Fab.)

It is the world's largest honey bee. Rock bee is met with all over India in the plains and in the hilly areas up to 1600 m above sea level. They build single combs, mainly in exposed places far above the ground, attached to a branch of tree, rocks and ceilings of buildings etc. Concentration of colonies on one tree is common and there can be 50 -100 colonies on a tree; the comb area can be up to 1 m^2 and the comb is typically covered by a dense mass of bees in several layers. Worker and drone cells are equal in size. They have ferocious temperament and is provoked by slight disturbance. Worker bees attack in mass and may follow the victim over long distances. They are good honey gatherers. Honey is stored in the top half portion of the comb. One nest can contain as much as 60 kg of honey. Rock bee has never been domesticated as it does not use enclosed cavities for nesting (Fig.1).

Little bee (*Apis florea* Fab.)

This species is found in plains of India up to 300 m above sea level. The size of the bee is smallest among the four *Apis* species described and smaller than Indian bee. This is a wild bee but attempts to keep it in specially designed hives have met with partial success in India. It is highly migratory but long distance migrations are unknown. Disturbances cause them to desert the comb

leaving behind honey, brood and pollen stores. *A. florea* also builds a single comb nest and the comb is fixed to branches of bushes, hedges, tree etc in the shady places. They have gentle temperament but do sting when irritated. The comb is broad at the top and it serves as a landing place for the foragers. The comb is always covered by a layer of worker bees. They are very prone to swarming. The species is a poor honey yielder and a comb yields about 200 g to 900 g of honey per year. Colonies can be shifted to crop fields at blooming time for pollination. This species seem to visit most of the agricultural crops (Fig. 2).

Indian bee (*Apis cerana indica* Fab.)

This species is found throughout India except the plains of North India. These bees are larger than *Apis florea* but smaller than *Apis mellifera*. It is used for commercial beekeeping in Kerala. The domicile include cavities of tree trunks, hollows of rocks, poles and other covered places. It builds multiple parallel combs. It is a bee with gentle temperament and it responds to smoking. It is frugal in habits but lack of flora is quickly reflected into their absconding. It also has a strong tendency for swarming. A colony may issue up to 5-6 swarms in a year. It is a poor propolizer and practically no propolis is brought to the nest. It is capable of being domesticated and is commonly reared in South India. In a bee colony of average size there may be 20,000 - 30,000 bees consisting normally of a queen, a few hundred drones and the remaining workers making up over 90 per cent of the population. It is a low honey yielder compared to rock bee and Italian bee. On an average a colony yielded 3-5 kg of honey per year earlier but now with adoption of scientific beekeeping methods it increased to 10-15 kg per colony (Fig.3).

European honey bee (*Apis mellifera* Linn.)

This species is found all over Europe and also spread to other continents during the last five centuries. Now it is found almost in every country. The Italian bee *Apis mellifera ligustica* is considered to be the best race for commercial beekeeping. It was introduced into Himachal Pradesh in 1962 and later on to Punjab and Haryana. From Haryana it was brought to Kerala in 1992. This bee is similar in habits to Indian bees in that it builds parallel combs in hollows of trees, walls or in shady places or in other enclosed situations. A colony is composed of relatively large populations, usually 60,000 -70,000 individuals. It maintains a prolific queen. They swarm less, gentle in temperament and good honey gatherer. They yield about 45-60 kg honey annually (Fig.4).

Stingless bee (*Trigona iridipennis* Smith)

This is the common stingless bee species found in India. These are not truly stingless but the sting parts are poorly developed. They defend by biting. They are fond of darkness and make nest in hollow trees, bamboos, rocks or cracks of walls etc. Nest cells are made of wax and plant resins called cerumen. A colony consists of a queen, few thousand workers and a few drones. Honey and brood cells are separate in the nest and the size is also different. They produce honey (200 g to 1 kg per hive) which is having high medicinal properties and widely used in Ayurveda. Stingless bees visit most of the crops which could not be foraged by true honey bees and it is an efficient pollinator (Fig.5).

BEE POLLINATION AND CROP IMPROVEMENT

Pollination Services

Agriculture depends greatly on the honey bees for pollination. They play a very critical role in our food chain. They are responsible for pollinating 80 per cent of the world's fruits, nuts, vegetables, seeds and other agricultural crops, thus laying the very foundation of our food chain. Honey bees have been working tirelessly in our fields for millennia, making sure that our crops stay pollinated and conserved for generations.

Bees start work early in the morning and continue till late evening and put more work. The body parts of the honey bees are modified to suit their mode of life. They have memory of the food source. They continue to visit a source as long as they do not find a better source. Nectar and pollen rewards are available at a particular time of the day and the bees memorize to visit the source during those hours. The availability of pollen and nectar is the only thing which links the pollinators with entomophilous plants. Bees have a sharp instinct for locating nectar and evaluating its quality.

