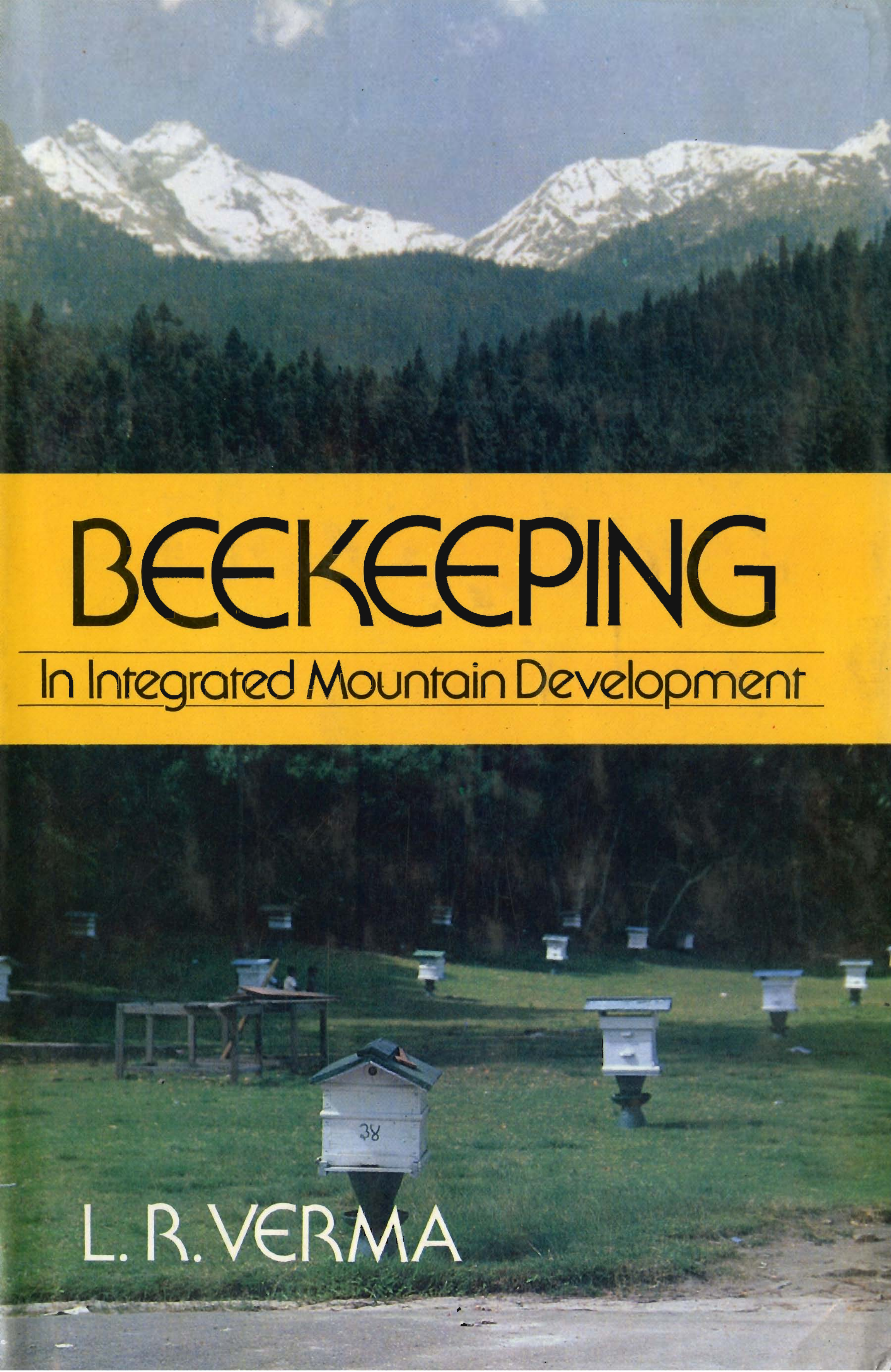
BEEKEEPING

In Integrated Mountain Development



L. R. VERMA

This important and interesting book on apiculture is unique in the sense that, besides presenting a comprehensive review, on scientific and practical aspects of beekeeping, it covers the economic and developmental aspects of apiculture as a cottage industry and analyses its prospects based on the ecological resources and socioeconomic conditions prevailing in the Hindu Kush-Himalayan region. Against this background, the conclusions and recommendations drawn by the author will be relevant to other developing countries.

This analysis of a diverse but specialized subject will be of immediate use to agricultural and other applied scientists, extension workers, policy makers, planners, and aid agencies and also go far beyond the sphere of its primary users to propagate the knowledge concerning the intrinsic value of bees and beekeeping to environment and society as a whole.

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In Integrated Mountain Development: Economic and Scientific Perspectives

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L.R. VERMA

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Dedicated to my father

SHRI CHET RAM

who even from a very remote village of the Shimla hills
enabled me to adopt a career in
scientific teaching and research

CONTENTS

Foreword

Throughout the developing countries of the world, mountain areas have been characterized by predominant subsistence economies which are now becoming critical. There can be no doubt that mountain resources and environments are deteriorating at an unprecedented rate and that increasing numbers of people and mountain communities are under considerable stress. Such tendencies are more pronounced in the agricultural sector which, defined broadly, includes all land-based activities, such as crop farming, horticulture, forestry, and livestock rearing. Many small and marginal farmers, as well as the landless, do not produce sufficient food or earn sufficient income to feed their families adequately throughout the year. Concentrated efforts to overcome these problems have been made over the past 10 years, but the results so far have been quite negligible. Under these circumstances, alternative strategies for sustainable mountain agriculture should entail full exploitation of underutilized resources in order to diversify the income and food sources of mountain people; giving due consideration to ecological sustainability and environmental safeguards.

Mountain Farming Systems' programmes at ICIMOD are aimed at the search for such non-landbased activities or options in the context of the sustainable development of mountain agriculture in terms of resource base availability, resource use/management practices, and production flow. Within this context, ICIMOD has identified beekeeping (Apiculture) as one such income- and food-generating activity which offers comparative advantages for mountain areas with positive ecological consequences. Beekeeping has been closely linked with the cultural heritage of the rural mountain population. This activity offers options for communities in the economically marginal category, because it is a low investment activity. In addition, it is flexible enough to match any scale of operation or any category of manpower. Hive products are in demand both locally as well as in foreign markets. The pollination activities of honeybees boost the productivity of several mountain crops and help in the conservation of forest and grassland ecosystems.

This book, "Beekeeping in Integrated Mountain Development: Economic and Scientific Perspectives", was written by Professor L.R. Verma during his tenure as a Senior Research Fellow at ICIMOD. This Senior Research Programme has been facilitated by a grant from Ford Foundation. Such a fellowship programme enables senior and distinguished professionals to undertake a period of individual "sabbatical" research and publication on a subject of direct relevance to key issues of integrated mountain development. The award of this fellowship to Professor Verma, a well-known authority on apiculture, was an appropriate choice, keeping in mind the vital importance of this subject in sustainable mountain farming systems and integrated rural development.

This important and interesting book on apiculture is unique in this sense that, besides presenting a comprehensive review on scientific and practical aspects of beekeeping, it covers the economic and developmental aspects of apiculture as a cottage industry and analyses its prospects based on the ecological resources and socioeconomic conditions prevailing in the Hindu Kush-Himalayan region. Against this background, the conclusions and recommendations drawn by the author will be relevant to other developing countries.

It is my hope that Professor Verma's professional analysis of a diverse but specialized subject will be of immediate use to agricultural and other applied scientists, extension workers, policy makers, planners, and aid agencies and also go far beyond the sphere of its primary users to propagate the knowledge concerning the intrinsic value of bees and beekeeping to the environment and society as a whole.

E.F. TACKE
Director, ICIMOD

Preface

Apiculture (Beekeeping) as a non-landbased income-generating activity is now becoming an important component of present-day strategies for sustainable mountain agriculture and integrated rural development programmes. The role of beekeeping in improving the subsistence economy of rural communities, especially those living in the developing countries of the Hindu Kush-Himalayan region, cannot be overlooked as it has always been linked with the cultural and natural heritage of mountain ecosystems and their people.

In recent years many valuable books have been published on beekeeping with the European honeybee, *Apis mellifera*, especially for use in developed countries, but still there is hardly a single reference book available on the Asiatic species of honeybees which require a different beekeeping perspective due to different ecological resources, technological levels, and socioeconomic conditions. To bridge this gap, Dr. Colin Rosser, Director, ICIMOD, offered me a Senior Research Fellowship, funded by Ford Foundation, to review the state-of-the-art in this important subject and also to suggest strategies for its further development and improvement, especially in the Hindu Kush-Himalayan regions.

The first section of this book (Chapters 1 to 5) is intended to serve as a guide to policy makers, planners, administrators, rural developers and agricultural and forestry experts to make them aware of the importance of beekeeping in providing extra food, cash income, nutritional benefits, pollination of crops, employment, and improvement of environmental health. It is hoped that this section will arouse considerable interest in Government, non-Government, and funding agencies for their continuing commitment to beekeeping development programmes. The second section (Chapters 6 to 9) deals with the scientific and practical aspects of beekeeping with both native and exotic species of honeybees. It focuses on their biology and management based on ecological and appropriate technological considerations for the Hindu Kush-Himalayan countries. In this section, an attempt has been made to review the up-to-date literature on apicultural research and development programmes, in this region, that is suitable for researchers, extension workers, and beekeepers; as well as for classroom reference. Finally, conclusions and recommendations are drawn for the promotion and development of the beekeeping industry in Asia in general and in the Hindu Kush-Himalayan region in particular.

L.R. VERMA

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This book could not have been completed without the valuable contributions and active cooperation of several individuals and institutions. I particularly wish to express my sincere thanks to Dr. E.F. Tacke, the current Director of ICIMOD, for his keen interest, advice, and encouragement; for providing necessary facilities in ICIMOD, for arranging for its publication; and for writing the foreword to this book. I also owe a great deal to Dr. Colin Rosser, the former Director of ICIMOD, who was quick to realize the importance of beekeeping for sustainable mountain development and showed deep personal interest in this subject. I shall remain indebted to him for the award of the fellowship and for his initial and continuing support for this work. Prof. K.C. Malhotra, Vice-chancellor H.P. University, Shimla, India, was kind enough to grant me sabbatical leave for the completion of this book.

Among my former and present graduate students from the department of Bio-sciences, Himachal Pradesh University, Shimla, I am especially thankful to Dr. V.K. Mattu, Dr. P.C. Dulta, Dr. B.S. Rana, Dr. M.P. Singh, Dr. Neelam Mattu, Dr. R.S. Rana, Miss Roopa Kumari, Miss Usha Mahajan, Miss Leelamma, Miss Alka Sharma, Miss Anju Sharma, Mr. P.C. Sharma, Mr. Pushpinder Chauhan, Mr. Vipin Kumar, Miss Sanjeevan and Miss Maya. Various data have been drawn from their graduate theses and publications.

I have made extensive use of the International Bee Research Association Library in Cardiff, U.K., and this is gratefully acknowledged. I must express my gratitude to Dr. Eva Crane, Honorary Life President and Scientific Consultant to the International Bee Research Association, Cardiff, Wales; Prof. Dr. F. Ruttner, Director, Institut für Bienenkunde, Goethe University, Frankfurt, West Germany; Dr. Rafiq Ahmad, Chief Scientific Officer, NARC, Islamabad, Pakistan; and the Bureau of Indian Standards, New Delhi, for their permission to use original tables and figures.

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Lastly, I am thankful to my wife Dr. Savitri Verma for her intellectual stimulation and inspiration during this work and to my daughters for their support and understanding.

L.R. VERMA

CHAPTER 1

Introduction

Honeybees are social insects with which man has established a harmonious coexistence. These insects have provided humanity with the very basis of civilization because of their highly evolved social behaviour and being the source of the earliest sweet food and trade commodity. Besides, honeybees provide free ecosystem services in the form of cross-pollination and propagation of several cultivated and wild plant species, thereby maintaining biological diversity. They, therefore, not only boost crop productivity but also help in the conservation of forests and grassland ecosystems and save several botanical sources from extinction.

There are at present, four or more species of honeybees in the Hindu Kush-Himalayan region. Among these, *Apis cerana* F., *Apis dorsata* F. /*laboriosa* and *Apis florea* F. are native, whereas an exotic European honeybee, *Apis mellifera* L. has been introduced in some Hindu Kush-Himalayan regions recently. All the native bee species in this region, have been extensively exploited by honey hunters since ancient times. Native *Apis cerana* resemble *Apis mellifera* in many biological and economic characteristics and like other livestock, both these species have been domesticated for honey production and pollination purposes. Other two species, *Apis dorsata*/*laboriosa* and *Apis florea* are found in wild state and so far all attempts to domesticate them have failed.

Apiculture (beekeeping) has been closely linked with the cultural and natural heritage of the rural people and mountain ecosystem, respectively. It is an important resource base of mountain farming systems and offers specific advantages for developing sustainable agriculture. The most important aspect of beekeeping is that it is an important income-generating activity in the hills for small and marginal farmers, landless labourers, and other weaker sections of the society living at, or below subsistence level. Hive products such as honey, beeswax, royal jelly and pollen provide both nutritious food and cash income. These are in demand both locally and for the export market. Yet another significant, but not widely recognized role, is that honey bees enhance the productivity levels of agricultural, horticultural and fodder crops through cross-pollination and thus provide important linkages to these farming systems.

In the Hindu Kush-Himalayan region, temperate (high hills and interior valleys), sub-temperate (middle hills) and sub-tropical (low-lying hills) have a thriving beekeeping industry. Great strides in modernizing beekeeping with the native and exotic honeybee species are being made. Beekeeping has not yet developed on modern scientific lines to the extent it has in the temperate zones of advanced countries. However, in the temperate mountain parts of China and India, efforts have been made to improve traditional methods of beekeeping with native *Apis cerana*, and in certain such areas, this native bee species matches the European honeybee, *Apis mellifera* in honey production and pollination activities. China at present is one of the major producer and exporter of honey and other hive products in the world. Similarly, Himachal Pradesh in northern India has taken the lead in south and southeast Asia in utilizing honeybees, in temperature fruits orchards for pollination purposes, to boost yield and improve quality. Such success stories can be encouraging for other mountain areas where initiative efforts are being made to develop beekeeping on modern scientific lines.

The Hindu Kush-Himalayan region, offers great potential for beekeeping development due to the ideal climatic conditions and diversity of bee floral resources available throughout the year. However, due to constraints such as lack of basic infrastructure, skilled manpower, training, extension facilities or basic and applied research programmes, the situation is far from satisfactory. The biological and economic potentials of native bee species have so far remained unexplored. Some of these native bee species are on the verge of extinction in the Hindu Kush-Himalayan region because of the traditional honey-hunting method, and the introduction of allopatric European honeybee, *Apis mellifera*, and declining habitat. As a result of this, irreversible damage is being caused to both the flora and fauna of this region because honeybees are an important component of the mountain ecosystems. Introduction of exotic *Apis mellifera* may have unfortunate ramifications because of this species allopatric nature, susceptibility to diseases, parasites and predators, different bee flora and high cost technology for operation.

Chapter 1 gives an overview of the apiculture status in this region. Chapter 2 deals with beekeeping as an important non-land based income and food-generating sustainable resource base of mountain farming systems with positive ecological consequences only. Special attributes of apiculture with regards to mountain specificities and constraints of human interventions for the promotion and development of beekeeping in developing countries of this region are discussed. Chapter 3 on apiculture and integrated rural development lays special emphasis on creating awareness among the policy makers and planners in different Government and non-Government organizations and international donor agencies regarding the role of beekeeping in solving the numerous and serious economic, nutritional, ecological and social problem of rural communities living at or below the subsistence level. Chapter 4 on apiculture and mountain crop productivity discusses the role of honeybees as one of the most effective and cheapest biological input by way of cross-pollination in increasing the yield and quality of different agricultural and horticultural crops. Harmful effects of biocides on honeybees are also discussed. An approach to the apiculture status, economics and profitability for different target groups (marginal, small, medium and commercial scale operations) in the Hindu Kush-Himalayan countries is made in Chapter 5. Chapter 6 covers different technological levels starting from the honey hunting state, which has given way to traditional beekeeping with fixed comb hive and how the latter has been wholly or partly replaced by modern beekeeping with movable frame hives. Chapter 7 describes the production technology and marketing potentials of different hive products such as honey, beeswax, royal jelly, pollen, propolis and venom along with their nutritional and medicinal uses. Chapter 8 on honeybee resources fills the longstanding need for a review on biology and management of Asian hive bee, *Apis cerana*. The problems and prospects of introducing the exotic European honeybee, *Apis mellifera* into the Hindu Kush-Himalayan region are also discussed at length. A comprehensive account of honey plant resources along with floral calendars and their linkages to social forestry especially in the Hindu Kush-Himalayan region, is given in Chapter 9. The last Chapter 10, gives the summary, conclusions and recommendations for the promotion and development of beekeeping in the developing countries of the Hindu Kush-Himalayan region.

CHAPTER 2

Apiculture in Mountain Farming Systems

2.1 INTRODUCTION

Mountain regions all over the world not only represent the most spectacular of the ecosystems on earth but have historically been the habitat of flourishing civilizations. However, the subsistence economy which has long been predominant throughout the mountain areas of developing countries is steadily worsening and reaching a near crisis situation. This is because of the increasing unsustainability of production potentials of the natural resource base as a result of demographic pressure and the emergence of new needs. In these mountain regions, pressure on land, always a precious and scarce source, has been mounting at an unprecedent rate. Consequently, the mountain areas are facing serious environmental problems such as soil erosion, degradation of watersheds and catchments, deforestation and desertification. Mountain development strategies therefore, need reorientation in order to strike a satisfactory balance between population, resource base and environmental health. Such a balance would first and foremost require diversification of income sources of the hill communities (Table 2.1).

2.2 APICULTURE IN THE MOUNTAIN ECOSYSTEM

The practice of modern apiculture occurs in the mountain regions of all continents ranging from zero degrees at the equator to at least 50° North and 30° South (Crane, 1990). Modern hive apiculture with the European species of honeybees, *Apis mellifera*, is practised successfully in the mountains of Switzerland and Austria, Colorado, in the USA, and at higher altitudes in Western Canada. Similarly, mountain apiculture occurs in the South American Andes in Ecuador, Colom-

Table 2.1: Match between mountains specificities and attributes of beekeeping

	MOUNTAIN SPECIFICITIES					
Attributes of beekeeping	Inaccessibility	Diversity	Fragility	Marginality	Niche	Adaptation experience
Product:						
Low weight	*					
High value	*					
Non-perishable	*					
Operation:						
Low investment				*	*	*
Flexible scale				*		*
Non-competing resource user			*	*		*
User of:						
Slack resource;			*		*	
diversity, niche		*				
local skill/ resource						*
Contributor to:						
Diversity, integration, environmental health, addn. income/employment, agriculture, productivity/ as a cottage industry	Can partially salvage the side effects of extractive "dependent patterns", help pollination of wild/diverse flora leading to ecological diversity.					

Source: Jodha, 1990.

bia, and in the temperate Morelos province of Mexico. On the African continent, apiculture is an integral part of the lifestyle of the rural communities living in the western highlands of Ethiopia, the Ruwenzori mountains of Uganda, and the Drakensberg mountains of South Africa (See also Tables 2.2 and 2.3).

The whole Hindu Kush-Himalayan region has a rich tradition of apiculture. In this region, the native domestic hive bee, *Apis cerana*, occurs at an altitude of 3,012 m in Kashmir and 2,970 m in Himachal Pradesh (Mattu and Verma, 1983). It is also believed, that the other wild honeybee species, such as *Apis laboriosa*, occurs at even higher altitudes than these. Apiculture with the native, *Apis cerana*, has been

Table 2.2: Examples of mountain beekeeping and prehistoric honey hunting at different altitudes and latitudes

	Place	Alt. (m)	Lat.	Honeybee	Type of Hive
1.	Andes, nr Quito, Ecuador	2800	0°	temp Am	movable-frame
2.	Andes, nr Bogota, Colombia	2600	5°N	temp Am	movable-frame
3.	Western Highlands, Ethiopia	2400	9°N	trop Am(n)	traditional
4.	Rocky Mts, Wyoming, USA	2140	42°N	temp Am	movable-frame
5.	Rocky Mts, Colorado, USA	2040	39°N	temp Am	movable-frame
6.	Drakensberg Mts, S. Africa	2000	27°S	trop Am(n)	honey hunting*
7.	Swat, NWFP, Pakistan	2000	35°N	trop Ac(n)	traditional
8.	Uludag, Turkey	to 1860	40°N	temp Am(n)	movable-frame
9.	Ruwenzori Mts, Uganda	1750	1°S	trop Am(n)	trad, top-bar
10.	Kashmir, India	1700	34°N	temp Ac(n)	trad, mf
11.	Morelos Province, Mexico	1700	28°N	temp Am	movable-frame
12.	White Highlands, Kenya	1630	0°	trop Am(n)	top-bar
13.	Matopo Hills, Zimbabwe	1600	20°S	trop Am(n)	hh*, mf
14.	Concession, Zimbabwe	1500	23°S	trop Am(n)	hh*, mf
15.	Andes, nr Medellin, Colombia	1500	6°N	temp Am trop Am	movable-frame movable-frame
16.	Caucasus Mts, USSR	c. 1500	43°N	temp Am(n)	movable-frame
17.	Alps: Switzerland, Austria etc.	c. 1500	47°N	temp Am(n)	movable-frame
18.	Western Ghats, India	1300	18°N	trop Ac(n)	movable-frame
19.	Kathmandu, Nepal	1280	28°N	trop Ac(n)	traditional, top-bar, mf
20.	Cascade Range, Oregon, USA	1200	44°N	temp Am	movable-frame
21.	Anatolian Plateau, Turkey	1100	38°N	temp Am(n)	trad, mf
22.	Central India	1000	22°N	Ad	honey hunting*
23.	Swat, NWFP, Pakistan	1000	35°N	trop Ac(n)	movable-frame
24.	Khyber Pass, NWFP, Pakistan	1000	34°N	trop Ac(n) temp Am	movable-frame movable-frame

Am = *Apis mellifera*; Ac = *A. cerana*; Ad = *A. dorsata*; n = native; temp = temperate-zone; trop = tropical; hh = honey hunting; mf = movable frame; nr = near; Mts = mountains; trad = traditional.

*Evidence from prehistoric rock paintings.

Source: Crane, 1990.

practised for at least 2000 years, and this species has been exploited extensively by mountain honey hunters and beekeepers. Indigenous log and pot hives, still in use in the Hindu Kush-Himalayan region, are relics of honey collection techniques used with this native bee species (Verma, 1989b).

In all of the above major mountain regions of the world, modern apiculture evolved in a similar way. Primitive honey hunting has given

Table 2.3: Honeybees used for honey production in mountain regions, with examples from Table 2.2

Honeybees	Altitudes of colonies
In hives	
native tropical *Apis mellifera*	up to 2500 m
3, (6), 9, 12, (13), (14)	
tropical (Africanized) *A. mellifera*	up to 3000 m
1, 2, 15	
European (temperate-zone) *A. mellifera*	up to 3000 m
native: 8, 16, 17, 21	
introduced: 1, 2, 4, 5, 11, 15, 18, 20, 24	
native tropical *A. cerana*	up to 2500 m
7, 18, 19, 23, 24	
native temperate-zone *A. cerana*	up to 2000 m
10	
Wild colonies	
native *A. dorsata*	up to 1200 m
(22)	
native *A. dorsata / laboriosa*	up to 3500 m
native *A. florea*	up to 500 m

Numbers in parentheses refer to prehistoric honey hunting.

Source: Crane, 1990.

way to traditional beekeeping and, in some areas, traditional beekeeping is gradually being replaced by modern movable hive beekeeping.

Mountain apiculture is dependent upon different environmental factors, and amongst these the climate of the region is the most important because of its effect on honey plant resources. Flowering plants, which support honeybee colonies and provide surplus honey to the beekeepers, occur from the equator to a height of 3,000 m above sea level. The final vegetation belt providing bee forage consists of fir and pine forests which extend up to to a latitude of 65° or up to a height of 4,000 m above sea level. From the fir and pine trees, honeybees collect honey dew, as an alternative to nectar, and honey dew is produced by aphids on such trees. On certain mountain slopes of New Zealand and Uludag, a mountain in Turkey, large quantities of honey dew are produced on firs and several species of pine and thousands of tonnes of honey are annually harvested from them. One distinct advantage of apiculture at high altitude is that days are very long in mid-summer with more than 14 hours of daylight. Flowers are stimulated by the long mid-summer days and secrete a lot of nectar (Crane, 1990).

Experiences at higher altitudes in Western Canada have shown that apiculture can be carried out, even if the flowering period (when bees can forage) lasts only four months a year. Although temperatures are too low for bees to fly during the remaining months, enough surplus honey is harvested in these four months to make apiculture a commercially viable industry.

Wilson (1965) studied the effect of high altitude on temperate zone European honeybees (*Apis mellifera*), in Rocky mountains at about 40°N in Colorado, USA. Bee colonies normally kept at 1,585 m were shifted to an altitude between 2,896 and 4,267 m for the period June to August. The results revealed that altitudes had no effect on prolificness of the queen bee, brood development, mortality of brood or adult bees, pollen and nectar collecting efficiency and even swarming despite the fact night temperatures in summer were below freezing point at these altitudes. When the colonies were inoculated with *Mellisococcus pluton*, European foul brood appeared in all colonies but high altitude did not increase the severity of the disease. At such high altitude one would expect bees to show some signs of stress but Wilson observed none.

In the mountainous area, the only noticeable difference was reduction in the foraging range of both *Apis cerana* and *Apis mellifera*. For example, *Apis mellifera* worker bees foraged 4 km from their hives at 1,609 m, and 1.6 km at 4,023 m (Wilson, 1965). Similarly, foraging range of *Apis cerana* was 0.25 to 0.30 m along steep slopes and 0.65 m along gentle slopes. However, this difference was not because of altitude but in relation to the gradient of the land (Dhaliwal and Sharma, 1974).

Honeybees living in cold temperate regions of the world adopt different strategies for winter survival which have been reviewed by several workers (Seeley and Heinrich, 1981; Johansson and Johansson, 1979; Michener, 1974; Ribands, 1953). These include careful selection of suitable protective nest site, storage of honey in the hive as winter food, compact dustering of bees in side colony. Isometric contraction of flight muscles inside the clusters and use of stored honey as winter heat fuel source enables honeybee colonies to survive, when the winter temperatures fall below −30°C or less and their survival is possible even at as far north as 60°N latitude.

The above review suggests that the constraints of severe cold climate and high altitude do not limit apiculture development programmes. They are successfully practised in both developing and developed mountain areas of the world.

2.3 APICULTURE AND MOUNTAIN PERSPECTIVE

The development scenario in the mountain areas of developing countries in general and in the Hindu Kush-Himalayan region in particular reflects a widening gap between effort and achievement. Due to extensive and intensive cultivation to increase agricultural production, per capita availability of land is declining. Agriculture is being extended to submarginal and marginal lands with serious environmental consequences. Likewise, the other development interventions in this region are showing increasing unsustainability. The underlying reasons for this scenario is the disregard of mountain perspective in development activities of mountain areas. According to Jodha (1989a) mountain perspective means "explicit consideration of mountain specificities (characteristics) and their implications, while conceiving and implementing activities in mountain areas. Several such mountain specificities include inaccessibility, fragility, marginality, diversity, niche (or comparative advantage) and people's adaptation experience in mountain areas (Jodha, 1989a). These specificities are not only interrelated due to their common causes as well as shared consequences, but they have intra-mountain variations. Moreover, these characteristics have physical (climate), biological and socio-economic dimensions." Thus for sustainable development of mountain agriculture, efforts should be diverted to activities/options that are in tune with mountain characteristics. Apiculture is one such non-land based activity which fits in very well in relation to sustainable development of mountain agriculture. The relevant attributes of apiculture in relation to mountain characteristics as defined by Jodha (1989a) are as follows (Table 2.1).

Physical dimensions of inaccessibility such as slope, overall terrain conditions and landslides play a less constraining role in apiculture development because hive products are characterized by low weight, high value, non-perishability, high storage capacity and easy transportation. Nevertheless, certain manifestations such as isolation, distance, poor communications and limited mobility create some problems for diffusion of modern bee management technology among the farmers and also in monitoring bee epidemics and other natural catastrophies. These can however largely be overcome through the improvement in traditional beekeeping with native *Apis cerana* instead of introducing the exotic European honeybee (*Apis mellifera*) which requires high cost modern bee management technology.

Exploitation of forest and grassland ecosystems by man has resulted in an overall degradation of environment and is largely responsible for the present ecological crisis. On the other hand, use of botanical resources of these ecosystems by bees for pollen and nectar have proved rewarding because of their activities as pollinators, thus helping in the conservation of a large number plant species. The natural population of honeybees is, therefore, an integral part of forest and grassland ecosystem. However, any pressure operating upon the mountain resource system, whether natural or man-made, adversely affects the beekeeping potentials of that area. For example, as a result of deforestation, overgrazing, changing agricultural practises and the use of biocides is causing irreversible damage to bee fauna with the result that different honeybee species in the region are facing threatened extinction. Such declining trends in populations of honeybees in nature, not only means a serious negative impact on the income level of the mountain farmers living at, or below subsistence level, but also serious impairment or partial loss of essential ecological services such as cross-pollination and propagation of several cultivated and wild plant species.

Apicultural diversity has different dimensions. It can be physical (climatic), bee species and genetic diversity, honey plant resources (biological) as well as hive products diversity. For example, different agro-climatic regions, i.e., higher hills and their interior valleys, middle hills and sub-tropical areas are ideally suited for beekeeping. In all these ecological zones of the Hindu Kush-Himalayan region, hundreds of flowering plants species (both wild and cultivated) are found which act as excellent nectar and pollen sources out of which honeybees produce diversified hive products such as honey, beeswax, royal jelly, pollen, propolis and venom. These provide both nutritious food and cash income to the mountain farmers. At present, the Hindu Kush-Himalayan region is the richest in the world from the honeybee species and genetic diversity point of view as all the four or more honeybees species are now found in this region. Each of these species can be further divided into several sub-species, and geographic ecotypes and offer excellent opportunities for their genetic improvement by selective breeding.

Apiculture offers options for communities in the economically marginal category because it is generally a low investment activity. In addition, it is flexible enough to match any scale of operation or any category of manpower (children, women, old people, etc.). The mountain region being marginal areas as against prime areas of plains, in terms of physical and economic resources do not in any way affect beekeeping. For example, less fertile and barren land (physical marginality) or socio-politically neglected mountain societies (landless labourers and marginal farmers, etc.) do not come in the way of beekeeping development.

It is interesting to note unlike in the green revolution, modern hive beekeeping first developed in the temperate Hindu Kush-Himalayan region, and it has now spread to the lowland plain areas of the sub-tropical region. This may have happened because of the following reasons:

- Honey is the only sweetening source in the hills as sugar cane does not grow in temperate climates. Transport from the plains is difficult due to inaccessibility and inadequate transport facilities.
- In the hills, more useful races of the native bee, *Apis cerana*, are found. These are larger in size, more productive, and less prone to negative traits like frequent swarming and absconding found in the plains.
- The wild bee, *Apis dorsata/laboriosa*, builds its nest in difficult and inaccessible sites, such as rock cliffs and this makes honey harvesting a risky exercise in mountain areas. This necessitated the need to introduce modern hive beekeeping in the mountain areas first.
- All the temperate fruits grown in the Hindu Kush-Himalayan region require honeybees for cross-pollination to ensure a good crop.
- During the British rule in the Indian subcontinent, several British officials preferred to settle in the hills. They played an important role in introducing modern apiculture as many of them kept bees as a hobby. Thus owing to ideal climatic conditions, great diversity of bee and floral resources, the mountains provide an excellent niche, for beekeeping development.
- Mountain honey produced from diverse bee flora, is considered better in quality than honey from lowland areas, as a result of which it fetches a higher price and produces effective upland-lowland trade links.
- Honey in the mountain areas is used, even today as a barter commodity in exchange for other life-sustaining essential and precious commodities.

Mountain communities in this region through trial and error over the generations, have evolved traditional methods of beekeeping with the basic concept to build beehives providing maximum natural conditions. For example, beekeepers in the mountain areas have devised fixed wall or log hives generally located in the kitchen room or in front of it to keep the bees warm in the cold climate and also to protect them from predators and other enemies. However, with the introduction of modern bee management technology, such traditional bee hives are now being replaced by modern movable frame hives.

CHAPTER 3

Apiculture and Integrated Rural Development

3.1 INTRODUCTION

Majority of the population in the Hindu Kush-Himalayan region lives at, or below, the subsistence level, and mainly in the rural areas. These include tenant farmers, landless people, farm labourers who have no access to land for the purpose of farming for themselves. Due to demographic pressures unemployment is increasing and the numbers of poor and destitude are constantly increasing. Efforts, therefore, must be made to raise the economic and social status of the weaker sections of the mountain rural communities within the overall context of human resource development. In this task, large multimillion dollar and multifaceted projects may be important; however, small farmers' projects such as on apiculture can also play an important role in a developing rural economy. Apiculture has great self-help potentials for the rural people of the developing countries. It can make a significant contribution to the economic upliftment of small and marginal farmers for the following reasons:

— provides food and cash income

— does not require ownership of land

— provides opportunities for small-, medium- and large-scale farming

— provides gainful employment close to home

— promotes cooperation within the family and society

— can be adopted as a spare-time, part-time, or full-time occupation

— requires little investment and infrastructure

— the technology is simple to follow

— helps local craftsmen to earn extra wages

— the hive products are harvested locally and do not require special storage facilities
— diversifies the economy
— earns foreign exchange
— enhances the productivity level of agricultural, horticultural and fodder seed crops
— helps in overcoming the problems of malnutrition and health in rural areas
— solves social and environmental problems

Traditional knowledge about beekeeping acquired over centuries has always been an important and substantial aspect of the culture and technology of mountain farmers. However, ecological degradation, changing agricultural patterns, use of biocides and diminishing faith in traditional wisdom has led to a decline in honey production. As a result, an item contributing to the subsistence economy of hill farmers has been left out. Today, it is difficult for the common man to purchase honey as it costs more than US $3.00 per kilogramme in the Hindu Kush-Himalayan region.

3.2 APICULTURE AND RURAL ECONOMY

Broad rational development of apiculture in the Hindu Kush-Himalayan region offers varied possibilities, several advantages and great promise to a developing economy. Even rough estimates show that modern beekeeping can contribute millions of dollars through the sale of hive products and pollination services. The impact of beekeeping as a cottage industry on rural income in the Hindu Kush-Himalayan countries is reviewed as follows:

3.2.1 India

As per 1985–1986 statistics, there are about 1 million bee colonies of native *Apis cerana* and exotic *Apis mellifera* kept in modern and traditional hives in India and annual honey production is more than 18,000 metric tons. At present more than 40,000 villages are covered by different national agencies under the beekeeping development programme and it provides part-time employment and cash income to more than 250,000 persons (Anonymous, 1987).