Scientific experiments and practical experience have proved that cross pollination of flowers of various entomophilous crops by insects is the most effective and cheapest means of increasing crop yield. It is estimated that the benefits obtained from honey bee pollination is to the tune of 14.6 billion US dollars per annum. The bees of an apiary consisting of 100 colonies visit and pollinate over the year not less than 60 billion flowers of entomophilous plants. The count of 600 million pollinated flowers can be taken as a unit of measurement for the pollination work of a single bee colony. Such, in reality, is the stupendous and biologically useful pollination work of honey bees. Apple, orange, grapes,

litchi, pear, vegetables, cucurbits, peas etc, are some crops benefited by bee pollination for yield increase (Fig.6, 7).

The economic effectiveness of using bees as pollinators for different crops can be assessed on the basis of the fluctuations in the yield for different years after bee-assisted pollination. The great value of bees as pollinators has been known from ancient times but unfortunately this knowledge is not widely appreciated and understood. The valuable insects like the honey bees are either ignored or getting less attention. We should start caring for the bees lest the words of Albert Einstein which goes thus *"IF THE BEES DISAPPEAR FROM THE SURFACE OF THE EARTH, MAN SHOULD HAVE NO MORE THAN FOUR YEARS TO LIVE, NO MORE BEES, NO MORE ANIMAL POLLINATION, NO MORE ANIMAL, NO MORE MEN"* is proved right.

Millions of honey bees are buzzing off and vanishing due to CCD (Colony Collapse Disorder), climate change, indiscriminate use of pesticides, adoption of genetically modified crops, incidence of parasitic mites, diseases caused by micro-organisms, radiations from mobile phones etc. It is time to give due attention to the environmental hazards, reducing bee population.

The yield of the plants depends upon nectar production and honey collection. Entomophilous flowers are showy, brightly coloured, large, odoriferous and produce nectar. The pollen grains liberated by them are generally sticky. When a bee is collecting nectar or pollen, thousands of pollen grains stick on the body of the bee. Upon landing on another flower and trying to collect the reward, pollen get deposited on the stigma of the flowers and pollination is effected. It would be highly desirable to have a high population of pollinating insects at the blossoming time of a crop so that maximum yield of the crop is obtained and the number of insects available at that time does not act as a limiting factor. The advantage of cross pollination by insect is that it helps to increase the yield of agricultural crops, increases fruit-set and reduces fruit drop.

Studies revealed that the queen of spices, cardamom depends on honey bees for its pollination and the yield can be increased upto 20 per cent by keeping bee colonies in cardamom plantation. In coconut (*Cocos nucifera)* also 20-30 per cent yield increase through bee intervention has been observed (Fig.8). In Europe, Australia, New Zealand and North America, fruit and berry growers pay beekeepers to bring bees for pollination in the blossoming season. Bee pollination not only results in a higher number of fruits, berries or seeds, but may also give a better quality of produce and the efficient pollination of flowers may also serve to protect the crops against pests.

Colonies of honey bees can be moved quickly to a crop field that is ready for pollination. The honey bees always tend to forage in the area which is closest to their hive. Care should be taken to place colonies for pollination inside or as near as possible to the crop requiring pollination. Bee colonies should be placed in the field when 5-10 per cent of the plant is in bloom. If the bees are moved too late they can only pollinate the late and less vigorous flowers. The effectiveness of honey bees is due to their great number, their social life and stability to pollinate a broad variety of different flowers. The number of bee colonies required for different cultivated species for pollination depends on density of plant stand, total number of flowers in the inflorescence of each plant, duration of flowering, strength of bee colonies and number of flowers over an area of the land. Crop improvement due to bee assisted pollination in some horticultural and agricultural crops is given below: (Table.1)

Table 1: Crop pollination statistics

Crop	% increase in yield	Crop	% increase in yield
Cashew	20-40	Pear	240-6014
Coffee	16.7 – 39.8	Cherries	56- 1000
Cardamom	20-30	Strawberry	17.4 – 91.9
Orange	47-900	Litchi	4538-10246
Papaya	5-10	Citrus	7-33.3
Apple	180 - 6950	Rapeseed	12.8 – 139.3
Badam	15-20	Mustard	128.1 – 157.8
Coconut	20-40	Niger	60.7 - 173
Vegetables	15-20	Berseem (seed)	24.3 - 33150
Grapes	756.4 - 6700	Buckwheat	62.5
Guava	70-140	Egyptian cotton	16-24
Mango	20-25	Other pulses	28.7 – 73.80
Plum	10-15	Sunflower	21-3400

Source: Bee World 2009 Ministry of Agriculture, Govt. of India, New Delhi

Biodiversity conservation and sustenance is important for bee pasturage and population survival of the social insect. Therefore data on pollinators of

economic groups of plants is of fundamental importance. A record of floral elements is provided in Table.2.