Keeping in view the vast areas of land under field crops and forests in the country, there exists tremendous potential for the expansion of apiculture in India. For example, total cropped area in India is about 160 million hectares, and out of this 55 million hectares are under entomophilous crops requiring cross-pollination by bees and other insect pollinators. So the number of colonies required exclusively for pollination purposes would exceed 150 million against the present strength of only one million (Mishra and Singh, 1987).

3.2.2 China

China is a vast country with 9.6 million sq km in area. After the USSR, this country is one of the largest producers of honey in the world.

There are at present more than 8.5 million honeybee colonies kept in modern hives in China. Out of these, 70 per cent are European honeybees *Apis mellifera* and the others are the native hive bee *Apis cerana*. The annual honey production is over 200,000 tons per year. China has also developed technology for royal jelly, pollen and propolis production on a commercial scale. The total royal jelly and bee pollen production is 800 and 1000 metric tons, respectively. In addition, beeswax and propolis are the other two important hive products harvested. About 30 to 40 per cent hive products are used for domestic consumption (Zhenming, 1990). At present China produces 60-70 per cent of the total Asian honey production and 13 to 14 per cent of the total world honey production (ITC-UNCTAD-GATT, 1986).

China is the largest honey exporter in the world. In 1984, this country exported more than 45,000 tons of honey which is about 93 per cent of the total Asian export and 16.72 per cent of the total world production export (ITC-UNCTAD-GATT, 1986). This has greatly helped in increasing the state income because for each ton of honey exported, it can import 3.5 tons of steel and 6 tons of fertilizers (Svensson, 1977). China plans to expand beekeeping on a larger scale still by establishing new commercial apiaries. The project target is to increase honey production by 1,300 tons every year.

3.2.3 Pakistan

There are at present 35,000 to 40,000 *Apis cerana* and 65,000 to 75,000 *Apis dorsata* colonies in Pakistan. In recent years, the European honeybee, *Apis mellifera*, has been introduced, and its present number is about 14,000. The current annual honey production from different species of honeybees is about 640 tons. The price of honey varies from 40 to 50 rupees at the producer level and 80–140 rupees per kilogramme in the city markets. At present more than 7.3 million hectares of land are under entomophilous crops which require about 21 million colonies of bees exclusively for pollination purposes. In addition, more than 10 million hectares of land area are under forests which can also support a large number of bee colonies. The projected target is to have 0.5 to 0.6 million bee colonies in Pakistan and to increase honey production to 8,000 to 10,000 tons per annum. Such expansion of the beekeeping industry in Pakistan is expected to provide employment to 35,000 to 40,000 persons (Ahmad, 1990).

The North West Frontier Province (NWFP) of Pakistan is very suitable for beekeeping on account of its different ecological zones containing rich bee flora and ideal climatic conditions. It has 8.33 million hectares of land of which 2 million hectares are cultivated. This province has the potential to produce 35 tons of honey per annum against the present low production of 2 tons (Shahid, 1990, Khan, 1990).

3.2.4 Bangladesh

Bangladesh at present produces 350 tons of honey worth about 42 million takka. There are about 8,000 beekeepers in Bangladesh maintaining 10,000 *Apis cerana* colonies in modern and traditional hives. There are certain potential beekeeping areas which can support 10 bee colonies per sq km. It has been estimated that Bangladesh has the potential to produce honey worth about 10 to 50 million US dollars (Svensson, 1988 and Mohamed, 1984).

3.3 APICULTURE AND FOOD SECURITY

In the developing countries of south and southeast Asia, a "Green Revolution" has been possible through the introduction of new high yielding varieties of crops which require substantial inputs of chemical fertilizers, biocides, irrigation facilities and heavy machinery, etc. It is only in plains, however that the "Green Revolution" has been successful because governments have provided capital, infrastructure and price incentives to help farmers take advantage of the new production package. For the majority of the mountain farmers this new technology continues to be unaffordable and unavailable. Further, indiscriminate use of biocides and fertilizers creates immediate dangers for the farmer's family, and long-term negative ecological consequences. The major emphasis for the socio-economic uplift of mountain farmers should therefore be to concentrate research and development efforts on technologies that are low cost, appropriate in scale and operations, safe and affordable.

Swaminathan (1986) in his forwarding note in FAO Service Bulletin on Tropical and Sub-tropical Apiculture stated "In spite of all global resolutions on food security, several hundred million children, women and men are going to bed hungry every day, particularly in the countries of 'South'. Since, prospects for a global food security system appear to be small at the present moment, it will be for the developing countries, characterized by poverty and under-nutrition, to build their own national food security systems. In this task, apiculture can play a useful role. At very little expenditure, honeybees will not only provide food and income, but will also enhance the productivity of horticultural and other field crops by their pollination activities."

The cultivated crop plants that are dependent on or benefited by honeybee pollination are listed here (Kevan, 1984).

1) Fruits and nuts
2) Vegetables and pulses
3) Cereals
4) Drug, beverage, condiment and spice plants
5) Oil crops
6) Forage crops
7) Timber trees and natural vegetation
8) Fibre plants and rubber

Beekeeping thus forms an integral component of the different farming systems such as agriculture, horticulture and animal husbandry. The importance of beekeeping lies in the fact that it does not compete with other farming systems for resources because the bees simply collect honey and pollen from the plants which would otherwise go waste in nature. It has been estimated that the value of honeybees as pollinators of different agricultural, horticultural and fodder crops are 10 to 20 times more than their value as honey producers.

The following facts and figures support this statement:

1) After achieving self-sufficiency in wheat and rice production, increasing the production of oil seeds is one of the major thrust areas in agriculture production being ensured by planners and policy makers, because half of the world's diet of fats and oils comes from these crops. Many of these plants are dependent on or benefited by honeybee pollination. Thus one-third of the total diet is directly or indirectly dependent on honeybee-pollinated plants.

2) The yield of animal husbandry products (dairy products, poultry, lamb, pork and beef) can be enhanced considerably because fodder and livestock ration feed is derived one way or another from honeybee-pollinated crops such as alfalfa, clover, trefoil and lespedza.

3) Increased use of fertilizers is creating serious problems of environmental pollution. Therefore, at present the major focus is on the utilization of atmospheric nitrogen for enriching the soil. Many honeybee-pollinated legume plants play an important role in this process.

4) Several commercial varieties of temperate fruits, vegetables and nuts are self-incompatible and require cross-pollination for which honeybees are the most efficient. This aspect is discussed in detail in Chapter 4.

One good example of beekeeping as an integral component of different hill-farming systems is being followed by the apple growers of Himachal Pradesh in northern India. Apple orchardists put honeybee colonies in the orchard at the time of apple bloom for cross-pollination of self-incompatible commercial varieties like Red or Royal Delicious without which efficient and sufficient pollination does not take place, and ultimately the yield of the apple crop is affected. At the same time, they also sow certain legumes in the orchard as cover crops. Such diversity of inter-crop systems not only provides the orchardist with oil seeds, fodder and soil-enriching nitrogen, but these cover crops are also excellent sources of nectar and pollen for honeybees. Thus they act as alternate bee forage plants particularly at a time when apple orchards are not in bloom and there is a scarcity of bee flora (Verma, 1989b).

3.4 APICULTURE AND NUTRITIONAL SECURITY

In the developing countries of the Hindu Kush-Himalayan region, malnutrition among the underprivileged and children, and lowered working capacity of the adult population offer serious constraints within the overall context of human resource development. In order to alleviate such nutritional problems, national development strategies are being reoriented. Now greater emphasis is being laid on food diversity through the production of supplementary foods, instead of putting their thrust on a few cereal crops such as maize, wheat and rice through monoculture practices. This new strategy will broaden the food base of the poor rural people and will ensure good nutrition and health. In solving the problem of malnutrition due to overall shortage of calories and proteins, different hive products of the apiculture industry can be of great help.

The natural products which honeybees produce and humans now use are honey, royal jelly, pollen, propolis, beeswax and bee venom. These materials have been widely used as nutritious food and for medicinal and pharmacological purposes since ancient times. Extensive research on the chemical and biological properties of honey has shown that it contains most elements found in food and pharmaceutical products. Besides sugars, honey is rich in minerals, proteins, amino acids, vitamins, enzymes and about 181 other minor constituents. It is generally eaten as table honey and is also used in packing, confectionery, preserves, spreads, syrups, meat packing, or in cosmetics, etc. Many tribal people in the Himalayan region are almost entirely dependent upon honey for sweetness because cane sugar cannot be grown in the hilly region. Even otherwise, honey is considered superior to other sugars because of its flavours, texture and preserving qualities.

Man has also been a consumer of pollen or pollen-containing foods. Pollen collected by honeybees is very rich in minerals, protein, carbohydrates, lipids and is considered a highly concentrated energy source.

Pollen products are now being marketed as human food supplements with various nutritional and health benefits. Pollen is also beneficial when incorporated in feed rations for certain farm animals. The importance of pollen for beekeeping was already recognized in ancient times, as it is required for the normal growth and development of the bee larvae. However, now pollen as a tablet or mixed with honey is often used as a 'natural food' for human consumption. Pollen and pollen protein extracts can serve as biostimulants in feeding rations of domestic animals. For example, pollen feeding increases egg production in poultry by 17 per cent.

Another miracle food produced by honeybees is royal jelly. The nutritional effects of royal jelly may be attributed to the combined action of various components such as sugars, proteins, vitamin B and sterols. It is used either fresh or raw, mixed with honey, or freeze dried. Royal jelly improves health and longevity. Several Asian countries have already taken a lead and are the world's largest producers of royal jelly. For example, China produces about 800 tons of royal jelly. The wholesale price of royal jelly is US $100/kg (FAO, 1986). The comparative chemical composition of these hive products is given in Table 3.1.

Table 3.1: Comparative chemical composition of hive and other food products (all mean values and ranges in percentages)

Product	Water	Protein	Carbo-hydrate	Fat	Minerals
Honey	17	—	80	—	0.02–1.0
Pollen (Bee collected)	7–17	7–30	21–48	1–14	1–6
Royal Jelly	65–70	14–18	9–18	2–6	0.7–1.2
Bee Brood (mature worker larvae)	77	15	0.4	4	3
Beef	64	19	16	Zero	1
Milk	87.2	3.5	4.9	3.7	0.7

Source: F.A.O. bulletin 68 (1986).

The above natural products of the hive, besides their nutritive role, have been used for centuries all over the world in therapy as medical agents. These materials along with bee venom (Acupuncture), beeswax and propolis can cure more than 50 human diseases varying from simple body burns or cuts to complex diseases like cancer. The list of such diseases curable through apitherapy is given in Table 3.2.

Table 3.2: Medicinal properties of hive products*

Honey:	— Anti-microbial properties — Curing burns and wounds — Respiratory infections — Heart diseases — Rapid source of energy — Sedative properties — Golden wonder
Royal Jelly:	— Anti-tumour activity — Anti-microbial properties — High blood pressure — Arthritis — Joint pains
Propolis:	— Anti-microbial activity — Skin burns — Joint pains
Bee Venom: (Acupuncture therapy)	— Paralysis — Rheumatism — Arthritis — Cancer — High blood pressure — Anti-microbial activity

*Compiled from multiple sources.

3.5 APICULTURE AND WOMEN'S DEVELOPMENT

In the overall socio-economic scenario of the Hindu Kush-Himalayan region, women are the most neglected and under-privileged group of the rural community. One of the important tasks for future policy planners must be integration of this under-privileged section of women into the social life of the whole rural population. The word integration implies full utilization of under-utilized resources which can improve the income, living standard and social status of women in rural communities. One such resource which comes under this category is beekeeping.

Projects to encourage beekeeping programmes for women are needed because the work is not heavy and they can perform all types of hive management operations such as harvesting, processing, packing and marketing of the hive products. It allows time flexibility and provides gainful employment close to home, nutritional benefits to the elderly and to children, and financial independence to housewives. It broadens the food base of rural communities and provides an excellent sweetening source particularly in the hills where sugar cane is not grown. The Asiatic hive bee, *Apis cerana*, is gentle in temperament and much easier to handle than the European honeybee, *Apis mellifera*. *Apis cerana* is ideally suited for women entrepreneurs to start beekeeping with this local honeybee species.

As compared to men, the level of education of women in the mountain areas is very low. For example in Nepal, women's literacy is 12.5 per cent as compared to men's literacy of 33.96 per cent (Shrestha, 1988). Even illiterate persons can practice beekeeping. Although women in the Hindu Kush-Himalayan region have been practising traditional methods of beekeeping since ancient times, there are only a few women entrepreneurs engaged in modern beekeeping.

CHAPTER 4

Apiculture and Mountain Crop Productivity

4.1 INTRODUCTION

At present, several countries of the Hindu Kush-Himalaya are making desperate efforts to achieve self-sufficiency in food production. This is being done by physical expansion of the area under cultivation and better management of resources. These include use of better quality seeds and animals, bringing more wasteland under cultivation, use of fertilizers, pesticides and more irrigation facilities. However, in the past decade or so, food production has come to a point of stagnation and it is no longer possible to enhance the productivity levels in certain cultivated crops. Emphasis in the future, therefore, should be on the full utilization of underutilized resources which are probably of unknown limitations. One resource which is of concern here is an increase in the yield of different cultivated crops through cross-pollination by honeybees.

The vital role which honeybees play in the pollination of large numbers of agricultural and horticultural crops is often underestimated. As a matter of fact, the main significance of honeybees and beekeeping is pollination, whereas hive products, like honey and beeswax, are of secondary value. This is evident by the fact that income from agriculture by the use of honeybees in crop pollination is many times greater than their value as honey and beeswax producers. Many cultivated crops do not yield seeds or fruits without cross-pollination of their flowers by honeybees and other wild insects. Cross-pollination of entomophilous crops by honeybees is one of the most effective and cheapest methods of increasing their yield. Other agronomic practices like manuring, fertilizers, pesticides and irrigation are quite cost-effective and these may not yield the desired results without the use of honeybees for enhancing the productivity levels of different cultivated crops through pollination. It is not only the self-sterile varieties/cultivars which require cross-pollination, but also the self-fertile forms, which would also produce more and better quality seeds and fruits if pollinated by honeybees and other insects.

Despite the great economic and biological significance of honeybees as pollinators of agricultural crops, it has not yet been made an integral part of agricultural and horticultural management technology, particularly in the developing countries of Hindu Kush-Himalaya.

4.2 HISTORICAL PERSPECTIVE OF POLLINATION ECOLOGY

The idea of the occurrence of sex in plants was given by Theophastus in the fourth century B.C., but it was during the end of the nineteenth century, only, that plant reproduction and the mechanism of pollination was discovered by Muller (1882–83). He wrote a book *The fertilization of flowers* in German which was translated into English in 1883. Later, Knuth published three volumes on flower pollination in German and these were translated into English in 1906–1908. Aristotle had the idea of a relationship between bees and flowers, but is was. Koelreuter and Dobbs in 1870 who first described the detailed flower structure and the role of insects in pollination. Sprengel (1793) put forward a theory stating that "every peculiarity of plant anatomy and physiology is related to the peculiarity of the structure and behaviour of the insects which visit and pollinate the flowers." Darwin (1887) used both hand and insect pollination techniques, and his research work helped greatly in understanding the theories of plant perpetuation and vigour maintenance through cross-pollination. These are being followed even today.

The practical use of honeybees, for the cross-pollination of cultivated crops and increasing their yield started with the practise of moving honeybee colonies to the crops in bloom. Mr. M. B. Waite was deputed by USDA in 1890 to learn the causes of crop failure in an orchard of 22,000 Barlett pear trees in Virginia, USA. He found that it was due to the problem of self-sterility in the pear plants, and reported that cross-pollination was necessary for a good fruit set. Because pear pollen was too heavy and sticky to be transferred by wind, Waite (1895) recommended the use of honeybees for pear pollination by moving them into the pear orchards. Similarly, honeybees were utilized for apple pollination in the late nineteenth century. In Australia and on the banks of Margabi River in central Asia, apple fruit trees became sterile as honeybees did not exist there prior to the turn of the present century. After the introduction of bees to these regions, apple orchards started bearing fruit. Benton (1896) also suggested five to six colonies of *Apis mellifera* per 100 trees for the pollination of self-sterile commercial varieties of apple in USA.

After this period, moving honeybee colonies to the crop for the purpose of cross-pollination of cultivated crops has become a standard practice in several developed countries. Beekeepers rent out bee hives to fruit growers and charge rental fees from the grower for this service. For example, McGregor (1976) proposed a fee of US$ 10.50 per 10 frame colony to be used for pollination purposes. Now, in all developed countries where the practice of renting bee colonies for the purpose of pollination has become a regular practice, there exist specific rules and regulations regarding pollination agreements and contracts between beekeepers and fruit growers.

In recent years, a number of techniques have been developed for increasing the productivity of certain agricultural crops through cross-pollination by honeybees. These include the use of pollen dispensers, pollen bombs, scent training of bees, development of high and low preference strains of honeybees for the pollination of specific crops through selective breeding, domestication and utilization of non-*apis* pollinators and safeguard of bees against pesticides. All these techniques are not solely used in developed countries, there is now a growing awareness in developing countries of the fact that agricultural crops give better yield and higher financial returns if honeybees are used for their optimal pollination. For example, Verma (1984) made the following observation in a report submitted to FAO Expert Consultation on Beekeeping:

"In view of the importance of bees for increasing the yield of cross-pollinated crops, different species of honeybees and solitary bees are being utilized for this purpose in northern India. Himachal Pradesh, Uttar Pradesh and Kashmir are the principal temperate fruit-growing regions of the country. In Himachal Pradesh, more than 75,000 hectares of land is under temperate fruit cultivation and more than 200,000 colonies of honeybees are required against the present number of 10,000." The population of non-*Apis* pollinators is declining at an alarming rate, owing to growing deforestation, vast clearance of wasteland for cultivation, and increased use of pesticides. This makes domesticated hive bees essential for pollination. In addition to pollinating temperate fruits, both the species (*Apis cerana* and *Apis mellifera*) are also being utilized for the pollination of vegetables, oil seed crops and clovers.

Considering the importance of bees in pollination, Himachal Pradesh has taken the lead in renting *Apis cerana* colonies to orchardists for the pollination of apple crops. This programme has created great awareness among orchardists about the importance of honeybees for pollination.

4.3 ADVANTAGES OF BEE POLLINATION

Honeybees are the most efficient pollinators of several cultivated and wild plants because of their following characteristics.

— body parts are specially modified to pick up many pollen grains
— flower fidelity and constancy
— potential for long working hours
— thorough micro-manipulation of flowers
— maintainability of high populations when and where needed
— adaptability to different climates and niches

Deodikar and Suryanarayanan (1977) have reviewed the increase in seed or fruit yields in various crops due to be pollination in India. As a result of cross-pollination by bees, somatic, reproductive and adaptive heterosis or hybrid effects occur in plant progeny either in a single way or in different combinations. Such hybrid effects bring the following qualitative and quantitative changes in the economic and biological aspects of plants:

— stimulates germination of pollen on stigmas of flowers and improves selectivity in fertilization
— increases viability of seeds, embryos and plants
— more nutritious and aromatic fruits are formed
— increases the vegetative mass and stimulates faster growth of plants
— increases number and size of seeds and yield of crops
— enhances resistance to diseases and other adverse environmental conditions
— increases nectar production in the nectaries of plants
— increases fruit set and reduces fruit drop
— increases oil content in oil-seed crops

4.4 PRINCIPLES OF BEE POLLINATION

Most investigations on crop-pollination have been carried out in developed countries where the European honeybee, *Apis mellifera*, has been extensively utilized for increasing the yield of different cultivated crops. A detailed account about the role of *Apis mellifera* in the pollination of different cultivated crop plants is discussed by several authors (McGregor, 1976; Free, 1970; Kozin, 1976 and Crane and Walker, 1984). There is very little information available on the role of the Asian hive bee, *Apis cerana*, in pollinating agricultural crops in the developing countries of South and Southeast Asia. Both these species of honeybees show remarkable similarities in foraging behaviour. Thus, the basic principles involved in crop pollination by these two species of honeybees should not differ significantly. Efficiency of a bee colony as a pollinator would, however, depend upon the following factors:

4.4.1 Colony Strength

Large and stronger colonies are four to five times better pollinators than smaller and weaker ones because the former have a higher percentage of older bees as foragers. Thus, good honey-yielding colonies are better and more efficient pollinators also. It has been estimated that one colony of *Apis mellifera* with 60,000 worker bees produces one-and-a-half times more honey than four colonies with 15,000 bees each. The same can be true for pollination activity also. The strength of a colony depends upon the honeybee breed, availability of nectar and pollen plants as food resources, and management practices being employed. It also depends upon the season. In the Hindu Kush-Himalayan countries, during winter the colony strengths are poor because of low temperatures and dearth of bee flora. In the early spring season, when honeybee colonies are required for the cross-pollination of apple bloom in this region, these colonies do not build enough strength for effective pollination. Keeping in view this constraint, apple growers in certain region in northern India migrate their colonies to the lower altitudes where the winters are warmer and there is no dearth of bee flora, so that in the spring at the time of apple bloom, an adequate strength of bees is available for effective pollination.

4.4.2 Number and Time of Placement of Colonies

The number of colonies required for pollination of different cultivated crops would depend upon the following factors:

1) Density of plant stand
2) Total number of flowers in inflorescence of each plant
3) Duration of flowering
4) Strength of bee colonies
5) Number of flowers over an area of one hectare of land.

In general, two colonies of *Apis mellifera* per hectare of crop in bloom are recommended for sufficient and efficient pollination. Keeping in view the smaller body and colony size of *Apis cerana* and also its shorter flight range, three colonies per hectare are recommended.

4.4.3 Distribution of Colonies in the Field/Orchards

Honeybees as a rule visit primarily those sources of nectar flow which are within 0.3 to 0.5 km radius from the apiary. At a distance of more than 0.5 km the pollination activity diminishes significantly. In the Hindu Kush-Himalayan countries, because of the small size of farm holdings and also due to the practice of mixed cropping, spacing of the colonies and their optimum arrangement do not pose a serious problem as in developed countries where monoculture in farming systems is a common practice. For effective pollination, *Apis cerana* hives should be placed singly instead of in groups. Honeybees always tend to forage in the area which is closest to their hive, particularly when the weather is not very favourable.

4.4.4 Time and Placement of Colonies

Bee colonies should be placed in the field or orchard when 5 to 10 per cent of the crop is in bloom. Earlier placement of colonies result in the bees foraging on other weeds and wild plants in the vicinity and later the bees ignore the crop in bloom. If the bees are moved in too late, they can only pollinate the late and less vigorous flowers.

4.4.5 Weather Conditions

Weather plays an important role in determining the success or failure of a pollination programme, as it affects both bee activities as well as seed/fruit setting. For example, in the temperate climate of the Hindu Kush-Himalaya, apple trees are in bloom in early spring when the temperature is low. Flower buds may be killed due to frost injury. It also adversely effects foraging activities of the bees. As reported earlier, the native hive bee *Apis cerana* can forage at lower temperatures than its European counterpart. *Apis mellifera* (Verma, 1986b). wind velocity of 15 miles per hour or more also adversely affects the foraging behaviour of bees. It is, therefore, recommended that a wind break around the crop field/orchard should be provided.

4.4.6 Attracting Bees to a Crop in Bloom

Russian bee scientists have strongly advocated the theory that bees should be fed syrup flavoured by the flowers required to be pollinated in order to attract large numbers of bees for effective pollination (Kozin, 1976). Theoretically this seems to be a logical approach, but in practice does not always yield the desired results. In Sweden, Canada and the USA, different research workers have also tried essential oils or flavour, especially from apple flowers, and their results are inconclusive.

Another method of attracting bees to a particular crop in bloom is by sowing high nectar-yielding crops amongst the other crops which are poor in nectar secretion. For example, sweet clover requires cross-pollination by bees for good seed yield. But this crop is not very attractive to bees due to poor or very low quantities of nectar in the nectaries, of this plant. However, by sowing the other nectiferous plants like buckwheat, larger number of bees are attracted to this crop. A crop to be pollinated can also be made more attractive to honeybees if nectar production in the nectaries is increased by breeding techniques or by improving other agronomic practices like addition of fertilizers and manures, or better irrigation facilities.

4.5 APPLE POLLINATION IN THE HINDU KUSH-HIMALAYA

Apple is the most important of the temperate fruits cultivated in the Hindu Kush-Himalayan countries. Of the total land in this region under fruit cultivation, more than two-third is under apple cultivation. The areas under this crop in different parts of the Hindu Kush-Himalaya are as follows[1]:

	Area (000 hectares)	Production (MT)
Arunachal Pradesh/India	4.821	3,373
Himachal Pradesh/India	52.380	359,320
Kashmir/India	65.107	723,826
Uttar Pradesh/India	52.000	170,000
Pakistan	19.000	212,000
Bhutan	3.656	4,600
Nepal	5.000	50,000

The above data show that in 1986-87, more than 17.5 thousand hectares of land was under apple cultivation in temperate India alone. Every year approximately 10 per cent of the total area already under apple cultivation is being added, and according to one estimate, about 250 thousand hectares of land should be under this crop in the entire region of the Hindu Kush-Himalaya.

With such a vast increase in the area coming under apple cultivation, various management problems have inevitably arisen, and pollination is the important one. The delicious and commercial varieties of apple are self-incompatible and require cross-pollination by honeybees. Populations of non-*Apis* pollinators are declining at an alarming rate due to increasing deforestation, vast clearance of wasteland, and

[1] Compiled from multiple sources.

wider use of pesticides. The most effective way of assuring adequate pollination is by the introduction of honeybees into the orchard at the time of blossoming, a practice well developed for apples in places like Western Europe, Eastern Europe and Japan.

Most of the orchards of the Hindu Kush-Himalayan region are small (about one hectare or less) and are owned by local farmers. Thus, each orchard requires about three hives of bees (although this figure is only an educated guess). Nevertheless, a conservative estimate of the number of bee hives needed exclusively for the pollination of apple crops in the entire region of the Hindu Kush-Himalaya is more than one million. In the temperate mountainous region of the Hindu Kush-Himalaya, the bee species which is available for beekeeping is not the European honeybee, *Apis mellifera*, but the native Asiatic honeybee, *Apis cerana*.

At present, there are only a few thousand colonies of *Apis cerana* kept in modern hives by a few farmers and orchardists. A major problem, therefore is that, the present large-scale expansion of the horticultural industry in the region has not been accompanied by a corresponding increase in pollination resources and technology through the availability of appropriately managed bee hives. Many orchards do not bear sufficient fruit because the population of bees is too small. Moreover, with the increase in the use of pesticides for the control of apple pests, the population of pollinators, as represented by various species of naturally occurring solitary ground nesting bees, is decreasing at an alarming rate. This makes domesticated hive bees essential for pollination, and beekeeping as an essential part of fruit production.

A large horticultural undertaking as present in the Hindu Kush-Himalayan region will not be able to flourish in the long run without the large-scale development of scientific beekeeping. Nevertheless, there are problems to be addressed and overcome. The wealth contributed by beekeeping, as a cottage industry, would run into several millions of dollars from hive rentals, pollination and honey production.

4.5.1 Distribution, Abundance and Diversity of Insect Pollinators

According to Verma and Chauhan (1985), insects visiting the apple bloom in the Shimla hills (Himachal Pradesh) comprised 44 species belonging to 14 families and five orders of these: 16 species belonged to Hymenoptera, 11 to Diptera, nine Lepidoptera, seven to Coleoptera and one to Hemiptera (Table 4.1). The data on relative abundance of different insect pollinators of apple in Shimla hills indicated that, *Apis cerana* was the most abundant insect species, whereas *Bombus tunicatus* was the least abundant (Table 4.2). Further, comparative abundance studies on various orchards indicated that *Apis cerana* constituted 24.01 to 43.03 per cent of the total pollinator population. Rai and Gupta (1983) also reported that honeybees, *Apis cerana*, constituted 39 to 84 per cent of the insects which visited apple flowers in the Uttar Pradesh hills of India.

Besides honeybees and bumble bees, *Halictus dasygaster* was predominant in one experimental orchard at Thanadhar (Shimla distt. of Himachal Pradesh). Besides hymenopterous insects, dipterns were other visitors of this crop in the Shimla hills. These were *Eristalis tenax*, *Eristalis angustimarginalis*, *Eristalis* sp., *Muscids* (*Musca* sp.), *Orthelia* sp. and *Syrphids (Epilobium* sp., *Scava* sp., *Metasyrphus* sp., and *Macrosyrphus* sp.).

The above results show that the relative abundance of all the insects varied from place to place (Table 4.2). Differences in environmental conditions, location and altitude of the orchards could be possible reasons for such variations (Verma and Chauhan, 1985).

4.5.2 Role of Honeybees on Yield and Quality of Apple Fruit

Most of the commercial varieties of apples give good yields only after cross-pollination. Cross-pollination is mostly done by insects because the rôle of the wind in cross-pollination of apple bloom is negligible due to the heavy and sticky nature of apple pollen. Honeybees are the most efficient pollinators among insects because they can be managed in sufficient number, and because they show flower constancy (Free, 1964). Although self-compatible varieties of apple do not need as many insect visits as self-incompatible varieties to give an adequate fruit set, yet some visits are essential. A lot of work has been done regarding the role of honeybees in the pollination of apple bloom in many developed countries (McGregor, 1976), but very little has been done in the temperate region of the Hindu Kush-Himalaya. Verma (1987b) and Dulta and Verma (1987a) studied the role of honeybees on fruit set, fruit drop and fruit quality of apples in the Shimla Hills, and the results are summarized as follow:

The following treatments were conducted in three different apple orchards of a size of 0.8 hectare each located in Annu, Kotkhai and Jubbal areas of Himachal Pradesh at heights of 1350, 1875 and 2400 metres above sea level, to study the effect of honeybee pollination on fruit set, fruit drop and fruit quality of apple fruit.

i) No insects pollinator
ii) Open pollinated flowers (natural insect pollinators)
iii) Honeybee-pollinated flowers

In these experiments, it was found that insect pollinators, mainly honeybees, play a significant role in improving fruit set and quality, and in reducing fruit drop.

Table 4.1: Insect species visiting apple flowers with their taxonomic status in the northwest Himalaya

(A) HYMENOPTERA	(B) DIPETRA	(C) LEPIDOPTERA	(D) COLEOPTERA	(E) HEMIPTERA
(a) APIDATE	(f) MUSCIDAE	(h) NOCTUIDAE	(l) COCCINELLIDAE	(o) PENTATOMIDAE
(1) *Apis cerana*	(17) *Musca* sp	(28) *Plusia onchaicea*	(37) *Cocinella septumpunctata*	
(2) *Apis mellifera*	(18) *Orthelia* sp.	(29) *Heliothis armigera*		(44) *Apodiphus* sp.
(3) *Bombus tunicatus*		(30) *Agrotis flammatra*	(m) CHRYSOMELIDAE	
(4) *Bombus* sp. (i)	(g) SYRPHIDAE	(31) *Agrotis ipsilon*	(38) *Altica* sp.	
(5) *Bombus* sp. (ii)	(19) *Melanostoma univitattum*		(39) *Alticinae* sp.	
	(20) *Eristalis tenax*	(i) NYMPHALIDAE	(40) *Nonartha variabilis*	
(b) ANTHOPHORIDAE	(21) *Eristalis angus-timarginalis*	(32) *Vanessa cashmirensis*	(41) *Minastra cymura*	
(6) *Anthophora* sp.		(33) *Neptis* sp.		
	(22) *Eristalis arvorum*		(n) SCARABAEIDAE	
(c) HALICTIDAE	(23) *Eristalis* sp.	(j) PIERIDAE	(42) *Protaetia neglecta*	
(7) *Nomodo* sp.	(24) *Epilobium boleatus*	(34) *Pieris canidia*	(43) *Brahmina cronicolis*	
(8) *Halictus dasygaster*	(25) *Scaeva pyrastri*	(35) *Delias belladona*		
(9) *Halictus* sp. (i)	(26) *Metasyrphus corollae*			
(10) *Halictus* sp. (ii)	(27) *Macrosyrphus,* sp.	(k) LYCANIDE		
(11) *Xylocopa* sp.		(36) *Heodes* sp.		
(d) VESPIDAE				
(19) *Polistes maculipennis*				
(13) *Vespa magnifica*				
(14) *Vespa auraria*				
(15) *Vespa flaviceps*				
(e) ICHNEUMONIDAE				
(16) *Netalia tatra*				

A,B,C,D,E = ORDER a,b,c,d. etc. = FAMILY *Source*: Verma and Chauhan, 1985.

Table 4.2: Comparitive abundance of different insect pollinators/branch/10 minutes at various apple orchards in the Northwest Himalaya

Pollinator species	Kotgarh A	Kotgarh B	Thanedhar A	Thanedhar B	Matiana R	Matiana G	Narkanda
Apis cerana	3.55* ±0.28** (26.10)	2.94 ±0.39 (24.01)	6.49 ±0.47 (26.02)	8.33 ±0.56 (33.63)	8.40 ±1.40 (39.05)	7.36 ±1.59 (40.15)	19.30 ±11.13 (43.03)
Eristalis tenax	2.38 ±0.21 (17.51)	1.94 ±0.26 (15.84)	2.77 ±0.35 (11.10)	3.11 ±0.36 (13.67)	1.29 ±0.36 (5.99)	0.77 ±0.27 (4.20)	6.63 ±0.39 (14.78)
Eristalis sp.	NR	NR	2.66 ±0.61 (10.66)	2.66 ±0.24 (9.01)	0.59 ±0.28 (2.74)	0.48 ±0.04 (2.61)	0.48 ±0.22 (2.74)
Eristalis angusti-marginalis	0.44 ±0.12 (3.23)	0.44 ±0.16 (3.59)	0.28 ±0.14 (1.12)	0.38 ±0.10 (1.67)	0.29 ±0.09 (1.34)	0.37 ±0.08 (2.01)	1.89 ±0.32 (4.21)
Orithelia sp.	0.88 ±0.17 (6.45)	1.05 ±0.10 (8.57)	1.10 ±0.24 (4.41)	1.16 ±0.22 (5.10)	NR	NR	NR
Peiris canidia	0.38 ±0.10 (2.79)	0.41 ±0.12 (3.59)	0.33 ±0.13 (1.32)	0.39 ±0.14 (1.71)	0.07 ±0.05 (0.32)	0.18 ±0.06 (0.98)	NR
Bombus tunicatus	0.33 ±0.19 (2.42)	0.33 ±0.19 (0.69)	0.05 ±0.001 (0.20)	0.11 ±0.06 (0.48)	NR	NR	0.29 ±0.09 (0.64)
Syrphids	2.83 ±0.30 (20.80)	2.44 ±0.18 (19.93)	3.97 ±0.51 (15.90)	3.27 ±0.77 (14.37)	2.84 ±0.38 (13.20)	2.14 ±0.40 (11.67)	3.56 ±0.37 (7.93)
Muscids	2.81 ±0.28 (20.66)	2.66 ±0.19 (21.73)	4.91 ±0.31 (19.68)	3.94 ±0.21 (17.32)	8.03 ±0.75 (37.33)	7.03 ±0.83 (38.30)	11.89 ±0.68 (26.85)

*Each value is overall average for an insect species at a place.