Table 2: **Economic plant groups identified as bee flora**

Common Name	Scientific Name	Family	Source N: Nectar; P: Pollen
Medicinal Plants			
Indigo	*Indigofera tinctoria*	Papilionaceae	N
Touch-me-not	*Mimosa pudica*	Mimosaceae	P
Ixora	*Ixora coccinea*	Rubiaceae	N+P
Phyllanthus (Bhumi Amla)	*Phyllanthus niruri*	Euphorbiaceae	N
Castor	*Ricinus communis*	Euphorbiaceae	N+P
Javanese wool plant	*Aerva lanata*	Amaranthaceae	N
Nagadandi	*Baliospermum montanum*	Euphorbiaceae	N
Periwinkle	*Vinca rosea*	Apocynaceae	N
Boerhavia	*Boerhavia diffusa*	Nyctaginaceae	N
Puliyarala	*Oxalis corniculata*	Oxalidaceae	N
Lawsonia	*Lawsonia alba*	Lythraceae	P
Holybasil(Thulsi)	*Ocimum sanctum*	Lamiaceae	N
Plantation crops			
Rubber	*Hevea brasiliensis*	Euphorbiaceae	N
Coconut	*Cocos nucifera*	Palmaceae	N+P
Cashew	*Anacardium occidentale*	Anacardiaceae	N+P
Coffee	*Coffea arabica*	Rubiaceae	N
Coffee (Congo robusti)	*Coffea robusta*	Rubiaceae	N
Condiments and spices			
Chillies (Red Pepper)	*Capsicum anuum*	Solanaceae	N+P
Tamarind	*Tamarindus indica*	Caesalpiniaceae	N+P
Cinnamon	*Cinnamomum zeylanicum*	Lauraceae	P

Indian Mustard	*Brassica juncea*	Umbelliferae	N
Vegetable crops			
Indian Sponge gourd	*Luffa cylindrica*	Cucurbitaceae	P
Drumstick	*Moringa oleifera*	Moringaceae	N+P
Chinese cabbage	*Brassica pekinensis*	Umbelliferae	N
Dolichos (Broad bean)	*Dolichos lablab*	Papilionaceae	N
Waterleaf (Ceylon spinach)	*Talinum triangulare*	Portulacaceae	P
Radish	*Raphanus sativus*	Cruciferae	N+P
Bilimbi	*Averrhoa bilimbi*	Averrhoaceae	P
Onion	*Allium cepa*	Alliaceae	P
Brinjal	*Solanum melongena*	Solanaceae	N+P
Sweet gourd	*Momordica cochinchinensis*	Cucurbitaceae	P
Black gram	*Vigna mungo*	Fabaceae	N
Field crops			
Bajra (Pearl Millet)	*Pennisetum typhoides*	Poaceae	P
Sunflower	*Helianthus annuus*	Compositae	N+P
Burmese	*Burmese coriander*	Umbelliferae	N
Redgram (Pigeon Pea)	*Cajanus cajan*	Papilionaceae	N
Gingelly	*Sesamum indicum*	Pedaliaceae	N
Ornamental plants			
Balsam	*Impatiens balsamina*	Balsaminaceae	N
Edward Rose	*Rosa chinensis*	Rosaceae	N+P
Coral creeper	*Antigonon leptopus*	Polygonaceae	N+P
Duranta (Golden Dewdrop)	*Duranta goldiana*	Verbenaceae	N
Hamelia (Scarlet Bush)	*Hamelia patens*	Rubiaceae	N
Anthurium	*Anthurium andreanum*	Araceae	P
Marigold	*Tagetes erecta*	Compositae	N
Peacock plant	*Caesalpinia pulcherrima*	Caesalpiniaceae	N+P
Pigeon Berry	*Duranta plumieri*	Verbenaceae	N

Canna	*Canna indica*	Cannaceae	N
Poinsettia	*Euphorbia pulcherrima*	Euphorbiaceae	N
Golden rod	*Solidago canadensis*	Compositae	P
Ball lilly	*Haemanthus cinnabarinus*	Amaryllidaceae	P
Bird of paradise	*Heliconia rostrata*	Zingiberaceae	N
Nymphaea	*Nymphaea stellata*	Nymphaeaceae	P
Sage	*Salvia splendens*	Labiatae	P
Gladiolus	*Gladiolus grandiflorus*	Iridaceae	N
Fibre crops			
Upland Cotton	*Gossypium hirsutum*	Malvaceae	P
Tossa Jute	*Corchorus olitorius*	Tiliaceae	P
Red silk Cotton tree	*Bombax malabaricum*	Bombaeaceae	P
Fruit crops			
Mango	*Mangifera indica*	Anacardiaceae	P
Banana	*Musa paradisiaca*	Musaceae	N
Guava	*Psidium guajava*	Myrtaceae	N+P
Papaya	*Carica papaya*	Caricaceae	P
Herbs, shrubs & bushes			
Euphorbia	*Euphorbia hirta*	Euphorbiacea	N
Crotolaria	*Crotalaria varrucosa*	Papilionaceae	N
Crotalaria	*Crotalaria mucronata*	Papilionaceae	N
Ciara Rubber (Wild tapioca)	*Manihot glaziovii*	Euphorbiaceae	N+P
Sesbania	*Sesbania rostrata*	Papilionaceae	N
Jatropha	*Jatropha kurcas*	Euphorbiaceae	N
Cassia	*Cassia alata*	Caesalpiniaceae	N
Justicia	*Justicia simplex*	Acanthaceae	N
Zizipus	*Ziziphus nummularia*	Rhamnaceae	N
Tuber crops			
Tapioca	*Manihot esculenta*	Euphorbiaceae	N+P