**Standard error about the mean.

NR = Not recorded.

Figures within parentheses indicate per cent population A and B are two orchards studied

R = Number of insect pollinators on Royal Delicious variety.

G = Number of insect pollinators on Golden Delicious variety.

Source: Verma and Chauhan, 1985.

1) Effect on fruit set

In self-compatible varieties like Golden Delicious, the percentage of fruit set in control, open and honeybees pollinated flowers were 24.57, 30.73 and 34.53, respectively, which did not differ significantly. Similarly, in another self-compatible variety, Red Gold, the percentages of fruit set in control, open and honeybee-pollinated flowers recorded 15.76, 18.34 and 22.45, respectively, did not differ significantly. Non-significant differences in fruit set of Golden Delicious and Red Gold under different conditions may be due to self-compatibility of these varieties. In self-compatible varieties like Royal Delicious and Red Delicious, there was no fruit set in the absence of insect pollinators but the fruit set was significantly higher ($P<0.01$) in honeybees-pollinated flowers of Royal Delicious (23.33 per cent) and Red Delicious (19.69 per cent) than in open pollinated flowers of Royal Delicious (13.21 per cent) and Red Delicious (11.42 per cent). No fruit set in the absence of any insect pollinator in self-incompatible varieties clearly indicated that there was no pollen transfer from pollinizer to pollinated varieties without an insect pollinator.

Moreover, higher fruit set in honeybee-pollinated flowers than in open pollinated flowers suggested that the degree of cross-pollination done by honeybees was certainly higher than that done by other natural insect pollinators. This is due to the fact that the bodies of honeybees are more efficient pollinators of apples (Table 4.2).

2) Effect of insect pollinators on fruit drop

The fruit drop in self-compatible varieties of apple was significantly higher ($P<0.01$) from flowers under the controlled condition as compared to the fruits from open and honeybee-pollinated flowers. For example, in Golden Delicious and Red Gold, the fruit drops were maximum (38.45 and 38.07 per cent, respectively) under control and minimum (25.22 and 25.02 percent, respectively) in honeybee-pollinated flowers. In open-pollinated flowers of Golden Delicious and Red Gold, the fruit drops were 27.62 and 28.38 per cent, respectively, with no significant difference. In self-incompatible varieties like Royal Delicious, the fruit drops in open-pollinated and honeybee-pollinated flowers were 28.69 and 25.50 per cent, respectively, without any significant difference ($P<0.01$). The same trend was observed in an other self-incompatible variety, Red Delicious, where the fruit drops in open- and honeybee-pollinated flowers were 28.86 and 25.73 per cent, respectively, with no significant difference ($P<0.01$). The high percentage of fruit drop in the control experiment was due to poor cross-pollination, whereby, the number of ovules fertilized was fewer (Table 4.3).

Table 4.3: Percentage of fruit set and fruit drop in three different experimental conditions

Varieties	Honeybee pollinated flowers (H)	Open pollinated flowers (O)	No insect pollinator (control)
A. Golden Delicious	34.53 (25.22)	30.73 (27.62)	24.57 (38.45)
B. Red Gold	22.45 (25.02)	18.34 (28.38)	15.76 (38.07)
C. Royal Delicious	23.33 (25.50)	13.21 (28.69)	0.00 (0.00)
D. Red Delicious	19.69 (25.73)	11.42 (28.86)	0.00 (0.00)

* Data in parentheses pertain to fruit drop.
For fruit set in C and D varieties: $H<O>C$ ($P>0.01$).
For fruit drop in A and B varieties: $C>O,H$ ($P<0.01$)
$P<0.01$ = Highly significant.

Source: Dulta and Verma, (1987a).

3) Effect on fruit quality

Honeybee pollination greatly improves the quality of apple fruit. For example, Verma (1987b), Dulta and Verma (1987a) showed that in Golden Delicious, there was an increase in the weight, length, breadth, volume and number of seeds per fruit by 22, 9, 7, 17 per cent, respectively in the fruits which developed from flowers exclusively pollinated by honeybees as compared to the open-pollinated flowers. Whereas, in Red Gold, the weight, length, breadth, volume and number of seeds per fruit increased 18, 9, 9, 9 and 32 per cent, respectively and the fruits of these two self-compatible varieties followed the pattern: Fruits from honeybee-pollinated flowers > fruits from open-pollinated flowers > fruits from the control experiment (Table 4.4).

In the Royal Delicious variety of apple, the increase in weight, length, breadth, volume and number of seeds per fruit was 33, 15, 10, 51 and 49 per cent, respectively in fruits which developed from flowers exclusively pollinated by honeybees as compared to the open-pollinated flowers. Similarly, in Red Delicious, the increase in weight, length, breadth, volume and number of seeds per fruit which developed from flowers exclusively pollinated by honeybees was 19, 9, 10, 16 and 30 per cent, respectively, as compared to those fruits which developed from open-pollinated flowers. In these self-incompatible varieties, the fruit quality was significantly better ($P<0.010$) in the fruits from honeybee-pollinated flowers as compared to the fruits from open-pollinated flowers. The improvement in the quality of fruits due to cross-pollination by honeybees (also other natural insect pollinators) might be as a result of heterosis. The increase in weight, size (length and breadth) and

Table 4.4: Effect of insect pollinators on the quality of apple fruit in different cultivars grown in the northwest Himalaya

Variety	Honeybees pollinated flowers (H)				No. of seeds (SH)	Open pollinated flowers (I)				No. of seeds (SI)	No insect pollinator (Control, J)				No. of seeds (SJ)
	Weight* (WH)	Length** (LH)	Breadth** (BH)	Volume (VH)		Weight (WI)	Length (LI)	Breadth (BI)	Volume (VI)		Weight (WJ)	Length (LJ)	Breadth (BJ)	Volume (VJ)	
A. Golden Delicious	208.88	7.34	7.74	193.33	8.92	188.00	6.76	7.26	165.77	8.11	104.44	5.58	6.12	82.86	6.00
B. Red Gold	152.67	5.97	7.00	138.00	9.11	135.53	5.81	6.85	133.00	7.77	82.00	4.94	5.75	63.67	7.00
C. Royal Delicious	266.55	7.88	8.13	268.39	6.78	201.16	6.87	7.41	177.00	6.20	No fruit set				
D. Red Delicious	217.67	7.21	7.69	184.44	6.78	183.80	6.61	7.00	159.80	5.33	No fruit set				

Statistical significance:

$A^{WH} > A^{WI} > A^{WJ}$ ($P < 0.01$); $A^{LH} > A^{LI} > A^{LJ}$ ($P < 0.01$); $A^{BH} > A^{BI} > A^{BJ}$ ($P < 0.01$); $A^{VH} > A^{VI} > A^{VJ}$ ($P < 0.01$); $A^{SH} > A^{SI} > A^{SJ}$ ($P < 0.01$).

$B^{WH} > B^{WI} > B^{WJ}$ ($P < 0.01$); $B^{LH} > B^{LI} > B^{LJ}$ ($P < 0.01$); $B^{BH} > B^{BI} > B^{BJ}$ ($P < 0.01$); $B^{VH} > B^{VI} > B^{VJ}$ ($P < 0.01$); $B^{SH} > B^{SI} > B^{SJ}$ ($P < 0.01$).

$C^{WH} > C^{WI}$ ($P < 0.01$); $C^{LH} > C^{LI}$ ($P < 0.01$); $C^{BH} > C^{BI}$ ($P < 0.01$); $C^{VH} > C^{VI}$ ($P < 0.01$); $C^{SH} > C^{SI}$ ($P < 0.01$).

$D^{WH} > D^{WI}$ ($P < 0.01$); $D^{LH} > D^{LI}$ ($P < 0.01$); $D^{BH} > D^{BI}$ ($P < 0.01$); $D^{VH} > D^{VI}$ ($P < 0.01$); $D^{SH} > D^{SI}$ ($P < 0.01$). — Highly significant.

*Weight in gm

**Length and Breadth in cm

Source: Dulta and Verma (1987a).

volume of the apple fruits which developed from honeybee-pollinated flowers might be due to the greater number of seeds per fruits (mean number of seeds, 8.92, 9.22, 7.31 and 6.78 in Golden Delicious, Red Gold, Royal Delicious, and Red Delicious, respectively, Table 4.4). Rai and Gupta (1983) also found that in honeybee-pollinated flowers of Red Delicious, Esopus and Spitzenberg cultivars of apple, yield was 5.8 and 1.6 kg per 100 flowers in comparison to open-pollinated flowers which yielded only zero and 0.75 kg, respectively. The better pollinating efficiency of honeybees helps in the fertilization of maximum number of ovules and thereby a greater number of seeds are formed. In this way, the maximum amount of auxin, a growth hormone, is produced which results in better size of the fruit (Table 4.4).

4.5.3 Comparative Foraging Behaviour of *Apis cerana* and *Apis mellifera* on Apple Bloom

Verma and Dulta (1986) studied comparative foraging behaviour of *Apis mellifera* and *Apis cerana* on apple bloom and the results of those investigations are reviewed as follows:

Worker bees of *Apis cerana* started their foraging activity earlier in the morning (mean time, 0603 hours) than *Apis mellifera* (mean time 0627 hours). In the evening *Apis mellifera* ceased its foraging activity earlier (mean time 1855 hours) than *Apis cerana* (mean time 1913 hours). Thus, the average duration of foraging activity in *Apis cerana* was 13.10 hours and in *Apis mellifera*, 12.28 hours (Table 4.5).

The duration of the foraging trip by *Apis cerana* was 11.85 minutes, and *Apis mellifera* was 17.92 minutes. Thus, the duration of a foraging trip was significantly longer for the latter than the former (Table 4.5).

Observations made at three different hours of the day (0900, 1200 and 1500 hours) during apple flowering in order to study the nature of food (nectar, pollen or both) collected by worker bees of *Apis cerana* and *Apis mellifera* revealed that, in both the species, nectar collectors were significantly more than pollen collectors (Table 4.6).

In *Apis cerana*, no pollen plus nectar collectors were observed; whereas, in *Apis mellifera*, the percentage of such worker bees varied from 6 to 11 during different hours (Table 4.6). However, in *Apis mellifera*, the number of nectar collectors was significantly higher than pollen collectors (41 and 20 per cent, respectively). For *Apis mellifera*, the number of nectar collectors was significantly higher at 0900 and 1500 hours (73 and 70 per cent, respectively) than pollen collectors (48 and 22 per cent, respectively). At 1200 hours, no significant difference was observed in the proportion of pollen and nectar collectors.

At 0900 hours, the number of pollen collectors of *Apis cerana* was significantly higher ($P<0.01$) than *Apis mellifera*; whereas, at 1200 and 1500 hours, there was no significant difference ($P<0.01$) in the num-

Table 4.5: Foraging data for *Apis cerana* and *Apis mellifera* honeybees on apple flowers at 1350 m in the northwest Himalaya in April-May

Parameter	*Apis cerana*	*Apis mellifera*
Initiation (time of day) of foraging	06.03 ± 0.01	06.27 ± 0.02
Cessation (time of day) of foraging	19.13 ± 0.01	18.55 ± 0.01
Duration (h) of foraging activity	13.10 ± 0.002	12.28 ± 0.003
Duration (min) of foraging trip	11.85 ± 0.36	17.92 ± 0.36
Peaking foraging hours (time of day)	09.00 – 11.30	11.00 – 13.20
Weight (mg) of pollen load: 09.00	9.06 ± 0.02	9.24 ± 0.04
12.00	9.26 ± 0.02	12.22 ± 0.04
15.00	8.64 ± 0.06	11.12 ± 0.03
No. stigmas touched/flower	3.09 ± 0.39	3.33 ± 0.32
Time(s) on flower (min)	5.90 ± 0.22	6.63 ± 0.23

Each mean (± SE) is for eight observations. For times of initiation, cessation and duration of daily foraging activity, duration of a foraging trip and weights of pollen loads, differences between species are significant (P<(0.01); for number of stigmas touched per flower and time spent on flower P>0.01.

Source: Verma and Dulta, 1986.

ber of pollen collectors of *Apis cerana* and *Apis mellifera* (Table 4.6). Nectar gatherers of *Apis mellifera* were significantly more (P < 0.01) than those of *Apis cerana* at 0900 hours; whereas, at 1200 hours the trend was reverse, i.e. the number of nectar collectors of *Apis cerana* was significantly greater (P<0.01) than that of *Apis mellifera*. At 1500 hours, there was no significant difference (P<0.01) in the number of nectar collectors of both the species. Pollen plus nectar collectors of *Apis mellifera* were maximum at 1200 hours (Table 4.6).

Observations made on hourly fluctuations in the number of bees leaving the hive per five minutes showed that peak activity of *Apis cerana* was between 0900 and 1100 hours (mean 132 bees/5 minutes) when the temperature ranged from 13.5 to 21.0°C, and that of *Apis mellifera* it was between 1100 and 1300 hours (mean 118 bees/5 minutes) when the temperature ranged from 21 to 25°C during March and April in the Shimla Hills (Fig. 4.1) (Table 4.5).

Pollen loads carried by *Apis mellifera* at 0900, 1200 and 1500 hours of the day were 9.24 mg; 12.22 mg and 11.12 mg, respectively, whereas, these values for *Apis cerana* were 9.06 mg, 9.26 mg and 8.64 mg at 0900, 1200 and 1500 hours, respectively. A worker bee of *Apis mellifera* carried significantly heavier (P<0.01) pollen loads than *Apis cerana* throughout the day (Table 4.5).

Table 4.6: Percentage of *Apis cerana* and *Apis mellifera* honeybees collecting pollen, nectar, or both from apple flowers at different hours of the day in April-May at 1350 m in the northwest Himalaya

Forage	09.00		12.00		15.00	
	Apis cerana	*Apis mellifera*	*Apis cerana*	*Apis mellifera*	*Apis cerana*	*Apis mellifera*
P	46.0	18.0	41.0	40.0	20.0	22.0
N	51.0	73.0	55.0	44.0	76.0	70.0
PN	0	6.0	0	11.0	—	7.0
P:N	1:1.11	1:4.05	1:1.34	1:1.10	1:3.80	1:3.18

Percentages are based on eight observations.
P = pollen collectors; N = nectar collectors; PN = pollen and nectar collectors.
P:N = ratio of pollen to nector collectors.

At 12.00, NC>PC (P<0.05) for *Apis cerana*; at 15.00, NC>PC (P<0.01) for *Apis cerana*; At 09.00 and 15.00 NC>PC (P<0.01) for *Apis mellifera*; at 09.00 PC *Apis cerana*>PC *Apis mellifera* (P<0.01) and NC *Apis mellifera*>NC *Apis cerana* (P<0.01); at 12.00 NC *Apis cerana*>NC *Apis mellifera* (P<0.01); at 12.00 PC+NC *Apis mellifera*>PC+NC *Apis mellifera* at 09.00 or 15.00 (P<0.05). Depending on the hour, 1–5% of bees might collect water.

Source: Verma and Dulta, 1986.

While foraging on apple bloom, *Apis cerana* contacted on an average 3.09 stigmas (2.65 to 3.60) per flower visit, whereas, *Apis mellifera* touched 3.33 stigmas (3.20 to 3.45) per visit at a height of 1350 metres a.s.l. (Table 4.5).

Apis cerana spent on an average 5.90 seconds per flower, whereas *Apis mellifera* spent 6.63 seconds on a single visit to an apple flower at height of 1350 metres a.s.l. (Table 4.5).

Foraging study results also showed that at 0.900, 1200 and 1500 hours *Apis mellifera* visited significantly more apple trees in the same row than in a different row. However, for *Apis cerana*, the number was significantly more in the same than in a different row at 1500 hours only. No significant difference (P<.05) was observed between *Apis cerana* and *Apis mellifera* with regards to their visits in the same or different rows of apple trees (Table 4.7).

There was no significant difference between *Apis cerana* and *Apis mellifera* in the number of flowers visited per apple tree except at 0900 hours. However, *Apis mellifera* visited significantly more apple trees at 0900, 1200 and 1500 hours than *Apis cerana* (Table 4.7).

The ratio of top and side worker bees on apple bloom at a particular time of the day did not differ significantly between *Apis mellifera*

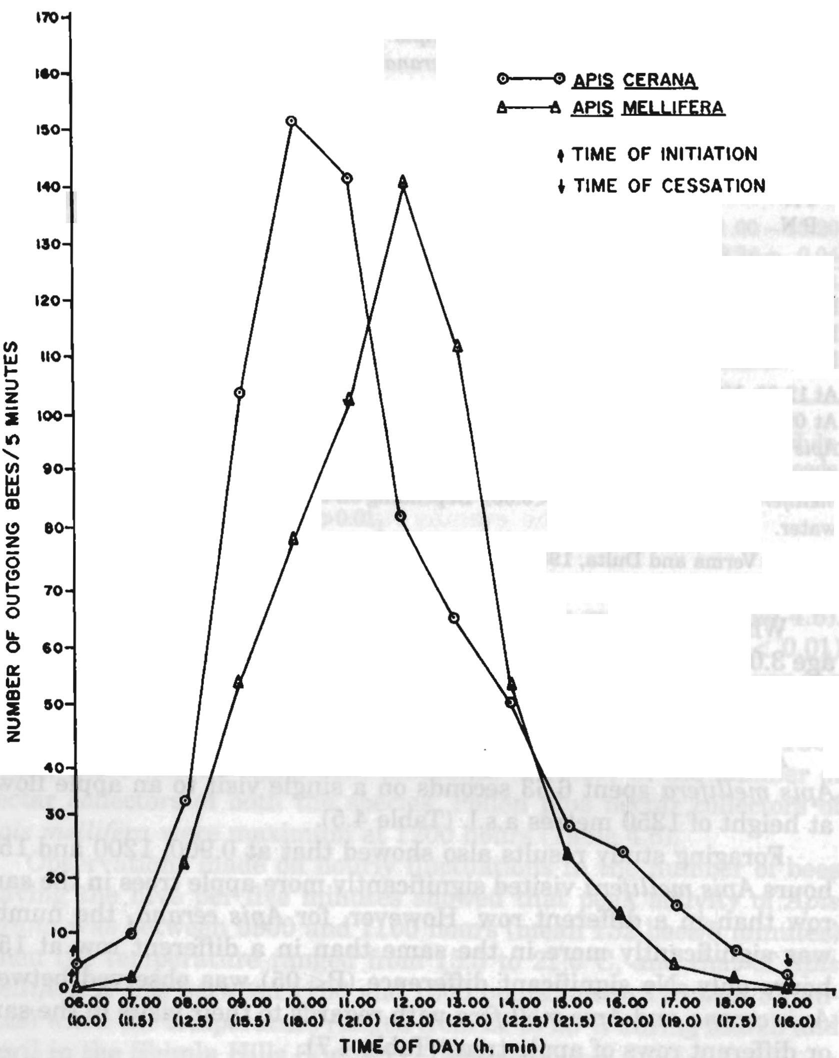


Figure 4.1: Peak hours of foraging activity (number or outgoing bees/5 min) of *A. c. indica* and *A. mellifera* honeybees on apple flowers in northwest Himalaya. Temperatures are indicated in parentheses (°).

Source: Verma and Dulta, 1986.

Table 4.7: Foraging behaviour of *Apis mellifera* and *Apis cerana* during pollination of apple bloom in the northwest Himalaya

Parameter		*Apis mellifera*	*Apis cerana*
A. No. of flowers visited per minute		6.4 ± 0.2	6.4 ± 0.3
B. No. of flowers visited per foraging trip by individual bee		193.1 ± 2.4	172.1 ± 2.6
C. No. of bees on sunny (SN) or shady (SH) sides of apple trees	SN	16.8 ± 1.4	17.8 ± 1.3
	SH	12.4 ± 1.3	14.3 ± 1.1
D. No. of trees visited in the same (SR) or different row (DR)	SR	2.7 ± 0.1	2.4 ± 0.1
	DR	3.5 ± 0.2	3.0 ± 0.1
E. Percentages of multi-floral (MF) or unifloral loads (UF)	MF	95.71	97.86
	UF	4.29	2.14
F. Preferences for foraging distance (No. of bees at different distances)	100 m	9.0 ± 0.7	9.8 ± 0.8
	250 m	8.5 ± 0.8	9.1 ± 0.8
	500 m	4.8 ± 0.6	5.1 ± 0.6

A, B = mean ± standard error of 210 observations
C = mean ± standard error of 21 observations
D = mean ± standard error of 105 observations
E = mean ± standard error of 140 observations
F = mean ± standard error of 63 observations
Statistical significance:
B = *A. mellifera* > *A. cerana* ($P<0.01$)
C = No bees of each species; SN>SH ($P<0.05$)
D = No bees of each species; DR>SR ($P<0.05$)
E = MF>UF in each species ($P<0.01$)
F = No. of bees at 100 m>500 m) ($P>0.05$)
F = No. of bees at 250 m>500 m) ($P>0.05$)
Source: Rana, 1989.

and *Apis cerana*. However, the percentage of side and top worker bees varied according to the time of the day in both the species. For example, at 0900 hours the top workers outnumbered side workers in both species, but at 1500 hours the reverse was true. At 1200 hours the percentage of side worker bees was greater than the top workers for *Apis cerana*. The time spent by top and side workers of both species on each flower did not differ significantly. However, at 1200 and 1500 hours the time spent per flower by side workers of *Apis cerana* was significantly greater than that by top workers (Table 4.8).

Table 4.8: Percentage of top or side worker bees at different hours

	0900 hours		1200 hours		1500 hours	
	Apis mellifera	*Apis cerana*	*Apis mellifera*	*Apis cerana*	*Apis mellifera*	*Apis cerana*
Top workers (TW)	65.0	67.1	42.9	41.9	36.0	41.4
Side workers (SW)	35.0	32.9	57.1	58.1	64.0	58.6
TW : SW	1.86:1	2.04:1	1:1.3	1:1.4	1:1.8	1:1.4

Each value is a mean of 140 observations

At 0900 hours, TW > SW for *Apis mellifera* and *Apis cerana* ($P<0.01$)

At 1200 hours and 1500 hours, SW > TW for *Apis mellifera* and *Apis cerana* ($P<0.05$)

Source: Rana, 1989.

4.5.4 Effects of Orchard Altitude on the Foraging Behaviour of *Apis cerana* and *Apis mellifera*

Studies by Verma and Dulta (1986) on the foraging behaviour of *Apis cerana* and *Apis mellifera* at three different altitudes, 1350, 1875 and 2400 metres a.s.l., showed that worker bees of the former started their foraging activities earlier in the morning and stopped later in the evening than the latter at all the altitude. Initiation of the foraging activity of both the species was delayed with the increasing altitude of the place. For example, time of initiations of *Apis cerana* were 0603, 0606 and 0618 hours at 1350,1875 and 2400 metres a.s.l.; whereas, for *Apis mellifera* the time of initiation at 1350, 1875 and 2400 metres a.s.l. were 0627, 0641 and 0648 hours, respectively. On the other hand, the foraging of both the species ceased earlier with the increase in the altitude of the place. *Apis cerana* ceased its foraging activity at 1913,1902 and 1825 hours at 1350, 1875 and 2400 metres a.s.l., and *Apis mellifera* ceased its activity at 1855, 1838 and 1804 hours at 1350,1875 and 2400 metres a.s.l. (Table 4.8). Thus, the duration of the foraging activity per day of *Apis cerana* and *Apis mellifera* bees on apple bloom decreased with the increase in altitude (mean duration, 13.10, 12.56 and 11.76 hours for *Apis cerana* and 12.28, 11.57 and 11.16 hours for *Apis mellifera* at 1350, 1875 and 2400 metres a.s.l. (Verma and Dulta, 1986).

The duration of each foraging trip in both the species of honeybees increased with the increase in altitude of the place where the orchard is located and it was found to be maximum (mean time, 17.83 minutes and 22.67 minutes in *Apis cerana* and *Apis mellifera*, respectively) at 2400 metres a.s.l., followed by at 1875 metres a.s.l. (mean time, 17.58 minutes and 22.25 minutes in *Apis cerana* and *Apis mellifera*, respectively) and at 1350 metres a.s.l. (11.85 minutes and 17.92 minutes in *Apis cerana* and *Apis mellifera*, respectively).

Altitude had no significant effect on other parameters, such as the bees' preference for pollen or nectar or both during a visit, peak hours of foraging activity, pollen load, number of stigmas touched per visit, or time spent per flower (Table 4.9).

The above data on comparative foraging behaviour of *Apis mellifera* and *Apis cerana* suggest that both species of honeybees are complementary to each other for sufficient and efficient pollination of horticultural and agricultural crops. Instead of providing two colonies of the same species per hectare of crop in bloom, one strong colony each of *Apis mellifera* and *Apis cerana* should be kept to ensure efficient pollination. During low temperatures, *Apis cerana* should be preferred over *Apis mellifera*. Additional research on comparative foraging behaviour of *Apis cerana* and *Apis mellifera* on other agricultural and horticultural crops in the Hindu Kush-Himalayan region should be carried out to augment the present data.

4.5.5 Renting of Bee Hives for Pollination

In Himachal Pradesh, the State horticulture department and a few private beekeepers rent *Apis cerana* and *Apis mellifera* colonies to the fruit growers at the time of apple bloom for pollination. Generally, at the onset of the winter season (November–December), colonies of both *Apis cerana* and *Apis mellifera* are migrated from the temperate hilly region to the sub-tropical plain areas, where brood rearing usually starts in the first or second week of February. By the middle of March, the colony strength reaches maximum and this is the time when flowering in apple orchards starts. These colonies are transported in trucks directly to the apple-growing belt of the state and distributed to the fruit growers at the rate of Rs. 25 per colony for one flowering season. However, private beekeepers charge a higher rental fee as compared to state Government-owned apiaries. At present, such colonies are distributed to about 1000 fruit growers, and each gets about two to five colonies irrespective of the size of the orchard. Although the number of colonies distributed for pollination is perhaps too small, keeping in view the large areas of land under fruit cultivation in Himachal Pradesh, it has created awareness among apple growers regarding the important role honeybees play in apple pollination. As a result of this practice, some growers maintain their own colonies of bees for the purpose of pollination and honey production (Verma, 1989b).

Table 4.9: Effect of altitude on foraging of *Apis cerana*and *Apis mellifera* honeybees on apple flowers in orchards at different altitudes in the northwest Himalaya in April–May

Parameter	Annu orchard		Penghunas orchard		Amin orchard	
	cerana	*mellifera*	*cerana*	*mellifera*	*cerana*	*mellifera*
IF	06.03 ± 0.01	06.27 ± 0.02	06.06 ± 0.00	06.41 ± 0.01	06.18 ± 0.01	06.48 ± 0.01
CF	19.13 ± 0.01	18.55 ± 0.01	19.02 ± 0.01	18.36 ± 0.01	18.25 ± 0.01	18.04 ± 0.01
DF	13.10 ± 0.002	12.28 ± 0.003	12.56 ± 0.003	11.57 ± 0.004	12.07 ± 0.004	11.16 ± 0.003
DT	11.85 ± 0.36	17.92 ± 0.36	17.85 ± 0.25	22.25 ± 0.39	17.83 ± 0.32	22.67 ± 0.32

Annu orchard is at 1350 m, Penghumas at 1875 m and Amin at 2400 m above sea level. Means (± SE) are for eight observations. Times of initiation and cessation, and duration of daily foraging activity in an orchard were not affected signigicantly by altitude. Duration of a foraging trip by either species at 2400 m or 1875 m > duration 1350 m ($P<0.01$).

IF = initiation (time) of daily foraging activity; CF = cessation (time) of daily foraging activity; DF = duration (h) of daily foraging activity; DT = duration (min) of an individual trip.

Source: Verma and Dulta, 1986.

4.5.6 Orchard and Bee Management Practices in Relation to Apple Pollination

1) It is now well documented that bee pollination improves the size, shape, colour, storage capacity and taste of apple fruit. To obtain good economic yield of apple, 5 per cent of flowers per 0.4 hectare of orchard must set and mature. Inadequate pollination in the apple orchard may be due to the following reasons:

— lack of pollinizer varieties suitable for cross-pollination
— non-overlapping of blooming period of main cultivar and pollinizer variety
— inadequate pollinator force in the orchard
— unfavourable weather conditions
— production of non-functional pollen or ovules
— irregularities in the development of embryo sacs.

2) Some of the above problems of orchard management can be overcome by adopting the following pollination practices:

— When planning a new apple orchard, the planting pattern should be such that every third tree in every third row is a pollinizer.
— The flowering period of pollinizer varieties should overlap with the flowering period of the main cultivars to be cross-pollinated.
— The pollinizer variety, besides helping in cross-pollination of the main cultivar, should also have commercial value.

3) Changes recommended for good pollination in the established orchards are:

— Replacing the whole tree
— Top working or grafting of pollinizer cultivars
— Providing cut flowering branches of pollinizer cultivar to main cultivar
— Hand application of collected pollen
— Use of pollen dispensers

4) Keeping in view the shorter flight range of *Apis cerana*, the bee hives should be spread throughout the orchard or possibly around the perimeter, rather than in groups.

5) Two bee hives of *Apis mellifera* per hectare of apple orchard provide an adequate pollinator force. However, due to smaller body and colony size of *Apis cerana*, three colonies per hectare are recommended.

6) If the weather is good, honeybee colonies should not be kept in the apple orchard for more than two days because of the adverse effects of pesticides.

7) Plant such trees around the orchard which act as good wind breaks.

8) Increase the strength of bee colonies to be used for pollination by adopting the following management practices:

— feeding sugar syrup,

— introducing a prolific queen, and

— increasing the amount of brood by adding combs of unsealed brood.

9) Remove combs containing stored pollen to create a pollen dearth in the colony.

10) Place colonies in the orchard at time when 10–15 per cent of the crop is in bloom.

11) Shift colonies from one site to another or even interchange them to broaden the search areas of bees, which is helpful in pollination.

12) Mow orchards in bloom to keep the bees away from the flowering weeds.

4.6 POLLINATION OF TEMPERATE FRUIT CROPS OTHER THAN APPLE

In the Hindu Kush-Himalayan countries, Apricot, Almond, Peach, Pear, Plum, Cherry, Grape, Citrus, Litchi, Olive and Persimmon are temperate fruit crops other than apple which are now being grown, and quite a considerable area is being brought under the cultivation of these fruit crops.

Information on the pollination ecology of these fruit crops in terms of their cross-fertilization status, ratio of pollinizer variety to main variety required for sufficient pollination, total bloom period, peak receptivity period of stigma to pollen, nectar and pollen potentials, chief insect pollinators, percentage of bloom required for optimum fruit set and economic yield, and number of colonies required per unit orchard area for sufficient pollination, are summarized in Table 4.10.

In the practical sense, very little is known (Atwal and Grewal 1968, Sharma, 1961) about the pollination requirements of these fruit crops under the ecological conditions of the Hindu Kush-Himalaya, and most of the information given in Table 4.10 has been compiled from western literature particularly Europe and America (McGregor, 1976; Free, 1970). In the western countries, beekeeping is an integral part of orchard management technology, and honeybees are extensively utilized for the pollination of temperate fruit crops. These results suggest that cross-pollination by honeybees increases the yield and quality of the different temperate fruit crops.

Rai and Gupta (1983) reported that honeybees were the main (48 to 76 per cent) pollinators of pear flowers in the Uttar Pradesh hills. Mann and Singh (1980) reported that *Apis mellifera* and *Apis dorsata* were dominant flower visitors of pear in the Punjab (India). The maximum population was that of *Apis mellifera* followed by *dorsata*. Their results also revealed that the yield of different pear cultivars such as Victoria, Jargonella, Burehardy and Conference increased significantly due to honeybee pollination.

Kumar et al. (1985) studied pollination requirements of 15 different peach cultivars in Solan district of Himachal Pradesh and concluded that insect pollinators do not play any significant role in fruit set of peach cultivars. Phadke and Naim (1974) concluded that honeybees were important for litchi pollination. *Apis florea* was the most important pollinator followed by *Apis cerana*. However, *Apis dorsata* did not seem to prefer litchi. Pandey and Yadava (1970) reported that litchi was highly self-sterile, and that insect-pollination was essential for good fruit set. Among the different species of insects visiting litchi flowers, the genus *Apis* was predominant. These authors also observed that *Apis cerana* visited litchi flowers mainly between 0630 and 1200 hours in the Uttar Pradesh hills.

Rao et al. (1984a) also reported *Apis cerana* as the major (78 per cent) pollinator of litchi flowers. Even in self-compatible cultivars like Shahi and China of litchi, honeybee pollination significantly increased the fruit set in trees caged with *Apis cerana* in comparison to open-pollinated flowers. Manzoor-ul-Haq et al. (1978) studied the usefulness of *Apis dorsata* and *Apis florea* in fruit set and maturation of kinnow. All results like fruit set, maturation, juice content, and the number of seeds were positive and significant.

4.7 APICULTURE AND VEGETABLE SEED PRODUCTION

Availability of the desired quantity of quality seed is one of the most important aspect for a successful vegetable industry. For the production of such quality seed, sufficient or adequate cross-pollination of vegetable crops is essential, especially under mountain conditions. Further, many of the vegetable crops are completely or partly self-incompatible and incapable of pollinating themselves (Tewari and Singh, 1983b). Cross-pollination by honeybees is, therefore, important. Vegetable flowers in return are excellent sources of pollen and nectar for bees.