Green manure crop			
Glyricidia	*Gliricidia maculata*	Papilionaceae	N
Forest Trees			
Cannon ball tree	*Courupita guianensis*	Lecythidaceae	N+P
Chinese Birds cherry	*Muntingia calabura*	Tiliaceae	N+P
Eucalyptus	*Eucalyptus globulus*	Myrtaceae	N+P
Sandal	*Santalum album*	Santalaceae	N+P

N: Nectar; P: Pollen

Source: AICRP, Vellayani Centre

The data in Table 2, indicate the wide variation in pollination biology in terms of both the insect and the plants/flowers they visit for nectar, pollen or both. The effective carriage of pollen and its transfer is associated with the structural features of the flower, both with regard to form (actinomorphic or zygomorphic) and fine structure (including nectariferrous glands). Colour, position of the nectary, the pollen presentation including anther and pollen production together serve to attract the bees to the flower and be benefited with food resources. The study of pollination ecology which can be considered for every structure and events associated with pollen transfer warrants field and laboratory investigation to gain a picture of nature's ways and means to effect the vital pollination process.

The Food Procurement Process

Bees are basically looking for two things when they visit the plants, nectar and pollen. Nectar is loaded with sugars and it is the bee's main source of energy and pollen provides the balanced diet of proteins and fats.

Rubber plant (*Hevea brasiliensis* Muell-Arg.) is the major source of nectar and coconut (*Cocos nucifera*) is the source of pollen to bees in Kerala. Bees have well adapted mouth parts (proboscis) that enable them to obtain the nectar from flowers. They collect nectar from flowers as well as extra floral nectaries of some plants like rubber, maruthi (*Terminalia paniculata*) etc. The main contents of nectar are sugars like sucrose, glucose, fructose, amino acids, proteins, lipids, antioxidants, minerals and enzymes. Bee has a complex anatomy to extract nectar from flowers. The extract is stored in a widened region called 'Honey Stomach'

or 'Honey Sac'. The process of conversion of nectar to honey starts here. The nectar is altered chemically by the secretions of two glands namely salivary and hypopharyngeal. The enzymes of these glands break larger sugar molecules to simpler molecules.

In the hive the forager bee disgorges (expels out) the nectar and it is transferred to a hive bee through a process called trophallaxis. The hive bee drinks the expelled nectar through her proboscis and may again disgorge and re-drink the same over a period of 15 – 20 minutes. This makes the nectar to mix up well with enzymic secretions. The nectar may also be passed on to another hive bee for additional processing. Finally the nectar droplet is deposited into the honey comb in thin layers ($1/10^{th}$ of a mm thickness). The ripening of nectar into honey is a combination of two processes, the conversion of complex sugar molecules to simpler molecules and the evaporation of excess water. The evaporation of excess water is facilitated by constant fanning of wings by the worker honey bees. Bee hives are slightly tilted to prevent pooling of water inside the hive. The process of conversion of nectar to honey takes 1- 3 days. In this way all the cells in the comb gets filled and after that cells are capped with newly produced bees wax.

Pollen is the male germ cell produced by all flowering plants for fertilization and plant embryo formation. Honey bees use pollen as a source of nutrition. It is necessary for the growth and development of honey bee larvae. It is also required for adult bees. Pollen is inevitable for the production of royal jelly from the hypopharyngeal glands of the nurse bees and production of wax from the wax glands. Pollen is required in large quantities during the brood rearing season in the hives. Deficiency of pollen results in the poor development of brood. Pollen is one of the richest and purest natural foods, consisting of upto 35 per cent protein, 10 per cent sugars, carbohydrates, enzymes, minerals, and vitamins A (carotenes), B1 (thiamin), B2 (riboflavin), B3 (nicotinic acid), B5 (pantothenic acid), C (ascorbic acid), H (biotin), and R (rutine).

A large bee colony in the course of the year uses 100 kg of honey and 30 kg pollen for feeding its adults and brood. In order to accumulate such a large amount of floral products, the bees of a given colony must visit not less than 500 million flowers. If we add to this 20-25 kg of marketable honey and 3-4 kg of reserve bee bread, the total number of flowers visited and pollinated by the bees of one large colony over one season of their work can reach 600 million

BEE KEEPING AS AN AGRIBUSINESS

There is immense potential for beekeeping in the State due to the

availability of a large array of diversified flora yielding nectar and pollen to honey bees. Kerala has 'Kalpavriksha' the coconut palm (*Cocos nucifera*), the ever-showering source of pollen to bees which is grown in an area of 9.05 lakh hectares. Rubber (*Hevea brasiliensis*) is the plant which produces the maximum quantity of nectar per plant. They secrete nectar from its extra floral nectaries from January to April. More than 5.5 lakh hectares of rubber plantations spread all over Kerala, offer immense potential for beekeeping in the State. Eighty three per cent of the area under rubber in India is in Kerala. Four lakh hectares are available for exploitation of honey; the potential for honey production being about 80,000 tons. We require 40 lakh bee colonies to collect the entire rubber honey from our State but we have only about eight lakh colonies at present. It is estimated that there are more than 50,000 beekeepers in the State. Honey worth Rs. 38 crores is being wasted due to lack of exploitation.

Beekeeping is an agro based enterprise, which farmers can take up for additional income generation. The growing market potential for honey and its products has emerged bee keeping as a viable enterprise.

BEE HIVE PRODUCTS

Honey

Honey has been familiar to man since pre-historic times. It is a sweet viscous liquid which is used as medicine as well as food. Ayurvedic as well as Yunani medicine have been using honey as a vital ingredient for centuries.

CHEMICAL COMPOSITION: Honey contains glucose and fructose which are quickly absorbed by the digestive system and converted into energy; this can be used as instant energizer which provides about 3000 calories per kg. It is a fat free food for all, old and young. It contains more than 180 different substances *viz.*, carbohydrates (fructose and glucose), organic acids (gluconic acid, citric acid, malic acid, formic acid), proteins and amino acids (Tryptophan, Lysine, Methionine, Cysteine, Histidine, Glutamine, Tyrosine), minerals (Calcium, Iron, Magnesium, Phosphorus, Potassium, Sodium, Zinc, Copper, Manganese and Selenium), enzymes (diastase, invertase, glucose oxidase, catalase), vitamins (Vit. C, B6, B12, Riboflavin, Niacin, Folic acid) and antioxidants (polyphenols, Pinocembrin, Pinobanksin, Chrysin and Galagin) (Fig.9). The percentage composition of honey is calculated as follows:

Water - 20.00 %; Fructose - 37.00 %; Glucose - 34 %; Sucrose and other sugars - 5 %; Total Ash (minerals) - 0.25 %; Organic acids - 0.20 %; Proteins, amino

acids - 1.50 %; Vitamins - 0.8 %; Others - 1.25 %

Table 3: **Nutritional value of honey per 100 g**

Content	Quantity	Content	Quantity
Energy	304 kcal	Folate (Vit. B_9)	2 µg (1%)
Carbohydrates, sugars	82.4 g	Vitamin C	0.5 mg (1%)
Dietary fiber	0.2 g	Calcium	6 mg (1%)
Fat	0 g	Iron	0.42 mg (3%)
Protein	0.3 g	Magnesium	2 mg (1%)
Water	17.10 g	Phosphorus	4 mg (1%)
Riboflavin (Vit. B_2)	0.038 mg (3%)	Potassium	52 mg (1%)
Niacin (Vit. B3)	0.121 mg (1%)	Sodium	4 mg (0%)
Pantothenic acid (B_5)	0.068 mg (1%)	Zinc	0.22 mg (2%)
Vitamin B_6	0.024 mg (2%)		

HEALTH-CARE VALUE: As honey is hygroscopic it speeds up wound healing, growth of healing tissue. It acts as a sedative and is very useful in bed wetting disorders. Honey is a very good antioxidant and a safe anti-ageing food which restores the damaged skin and gives soft, young looks. Honey has antibacterial properties due to its acidic nature and enzymically produced hydrogen peroxide. Constant use of honey strengthens the white blood corpuscles to fight bacterial and viral diseases. Honey is very good for eyes and eye sight, quenches thirst, dissolves kapha, reduces effects of poison, and stops hiccups. It is very useful in urinary tract disorders, worm infestations, bronchial asthma, cough, diarrhoea, nausea and vomiting.

Bee Pollen

Bee pollen contains most of the known nutrients, including all of those necessary for human survival. When compared to any other food, it contains a higher percentage of all necessary nutrients. Bee pollen is approximately 25 per cent complete protein containing at least 18 amino acids. In addition, bee pollen provides more than a dozen vitamins, 28 minerals, 11 enzymes or co-enzymes,

14 beneficial fatty acids, 11 carbohydrates, and is rich in minerals, the full spectrum of vitamins, and hormones. It is low in calories.

QUANTITATIVE ANALYSIS: Proteins- 23.7 per cent , Fat - 4.8 per cent, Sugars - 27.0 per cent, Phosphorus - 3.53 per cent, Potassium - 0.58 per cent Calcium - 0.225 per cent, Magnesium - 0.148 per cent, Sodium - 0.04 per cent, Iron - 140 mg/g, Manganese - 100 mg/g, Zinc - 78 mg/g, Copper - 14 mg/g, Thiamine - 9.4 mg/g, Niacin - 157 mg/g, Riboflavin - 18.6 mg/g, Pyridoxine - 9 mg/g, Pantothenic acid - 28 mg/g, Folic acid- 5.2 mg/g, Biotin -0.32 mg/g, Vitamin C - 350 mg/g, Carotene - 95 mg/g, Vitamin E - 14 mg/g.