In the Hindu Kush-Himalaya, seed production of temperate vegetable crops was initiated in 1942-43, in Quetta, Baluchistan (Pakistan) by a private company. Simultaneously, vegetable seed production farms were established in Kulu (Himachal Pradesh) and Kashmir

Table 4.10: Floral biology and pollination requirements of fruit crops in the Hindu Kush-Himalayan region

(Per cent)

Crop	Per cent degree of cross-pollination	Ratio of pollinizer variety to main variety	Total bloom period	Peak receptivity period of stigma to pollen	Nectar or pollen potentials	Chief pollinators	Percentage bloom required for good fruit set	Increase in yield due to cross-pollination	Pollination requirements (No. of hives/ha)
Apple	All commercial varieties require cross-pollination	Every third tree in every third row should be a pollinizer	9 days	2–3 days	NP	Honeybees Bumblebees Halictus	50–95	180–6950	2
Almond	Cross-pollination essential	One pollinizer row for two rows of main variety	one month	3–4 days	N^1P^1	Honeybees Wildbees	90–100	50–75	5–8

Apricot	Cross-pollination beneficial and for some cultivars, it is essential	Same as for apple	15–20 days	4–5 days	NP	Honeybees	50–95	5–10	2.5
Black currants	Cross-pollination essential	No specific recommendation	21 days	5–6 days	N^2P^2	Honeybees	90–100	81–2200	Occur in wild state in the Hindu Kush-Himalayan region
Blueberry	Cross-pollination essential	No specific recommendation	21 days	5–8 days	NP	Honeybees Bumblebees	50–80	11–9800	Occur in wild state in the Hindu Kush-Himalayan region
Cherries	Cross-pollination is essential	One pollinizer for 10 trees of main cultivar	7–8 days	First two days after opening of flowers	N^1P^1	Honeybees	21–32	56–1000	2.5–3

Table 4.10 (Cont'd . . .)

(Per cent)

Crop	Per cent degree of cross-pollination	Ratio of pollinizer variety to main variety	Total bloom period	Peak receptivity period of stigma to pollen	Nectar or pollen potentials	Chief pollinators	Percentage bloom required for good fruit set	Increase in yield due to cross-pollination	Pollination requirements (No. of hives/ha)
Citrus	Vary from self-sterile to self-fertile form	No specific recommendation	1 month	6–8 days	N^2P^2	Honeybees	80–90	7–233	1–2
Cranberry	Cross pollination essential	No specific recommendation	2–3 weeks	3 days	NP	Honeybees Bumblebees	90–100	9–2153	1 hive per 2.5 ha
Gooseberry	Cross pollination essential	No specific recommendation	Less than one month	2–3 days	NP	Honeybees	90–100	29–300	No specific recommendation

Grapes	Self-fertile to self-sterile	Inter-planting of different cultivars essential	20–25 days	3 days	N^3P^3	Honeybees halictus	90–100	23–54	One
Guava	Cross-pollination beneficial	Every third row should be a pollinizer	25–45 days	1–2 days	N^3P^3	Honeybees	80–86	12	No specific recommendation
Litchi	Cross-pollination beneficial	Inter-planting of diffe-rent cul-tivars un-necessary	3 days 26–36 days	3 days	N^1P^2	Honeybees Flies, Ants, Wasps	50–90	4538–10246	No specific recommendation
Peach	Most vari-eties self-fertile and a few self-sterile	Same as for almond	20–24 days	3 days	N^1P^1	Honeybees	50–90	7–3788	1 to 2 in young orchard and 2.5 in old orchard

Table 4.10 (Cont'd...)

(Per cent)

Crop	Per cent degree of cross-pollination	Ratio of pollinizer variety to main variety	Total bloom period	Peak receptivity period of stigma to pollen	Nectar or pollen potentials	Chief pollinators	Percentage bloom required for good fruit set	Increase in yield due to cross-pollination	Pollination requirements (No. of hives/ha)
Pears	Partly or entirely self-sterile	"Barlett" variety be inter-planted with other varieties	One week	4–5 days	N[1] P[1]	Honeybees Flies Beetles	6–7	240–6014	1–5
Persimmon	Mainly self-fertile	No specific recommen-dation	25–30 days	3–4 days	—	Honeybees Bumblebees	75	21	No specific recommendation

Plums	Vary from self-fertile to self-sterile forms	Every fourth tree in every fourth row be a pollinizer	5 days	2 days	N^1P^1	Honeybees Bumblbees Blow flies	50–90	5–10	2.5
Rasberry	Cross-pollination beneficial	No specific recommendation	3–6 weeks	2–3 days	N^2P^2	Honeybees	90–100	291–463	1–2
Strawberry	Cross-pollination beneficial	No specific recommendation	45–60 days	3 days	N^2P^2	Honeybees Wild bees	90–100	5–10	1 to 10, 25 or even more

Source: Compiled from multiple sources.

Valley (North-West India). After partition in 1947, a vegetable seed production station was established in Katrain, Kulu Valley under the administrative charge of Indian Agricultural Research Institute, New Delhi (Gowda et al., 1986). Now temperate vegetable seeds are being produced in Solan, Kulu Valley, Kalpa Valley of Himachal Pradesh and also in Kashmir Valley Uttar Pradesh Hills by many private growers. Incidentally, most of these areas have a very old and rich tradition of beekeeping. Farmers kept bees in these areas for honey production, but they were quite ignorant about the role of honeybees in enhancing the yield and quality of vegetable seeds through cross-pollination. In recent years, with this new awareness, beekeeping is becoming an important and integral part of vegetable seed production technology. Among the Hindu Kush-Himalayan countries, India has taken the lead in making apiculture an essential component for vegetable seed production.

In India, the pollination requirements of different cultivars of cauliflower have been studied in great detail. A large number of insect pollinators visit cauliflower at the time of bloom and predominant among them are different species of honeybees, *Eristalis* sp., *Ceratina* sp., *Halictus* sp. (Kakkar, 1983; Verma and Joshi, 1983). Among the different species of honeybees, *Apis cerana* was found in maximum concentration (49.9 per cent). Adlakha and Dhaliwal (1979) reported that native *Apis cerana* was a better pollinator of cauliflower than the exotic *Apis mellifera*. Gupta et al. (1984a) reported that peak periods of foraging activities of honeybees on cauliflower were during noon and evening hours, and the minimum activity was observed during morning hours. Among the five different cultivars of cauliflower tested, honeybees preferred flowers of section-25, section-1 and snowball-16. Tewari and Singh (1983a) observed that *Apis cerana* preferred to visit the cauliflower bloom nearer the hive. For example, the maximum number of forager bees were observed at a distance of 12.5 m away from the location of the hive, and the minimum at 200 m. Fruit set, length of siliqua, number of seeds per stigma and yield of cauliflower seed decreased as the distance of flowering plants from the hive increased. Verma and Joshi (1983) reported that pollination by honeybees increased the percentage of setting buds by 44.70 to 74.20, the number of seeds per pod by 2.32 to 4.07, and weight of the single seed by 0.19 to 1.17 mgm in comparison to pollination by other insects and under controlled experimental conditions or self-pollination. Kumar et al. (1988) and Rao et al. (1984b) also confirmed the results of the earlier work that seed set and seed weight in cauliflower increased significantly due to bee pollination.

In the temperate Indian Himalaya, a large area of land is coming under off-season vegetable production which brings to the farmer four to five times higher income than the normal seasonal vegetables. Similarly, in other parts of the Hindu Kush-Himalaya, vegetable cultivation is expanding rapidly because of the change in the food habits of the people, and also because it is a source of cash income. Keeping this in view, the demand for high quality vegetable seed at a cheaper rate will increase tremendously in the future. One way to meet such demands will be through the utilization of pollination services of honeybees, and including beekeeping as an essential component of vegetable seed production technology. Data on the floral biology of different vegetable crops and their pollination requirements is summarized in Table 4.11.

4.7.1 Isolation Distance in Relation to Pure Seed Production

It is now well-documented that cross-pollination by honeybees helps in increasing the yield and quality of vegetable seeds. This activity of honeybees also hampers pure seed production in such crops due to intercrossing. This problem, can be solved by providing the necessary isolation distance between different cultivars of the same crop in order to avoid crossing and contamination. Foraging areas of the adult worker bees are always limited and they keep their foraging activities confined to this particular area only during their successive field trips to collect pollen, nectar or both. In cases where fields with compatible varieties/cultivars are quite adjacent, chances of intercrossing or contamination will be more. However, in distant fields with compatible varieties or cultivars, foraging areas of bee visits will not overlap, and pure seed production is possible. Such actual isolation distance would depend upon the degree of the purity of seed required, i.e. if the seed is being produced as foundation seed or certified seed by the grower. The actual distance required by the different vegetable crops for the production of pure seed is given in Table 4.11.

In Britain, the isolation distance required varies from 193 to 214 m for different crops. In Canada, isolation distances for certified, registered and foundation kinds of seeds are 46, 91 and 183 m respectively (Goyal and Kandoria, 1988). However, these figures have been taken from the work carried out in western countries, and no such information is available on this aspect under local ecological conditions of the Hindu Kush-Himalaya.

4.8 APICULTURE AND OILSEED PRODUCTION

Oilseeds play an important role in the national economy of many countries. Oils and fats derived from oilseeds not only constitute an essential part of human and animal diet but are also indispensable. It has been noticed that oilseed production in the Hindu Kush-Himalayan

Table 4.11: Floral biology and pollination requirements for vegetable seed production in the Hindu Kush-Himalayan region

Crop	Per cent degree of cross-pollination	Total bloom period	Peak receptivity period of stigma to pollen	Nectar or pollen potentials	Chief pollinators	Honeybee pollination requirements (number of hives per hectare)	Per cent increase in yield due to honeybee pollination over self-pollination	Isolation distance required for pure seed production in metres
Cole crops Cauliflower Cabbage	72–95	1 month	9 days	N^2P^3	Honeybees Bumblebees Wildbees Flies	5	100–300	3000 for breeder seed and 1500 for certified seed
Tomato	Less than 2	12–15 days	4–8 days	P	Solitary bees Thrips Honeybees	No specific recommendations	No specific data	250–400
Chilli Pepper green Pepper chilli	7–36	2–3 days	2 days	NP	Honeybees Ants	No specific recommendation	No specific data	200 for foundation seed and 100 for certified seed

Radish	85	2 days	A few hours in a day	N^3P^3	Honeybees only	5	22–100	1600 for foundation seed and 1000 for certified seed
Carrot	Mainly cross pollinated	1 month	One week or longer	N^3P^3	Honeybees House flies	8 bees per square metre	9–135	1000
Turnip	Mainly cross pollinated	22–30 days	2–3 days	N^2P^2	Honeybees	2.5	100–125	1600 for foundation seed and 1000 for certified seed
Cucurbits	60–80	1 day	2 hours	N^2P^2	Honeybees Halictus	2–4	21–6700	800–1000
Okra	4–42	After sunrise till noon	2 days	N^3P^3	Honeybees Bumblebees	None	No specific recommendation	No specific recommendation

Source: Compiled from multiple sources.

region is either stagnant or declining gradually (Rao et al., 1984b). Efforts are being made by different Government of the region to bring more area under oilseed production in order to meet the growing demand. One way of increasing oilseed production is by introducing a planned honeybee pollination programme as one of the essential inputs which has not been so in this region. The main reason for which is ignorance on the part of the agriculture extension agencies and farmers.

Among the important oilseed crops, groundnut, mustard, sesame, safflower, niger and sunflower are extensively grown in this region. Since most of these crops, except groundnut, are cross-pollinated, adequate pollination is vital for increasing the yield per unit area of the land. It is also now well-documented that pollination by honeybees ensures uniform maturity and early harvest of these oilseed crops,thus facilitating timely sowing of the next crop in rotation. The percentage increase in yield due to honeybee pollination in different oilseed crops is given in Table 4.12 along with the pollination requirements and floral biology of these crop plants. Rao et al. (1984b) has shown that in India, honeybee pollination also enhances the oil contents of seed crops. For example, there was 6.5 per cent increase in the oil content of the seed harvested from honeybee-pollinated flowers of sunflower.

In view of such encouraging results, farmers in India are being given honeybee pollination demonstrations by different extension agencies in various parts of the country to create awareness of the beneficial effects of honeybee pollination. Panchabhavi and Deviah (1977) Panchabhavi et al. (1976) and Thakar (1974) reported that *Apis florea* was the main pollinator of sunflower plants. Deshmukh et al. (1985) reported *Apis cerana* and *Apis dorsata* were the main insect pollinators of safflower. As a result of bee pollination, seed yield of the this oilseed crop increased by 23 and 28 per cent in NRS-209 and No. 83 cultivars, respectively. Similarly, Pande et al. (1988) also observed that, both in bee-pollinated as well open-pollinated flowers of sesamum and niger, an increase up to 50 to 59, and 22 to 33 per cent, respectively was found respectively as compared to control experiments. Thakur et al. (1982) compared the foraging behaviour of *Apis cerana* and *Apis mellifera* on mustard in the Kangra valley (Himachal Pradesh). *Apis cerana* initiated foraging activity earlier in the morning, whereas *Apis mellifera* ceased foraging later in the evening. In both species, the pollen collectors outnumbered the nectar collectors and the peak periods of foraging activity were recorded at 1200 to 1400 and 1530 hours.

4.9 MISCELLANEOUS CROPS

1) Fodder crops

Improvement of animal products such as beef, pork, poultry, lamb or dairy products, is strongly dependent upon improving the quality and quantity of fodder and livestock ration feed. Availability of such quality fodder in sufficient quantities would depend upon reliable, cheap and good quality seed supplies. Three conventional components of seed quality (i.e. physical, genetical and vital quality) are greatly improved if the flower in bloom is pollinated by honeybees. Many of the fodder crops are dependent on or benefited by honeybee pollination. Major fodder crops grown in the Hindu Kush-Himalayan countries are alfalfa, clover, trefoil, vetch and sainfoil. For all these crops, cross-pollinating is either essential or beneficial to enhance their seed production. Floral biology and pollinating requirements of these crops have been summarized in (Table 4.12).

2) Cardamom (Ellettaria Cardamom)

Cardamom is one of the world's costliest seed species. It is also a cross-fertilized crop and depends exclusively upon honeybees for pollination. A large number of insect pollinators such as different species of honeybees, wild bees, ants, thrips and aphids visit cardamom flowers. However, honeybees are the main pollinators constituting more than 88 per cent of the total insect pollinators. Even a single visit to a cardamom flower by *Apis cerana* is enough for fruit set (Siddappaji and Channabasavanna, 1983, Chandran et al., 1983). Joseph and Mohandas (1985) recommended four colonies per hectare for effective cardamom pollination. Pattanshetti and Prasad (1973, 1974) reported 66 and 11 per cent fruit set and 27.4 and 2.1 seed pods per panicle from bee-pollinated flowers and control experiments, respectively. Similarly, Chandran et al. (1983) observed 37.2 and 21.9 per cent fruit set from honeybee-pollinated and open-pollinated flowers.

Verma (1987) reported that greater Cardamom (*Amomum subulatam*); an important spice crop of sub-Himalayan region, is greatly benefited by bee pollination. *Apis* sp. constituted more than 60 per cent of the insect pollinators. In open-pollinated flowers, the per cent fruit set, green and dry fruit weight, number of seeds per capsule were significantly more than in bagged inflorescences with no access to insects at all.

3) Buckwheat

Buckwheat, an underutilized genetic resource in the Hindu Kush-Himalayan region, is unable to self-pollinate, and honeybees are es-

Table 4.12: Floral biology and pollination requirements for oilseed and fodder crops in the Hindu Kush-Himalayan region

Crop	Per cent degree of cross-pollination	Total bloom period	Nectar or pollen potentials	Chief pollinators	Per cent increase in yield due to cross pollination	Pollination requirement number of hives per hectare	Isolation distance in metres
Mustard	Mainly cross-pollinated	3 days	P^1N^2	Wind Honeybees	13 to 222	2.5 to 5	—
Sarson (rape)	Mainly cross-pollinated	22–45 days	P^1N^2	Honeybees Bumblebees Beetles	131.63	2–6	—
Safflower	5 to 40	10–40 days	P^2N^2	Honeybees	4–114	2	—
Sesame	5–65		P^1N^1	Honeybees	24.41	No specific recommendation	180–360
Sunflower	20–75	2 or more days	P^2N^2	Honeybees Bumblebees	21–3400	1 to 2 and for hybrid seed production 2 to 4	800

Alfalfa	Mainly cross pollinated. Bees are necessary for tripping	One week	P^1N^2	Honeybees Wild bees	23–19733	5–10	
Trefoil	Cross-pollination necessary	8–10 days	P^1N^1	Honeybees Bumblebees Wildbees	900	2	
Clovers	Cross-pollination essential	—	P^2N^2	Honeybees	40–33150	2–5	
Vetch	Cross-pollination beneficial	—	P^3N^3	Honeybees Bumblebees	39–20000	Several colonies	3
Sainfoin	Cross-pollination essential	—	P^1N^2	Honeybees	2815	2–3	90

Source: Compiled from multiple sources.

sential for its cross-pollination. It is an excellent sources of nectar to which large numbers of bees get attracted. Farmers in the entire Hindu Kush-Himalaya harvest surplus honey from this plant. According to Deodikar and Suryanaryana (1977) due to bee pollination, buckwheat seeds yield can be increased by 63 per cent. For optimum seed set, two-and-a-half to eight colonies per hectare have been recommended in Canada or the USSR (Crane and Walker, 1984).