Bee pollen rejuvenates our body, stimulates organs and glands, enhances vitality, and brings about a longer life span. Bee pollen's ability to increase energy levels consistently and noticeably makes it a favourite substance among many world class athletes and those interested in sustaining and enhancing quality performance. Several nutrients in bee pollen such as proteins, selenium, nucleic acids, lecithin and cysteine are scientifically well documented for their ability to strengthen immunity, counteract the effects of radiation and chemical toxins. Bee pollen provides anti-oxidants that scavenge free radicals caused by exposure to radiation, chemical pollutants, and other intense physical or emotional stressors (Fig.10).

Consumption of bee pollen is increasing day by day. China, America, Russia, Spain and Europe are the main commercial producers of bee pollen. China is the leading country which produces about 3000- 5000 metric tons of pollen every year. Coconut palm is one of the rich sources of pollen to bees which showers the pollen throughout the year. One inflorescence of coconut contains about 272 billions of pollen grains (Fig.11). It is pale white in colour. There is great scope for pollen production in Kerala. Pollen is available in market as granules, capsules, pollen with honey etc.

iii) Bees wax

Bees wax is a voluntary secretion from the fourth to seventh ventral plates of the bee's abdomen. The wax originates in a liquid state in the wax secreting gland and it solidifies and forms small scales about 3.0 mm across and 0.1 mm thick which the bees use for construction of comb for sealing ripened honey and brood.

Wax can be processed from the old combs and made into pure form. Pure bees wax having pale yellow colour, is sometimes nearly white, and the difference in colour is due to pollen consumed by the bees.

The constituents of bees wax include Hydrocarbon -14 per cent, Monoester-35 per cent, Diesters -14 per cent, Triester -3 per cent, Hydroximonoesters- 4 per cent, Hydroxy polyesters - 8 per cent, Acid esters- 1 per cent, Acid polyesters - 2 per cent, Free acids - 12 per cent, Free alcohols - 1 per cent, Others - 6 per cent.

It is used for making candles, metal castings and modelling, varnish, paints, ink, paper, pencils, crayons, carbon paper, chewing gums, comb foundation sheets, cosmetics like lotions, creams, lipsticks, coating for drugs or pills etc.

iv) Royal jelly

Royal jelly is secreted by the hypopharyngeal glands of young worker (nurse) bees, to feed young larvae and the adult queen bee. It is whitish in colour with a pungent phenolic odour and a characteristic sour flavour. Royal jelly is collected and sold as a dietary supplement, claiming various health benefits because of components like B-complex vitamins such as pantothenic acid (vitamin B_5) and vitamin B_6 (pyridoxine). The overall composition of royal jelly is 67 per cent water, 12.5 per cent crude protein (including small amounts of many different amino acids), and 11 per cent simple sugars (monosaccharides), also including a relatively high amount (5 per cent) of fatty acids. It also contains many trace minerals, some enzymes, antibacterial and antibiotic components, and trace amounts of vitamin C. The fat-soluble vitamins, A, D, E and K are completely absent in royal jelly.

Royal jelly provides vigour and vitality to humans. It is available in market in liquid form as well as capsules. Royal jelly can be sold in its fresh state, unprocessed except for being frozen or cooled, mixed with other products, or freeze-dried for further use in other preparations. It is used as a food supplement, medicine and also as a cosmetic. China is the largest producer of royal jelly. They produce 500-800 tons of royal jelly per year. Approximate cost of 1 g of royal jelly is about Rs. 3000/-. The technology is available for production and storage of royal jelly. THERE IS ABUNDANT SCOPE FOR India/Kerala to enter into the commercial production of royal jelly in days to come.

v) Bee venom

Honey bee venom - Apitoxin is produced by two glands associated with the sting apparatus of worker bees. A honey bee can inject 0.1 mg of venom through its stinger. Honey bee venom is a clear, odourless, watery liquid. It

contains histamine, apamin, asithianase, hydrochloric acid, formic acid, sulphur, calcium, copper, magnesium sulphate etc.

Bee venom therapy (apitherapy) is used by some as a treatment for rheumatism and joint diseases due to its anticoagulant and anti-inflammatory properties. Since bee venom has both a local and a systemic effect, correct placement of injections or stings and the dosage are very important. Therefore, bee venom therapy must be properly learned. Still, relief of some ailments can be obtained by simply applying a sting or two to the affected area. Bee venom may be sold as whole bee extract, pure liquid venom or an injectable solution. Most venom is sold in a dry crystalline form. Cost of bee venom is about $100-200 per gram.

vi) Propolis

Propolis is another product from bee hive. Italian bees are the better collectors of propolis but the Indian bees are least one.

Marketable forms of honey

Generally, honey is classified by the floral source of the nectar from which it was made (e.g. cardamom honey, coshew honey, rubber honey, litchy honey, coconut honey etc).

Polyfloral

Polyfloral honey, also known as wild flower honey is derived from the nectar of many types of flowers. The taste may vary from year to year, and the aroma and the flavour can be more or less intense, depending on which bloomings are prevalent.

Monofloral

It is made primarily from the nectar of one type of flower. Different monofloral honeys have a distinctive flavor and colour because of differences between their principal nectar sources. In order to produce monofloral honey beekeepers keep beehives in an area where the bees have access to only one type of flower. Eg. Litchi honey, rubber honey, cashew honey, coffee honey etc.

Generally, honey is bottled in its familiar liquid form. However, honey

is sold in other forms also. Honey is available in markets in different forms.

Comb honey

It is honey still in the honey bees' wax comb untouched by human hand Comb honey traditionally is collected by using-standard wooden frames in honey supers. The frames are collected and the comb cut out in chunks before packaging As an alternative to this labor intensive method, plastic rings or cartridges can be used that do not require manual cutting of the comb, and speed packaging Comb honey harvested in the traditional manner is also referred to as "Cut-Comb honey"

Chunk honey

The honey packed in wide mouth containers consisting of one or more pieces of comb honey immersed in extracted liquid honey.

Raw honey

Raw honey is as it exists in the bee hive or as obtained by extraction. It contains some pollen and may contain small particles of wax.

Pasteurized (Processed) honey

It is the honey that has been heated in a pasteurization process. Pasteurization destroys yeast cells. It also liquefies any micro-crystals in the honey which delays the onset of visible crystallization. However, excessive heat-exposure also results in product deterioration as it increases the level of hydroxymethylfurfural (HMF) and reduces enzyme (e.g. diastase) activity. Heat also affects appearance, taste, fragrance and darkens the natural honey color (browning).

Whipped honey

It is also called creamed honey, spun honey, churned honey, candied honey, and honey fondant, is honey that has been processed to control crystallization. Whipped honey contains a large number of small crystals in the honey. The small crystals prevent the formation of larger crystals that can occur in unprocessed

honey. The processing also produces a honey with a smooth spreadable consistency.

Dried honey

Dried honey has the moisture extracted from liquid honey to create a completely solid, non-sticky honey. This process may or may not include the use of drying and anti-binding agents. Dried honey is commonly used to garnish desserts.

Value addition of honey

Honey is considered the food of foods, the drink of drinks and the drug of drugs. It is a good substitute for sugar especially in children's diet. Awareness about the nutritive and medicinal value of honey is lacking among the common people. Per capita consumption of honey in India is among the lowest in the world. Honey can be consumed as food as such, as well as in many other recipes *viz.*, honey spread, honey with fruits and nuts, honey jelly, honey candies, chocolate, honey breads, honey cakes, honey biscuits , honey vinegar, honey wine, honey drink etc.

Honey is also widely used in cosmetic industries. Many face creams and lotions contain honey. Honey has a nourishing, bleaching, astringent and antiseptic effect on the skin. Honey packs, honey masks and honey facials are getting more and more popular.

CONCLUDING REMARKS

Apiculture is an enterprise which helps farmers to earn additional income through sale of bee appliances, honey, bee pollen, bees wax, bee colonies, gravid good quality queen and value added products. Beekeeping is generally meant for production of honey. The benefit obtained through pollination by honey bees is much greater than the income generated through the above. Beekeeping helps for employment generation to unemployed youth and women. Motivation of people to adopt hi-tech apiculture will enable them to develop raw material for agribusiness and their welfare

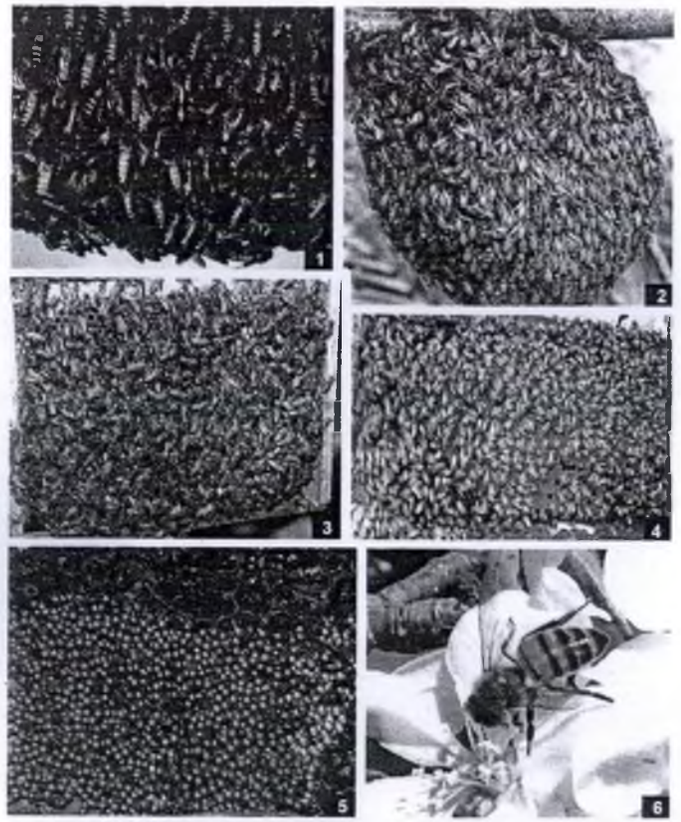

PLATE 1

Fig. 1. ***Apis dorsata*** (Rock bee)
Fig. 2. ***Apis florea*** (Little bee)
Fig. 3. ***Apis cerana*** (Indian bee)
Fig. 4. ***Apis mellifera*** (European bee)
Fig. 5. ***Trigona iridipennis*** (Stingless bee)
Fig. 6. Apple flower foraged by worker bee

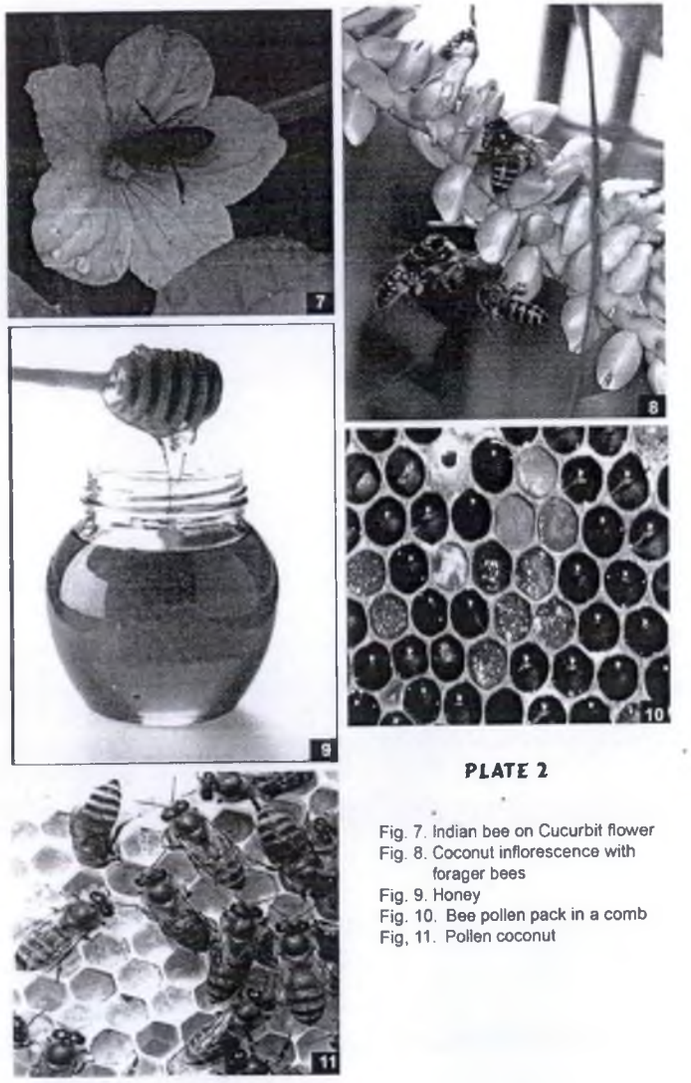

PLATE 2

Fig. 7. Indian bee on Cucurbit flower
Fig. 8. Coconut inflorescence with forager bees
Fig. 9. Honey
Fig. 10. Bee pollen pack in a comb
Fig, 11. Pollen coconut

Advantages of beekeeping as an income-generating activity

- Bee keeping requires less time, money and infrastructure investments
- Honey and beeswax can be produced from an area of little agricultural value
- Honey bee does not compete for resources with any other agricultural enterprise
- Beekeeping has positive ecological consequences. Bees play an important role in the pollination of many flowering plants
- Honey is a delicious and highly nutritious food
- Beekeeping can be initiated by individuals or groups
- The market potential for honey, wax, pollen and other hive products is high

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BOTANY, PALYNOLOGY AND MODERN AGRICULTURAL BIOTECHNOLOGY

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ABSTRACT

Conventional biotechnology, involving selection of desired variations arising out of natural or induced mutations has a history of over 10, 000 years in which Triticale an intergeneric hybrid between wheat and rye is an example. Modern biotechnology involves genetic engineering technology producing transgenic crops, with desired traits, with enhanced nutritional qualities, higher farm production and ecologically friendly. The success achieved through *Bt* cotton, is well recognized. The issues regarding the development GM crops with regard to various food crops in India, together with the origin and domestication of some crops are discussed.

Key words: Agricultural Biotechnology, Transgenic crop, *Bt* cotton, *Bt* brinjal, Triticale, Palynology, Genetic resources.

INTRODUCTION

Modern Agricultural Biotechnology (MAB) has demonstrated its potential during the past 14 years of commercial cultivation. By and large the farmers,