4.10 APICULTURE AND PESTICIDES

Beekeeping and pesticides are both essential inputs of modern agriculture management technology. By ignoring either of the two, global food production would be seriously impaired. Since the advent of synthetic pesticides several decades ago, the beekeeping industry, both in the developed and developing countries, has been incurring heavy losses. In developed countries large-scale monoculture cultivating of crops and a high degree of mechanization has greatly amplified the problem of honeybee poisoning by pesticides. On the other hand, in developing countries the basic problem is lack of information about the harmful effects of pesticides to honeybees. Side-by-side agricultural scientists also prescribe pesticides indiscriminately. With the tremendous increase in apple cultivation in the Hindu Kush-Himalayan region, the incidence of pest and diseases has increased which is adversely affecting crop yields. Apple blossom thrip, a serious pest of apple especially at the time of flowering, requires insecticide application for its effective control. Similarly, apple scab caused by *Venturia inaequalis* has gradually spread to all the apple-growing areas of the Hindu Kush-Himalayan region, crossing the high mountain barriers. For example, in 1983, the severity of the disease was such that more than 25 per cent of the crop was destroyed. Therefore, in Himachal Pradesh the use of fungicides has become necessary as these chemicals act as protectants against this disease. Other insecticides, fungicides and herbicides are also coming into use in orchard management, and attention needs to be paid to their effects on insect pollinators, especially honeybees. Such over-reliance on chemical methods for the control of pests and diseases is also causing serious pollution problems. Fruit growers in this region use blanket applications. This is caused by a lack of knowledge as to what and how much to use, and when. As a result of this, there is a danger of the extinction of wild pollinating insects due to the excessive use of pesticides. Unlike developed countries, there is also a lack of legislation to prohibit the use of pesticides to the extent that it kills bees. Thus, there is a need to develop integrated pest-management strategies for protecting honeybees from broad-spectrum biocides. Literature on pesticides in relation to beekeeping has been reviewed by Adey et al., 1986; Crane and Walker, 1983; Anonymous, 1981; Anderson and Atkins 1968; and Indian Standards Institution (1973a, b).

4.10.1 Bee Poisoning Symptoms

One of the obvious signs of poisoning is the presence of a large number of dead or dying bees at the hive entrance. These adult bees are foragers who would have made contact with pesticides sprayed on flowering plants. The mortality figures in Table 4.13 are used as guidelines to assess the extent of bee poisoning by pesticides.

Table 4.13: Extent of bee poisoning by pesticides

Number of dead bees per day at entrance	Level of poisoning
100	Normal death rate
200– 400	Low
500–1000	Medium
Over 1000	High

Source: FAO Bulletin 68/3, 1988.

As a result of organophosphorus poisioning, dying bees extend their tongue through which nectar is regurgitated and a moist and sticky mass of dead bees is often found at the hive entrance. The fast-acting insecticides kill the foraging bees in the field itself, and only a small number of such bees manage to return to the hive. Sometimes, the whole bee colony may die instantly. Strong bee colonies suffer greater losses due to pesticide poisioning than the weaker ones because the former have a larger foraging bees.

Foraging bees often carry residual pesticides into the hive in their pollen loads. As a result of this, the behaviour of bees in the hive changes abruptly. Honeybees in such colonies become more agitated or aggressive. As and when the hive with pesticide-affected forager bees is opened, they often fly off the top bars of the hive and sometimes straight into the face of the beekeeper handling them. Other symptoms of pesticide poisoning include stupefaction, paralysis, abnormal, jerky or spinning movements. Carbaryl poisoning causes bees to crawl around at the hive entrance, they lose their ability to fly, and ultimately die in two to three days after poisoning.

Nurse bees in pesticide-affected colonies lose their ability to clean the dead bees from the hive, as a result of which the hive entrance is completely blocked.

Pesticide poisoning also affects the colony strength because there is a break in the brood rearing cycle and often dead or deserted colonies cease foraging, as a result of which there is a sharp decline in food storage, and incoming foragers are attacked at the hive entrance by other bees.

4.10.2 Protective Strategies Recommended

i) As far as possible, biocide applications should always be recommended outside the blooming period.

ii) Pesticides which have short residual effects and are the least hazardous to honeybees should be selected.

iii) Ignorance and lack of extension programmes to educate the farmers about the harmful effects of pesticides is the biggest problem in developing countries. Both the orchardists and beekeepers should be educated properly about pesticide application schedules and how to reduce poisoning in a particular area.

iv) Broad-spectrum pesticides should be avoided as they are much more hazardous than selective pesticides which are safer for bees and other beneficial insects.

v) Night or early morning application of pesticides is always desirable because foraging honeybees are at that time in the hive and thus out of danger. Night application of pesticides allows adequate time for the pesticide to dissipate or break down to substances non-toxic to bees.

vi) It has been recognized that spray or liquid formulations are safer than dust or wettable powder formulations. There is an almost sixfold greater kill with powder formulations than with liquid ones. The addition of solvents or oily substances to spray material reduces bee losses significantly.

vii) Insecticide formulations can be classified as follows in order of their toxicities:

Dust > wettable powder > flowable > emulsifiable concentrate or soluble powder or liquid solution > granular formulation (Johansen and Kleinschmidt, 1972).

viii) It is always advisable to keep bee colonies as far away from the pesticide-treated fields as possible. Even a distance of 1 km from the site of the spray will reduce honeybee mortality ninefold.

ix) Remove all the flowering weeds from the orchards either by mowing or beating so that they do not act as a source of poison to the bees. This practice will force the bees to forage in longer distances, free from the adverse effect of pesticides.

x). In the temperate Hindu Kush-Himalayan regions, residues would remain toxic for a longer time due to lower temperatures. But at the same time, low temperatures delay the initiation of foraging activities of honeybees in the morning. Keeping this in view, pesticide application times should be shifted accordingly.

xi) Primary emphasis should be on the use of an integrated pest management programme which mainly relies on biological or cultural methods of insect-pest control and minimizes the use of poisonous chemicals.

4.10.3 Relative Toxicity of Some Biocides to Asian Hive Bee, *Apis cerana*

In several developing countries of southeast Asia, beekeeping with *Apis cerana* has been sustaining heavy losses since the advent of synthetic pesticides several decades ago. Such widespread and careless use of toxic pesticides during the blooming periods of agricultural and horticultural crops not only kills bees but also contaminates hive products.

In India several research workers have compared the relative toxicities of commonly used pesticides on *Apis cerana*, and these have been classified as highly toxic, moderately toxic and non-toxic. The results of these investigations are reviewed as follows:

Group I: Highly toxic insecticides

Application of these pesticides on blooming crops or weeds may cause severe damage to bees. Beekeepers should be warned in advance by the growers when these insecticides are to be used so that they can move the colonies temporarily to safer locations. Even after 10 hours of spray these pesticides are still highly toxic to bees.

Insecticide	*Reference*
Carbaryl 50% WP	Bai and Reddy (1977) Singh *et al.* (1974)
Carbofuran 3% WP	Bai and Reddy (1977)
Carbophenothion 20 EC	Bai and Reddy (1977)
Cypermethrin 10 EC	Prakash and Kumaraswami (1984)
Decamethrin 20 EC	Prakash and Kumaraswami (1984)
Dichlorovos 100 EC	Bai and Reddy (1977)
Dimethoate 30 EC	Attri and Sharma (1969), Singh *et al.* (1974)
DDVP 100 EC	Singh *et al.* (1974)
Monocrotophos 36 WSC	Rana (1989) Bai and Reddy (1977)
Oxydemeton-methyl 25 EC	Bai and Reddy (1977)
Parathion	Kapil and Lamba (1974)
Phosphamidon 100 EC	Bai and Reddy (1977) Kapil and Lamba (1974) Singh *et al.* (1974)

Phorate	Kapil and Lamba (1974)
Permethrin 25 EC	Prakash and Kumaraswami (1984)
Quinalphos 25 EC	Bai and Reddy (1977)
Sumithion 50 EC	Rana (1989)
Thiometon 25 EC	Attri and Sharma (1969)
	Singh *et al*. (1974)

Group II: Moderately toxic insecticides

The following pesticides should be applied during late evening when bees are not actively foraging. Bee hives should not be directly exposed to these insecticides. For minimal hazards to honeybees, the dose, the timing and the application methods are very important.

Insecticide	*Reference*
BHC 50 per cent	Bai and Reddy (1977)
Carbyl 50 WP	Prakash and Kumaraswami (1984)
DDT 50 per cent	Bai and Reddy (1977)
Dieldrin	Kapil and Lamba (1974)
Endrin	Kapil and Lamba (1974)
Hinosan 50 EC	Thakur *et al*. (1981)
Heptachlor 10 WP	Bai and Reddy (1977)
Malathion 50 EC	Singh *et al*. (1981)
Methyl demeton	Kapil and Lamba (1974)
Monocrotophos 40 EC	Prakash and Kumaraswami (1984)
Trichlorfan 50 EC	Thakur *et al*. (1981)
Diazinon 20 EC	Singh *et al*. (1981)
Ethyl parathion 46%	Singh *et al*. (1981)
Fenitrothion 100 EC	Thakur *et al*. (1981)
50 EC	Bai and Reddy (1977)
Fenthion 100 EC	Thakur *et al*. (1981)
Formothion 25 EC	Kapil and Lamba (1974)
	Singh *et al*. (1981)
Gamma BHC 20%	Singh *et al*. (1981)
Lindane	Kapil and Lamba (1974)
Metacid 50 EC	Rana (1989)
Metasystox 50 EC	Rana (1989)
25 EC	Attri and Sharma (1969)
	Singh *et al*. (1981)
Mevinphos	Kapil and Lamba (1974)
Methyl parathion 50 EC	Bai and Reddy (1977)
	Singh *et al*. (1981)

Moderately toxic fungicides

Insecticide	*Reference*
Dithane M-45 75 WP	Rana (1989)
Foltaf 80 WP	Rana (1989)
Difolitan 50 WP	Rana (1989)
Hexacap 50 WP	Rana (1989)
Bavistin 50 WP	Rana (1989)

Group III: Relatively non-toxic insecticides

These pesticides cause minimum damage to the bees. They should be applied during late evening, night or early morning.

Insecticide	*Reference*
Endosulfan 35 EC	Attri and Sharma (1969)
Menazon 70 DP	Singh *et al.* (1981)
Phosalone 35 EC	Prakash and Kumaraswami (1984)

CHAPTER 5

Status and Economics of Beekeeping in the Hindu Kush-Himalayan Countries

5.1 INTRODUCTION

Beekeeping in the developing countries of the Hindu Kush-Himalayan region is still an old traditional household activity. It is only in recent years that this enterprise is becoming commercially organized in parts of China, India and Pakistan as a result of the introduction of the high honey-yielding species of *Apis mellifera*. In other parts, it is mostly small and marginal farmers who keep one to five colonies of *Apis cerana* in different types of traditional hives and even today, honey is extracted by the "squeezing method" without any quality control standards. One of the reason for such a deploring scenario is that direct and indirect economic gains/benefits of this important enterprise have not been projected properly. Economists are generally criticised for not taking ecology seriously, similarly beekeeping has been overlooked by them. So far no systematic studies on the economics of beekeeping has been carried out to project the immense importance of this enterprise.

In the this Chapter, the economics of beekeeping based on the data supplied by different bee scientists of the region have been worked out. Such an analysis provides broad guidelines to initiate action to develop beekeeping as an enterprise for different target groups at various technological levels.

For example, the present analyses include the comparative economics of beekeeping with native *Apis cerana* versus *Apis mellifera* in Himachal Pradesh; modern movable frame "Newton hive" versus traditional beekeeping with *Apis cerana* in Bangladesh and Nepal; standard Langstroth hive beekeeping versus low cost hive beekeeping; and small-scale versus commercial-scale beekeeping with *Apis mellifera* in Pakistan.

For each country/region, firstly the present status of beekeeping is reviewed and this is followed by economic analyses made on the following lines:

1) Cost and returns per colony.

2) Cash flow projections assuming that a farmer starts with two colonies in the first year and increases subsequently to 10 colonies in the fifth year at the rate of two colonies per year and then keep this number constant.

3) Sensitivity analysis, by reducing the returns by 50 per cent and maintaining the cost at the same level.

5.2 HIMACHAL PRADESH (NORTHERN INDIA)

Keeping in view the varied socio-economic and ecological conditions of a vast country like India, only the case study of Himachal Pradesh on economics of beekeeping has been chosen. Modern beekeeping in India has its origin in Himachal Pradesh, where this cottage industry is a source of food and income to the people. All the four species of honeybees are found in different climatic zones of Himachal Pradesh. Within the past two decades, the sub-tropical and sub-temperate zones in the state have successfully developed beekeeping programmes with exotic *Apis mellifera*, while in the temperate zone, beekeeping with *Apis cerana* has progressed well through the centuries by improvement in management techniques. At present, both *Apis cerana* and *Apis mellifera* are complementary to each other as far as beekeeping in the temperate and sub-tropical regions, respectively, of the state are concerned.

Apis cerana is kept either in wall (fixed type) hives or movable hollowed out logs, wooden boxes, mud receptacles or earthen pitchers. At some places very crude and indigenous methods are still in use for the collection and extraction of honey from such traditional hives. However, the introduction of modern bee management techniques has changed all this. The modern hive used for beekeeping with *Apis cerana* in Himachal Pradesh are movable wooden frame hives (called villager's hive) adapted to the size of *Apis cerana*, whereas *Apis mellifera* is kept in standard Langstroth hives. Modern beekeeping equipment for extraction and processing of honey is supplied by different government agencies and private firms. In Himachal Pradesh, the annual production of honey is more than 150 tonnes. Recently, the State Horticultural Produce, Marketing and Processing Corporation, Ltd. (HPMC) has taken over the marketing of surplus honey in the state. This organization purchases bulk honey from the beekeepers and is responsible for its processing, packing and grading. At present, the state produces only about 30 quintals of beeswax which is mainly used for the preparation of comb foundation sheets.

Himachal Pradesh is a leading state in India and southeast Asia where the management and renting of *Apis cerana* and *Apis mellifera* colonies is being done in a scientific way for the pollination of apple orchards. Thus, beekeeping forms an integral part of horticultural management technology in the state (Verma, 1984).

Although there is a great variety of pollen and nectar-yielding plants in Himachal Pradesh, they are mostly multifloral sources of honey. *Plectranthus* sp., is one of the few honey plants of northern India which acts as a unifloral source of honey. Besides the harmful effects of biocides on honeybees in the state, recently (1983–1988) a sacbrood virus disease killed more than 95 per cent of the colonies of *Apis cerana* in northern India. However, this loss has been duly compensated by starting beekeeping with *Apis mellifera* on a large scale in the state. Moreover, sacbrood virus disease has completed its four-year cycle in Himachal Pradesh and all the districts are now disease-free (Verma, 1989b).

The estimation of costs and returns for *Apis cerana* and *Apis mellifera* are based on the information collected from a sample of 50 growers who are engaged in honey production, as well as from the State Horticulture Department which is maintaining bee colonies at 43 different beekeeping stations in Himachal Pradesh. The survey was conducted in 1987. Hence estimation of costs is based on 1987 prices (Verma, 1989b).

The costs and returns per colony of *Apis cerana* and *Apis mellifera* are given in Tables 5.1 and 5.2, respectively. It may be observed from the tables that the annual cost for the installation and operation of one colony of *Apis cerana* and *Apis mellifera* has been estimated at Indian rupees 123 and 317 comprising Rs.90 and Rs.240 as recurring and Rs.32 and Rs.77 as non-recurring costs, respectively. Direct payments to labour are not involved, so while estimating net returns, "Opportunity cost" of labour has not been taken into account. Thus, a bee colony generates net profit of Rs.369 per year in the case of *Apis cerana* and Rs.920.80 for *Apis mellifera*. These results show that beekeeping with *Apis mellifera* is more beneficial than *Apis cerana*.

The cash flow projections of honey and beeswax production are given in Table 5.3 for *Apis cerana* and Table 5.4 for *Apis mellifera*. It may be observed from these tables that during the first year of operation the entrepreneur will incur a loss of Rs.216 in beekeeping with *Apis cerana* and Rs.27 with *Apis mellifera*. Subsequently, the profit he will derive during a period of one decade has been estimated at over Rs.29,000 and Rs.78,900 for *Apis cerana* and *Apis mellifera*,

Table 5.1: Costs and returns of a beekeeping enterprise with the Indian hive bee *Apis cerana* in Himachal Pradesh, India, 1987

	Item	Price (Rs.)	Life years	Cost/year (Rs.)*
I.	COSTS			
A.	*Fixed costs:*			
	Bees	25.00	10	2.50
	Bees veil	25.00	3	0.75
	Hive tool	15.00	10	0.15
	Smoker	30.00	5	0.60
	Honey extractor	300.00	5	6.00
	Uncapping tray and knife	250.00	5	5.00
	Village hive	150.00	10	15.00
	Hive stand	25.00	10	2.50
	Sub-total	820.00	—	32.50
B.	*Variable costs:*			
	Comb foundation sheet	40.00	1	40.00
	Hessian cloth	8.00	1	8.00
	Sugar (5 kg @ Rs.8/per kg)	40.00	1	40.00
	Acaricide and other drugs	2.00	1	2.00
	Sub-total:	90.00	—	90.00
	Total costs (A+B)	910.00	—	122.50
II.	RETURNS			
	Honey (8 kg @ Rs.60/per kg)			480.00
	Beeswax (0.15 kg @ Rs.75/per kg)			11.25
	Total returns			491.25
III.	NET RETURNS (II–I)			368.75

Source: Verma, 1989b.

*One U.S. Dollar = 17 Indian Rupees.

respectively. The loss incurred in the first year will be recouped in the following year of operation with both the species. Even after recouping these losses there will be a profit of Rs.993 and Rs.3,163 for *Apis cerana* and *Apis mellifera*, respectively. The State Government is providing subsidy on the purchase of bees, villager's hive, hive stands,

Table 5.2: Costs and returns in honey production in beekeeping with European honeybee *Apis mellifera* in Himachal Pradesh, 1987

(per hive)

	Items	Cost (Rs.)	Life (years)	Cost/year/ colony (Rs.)
I.	COSTS			
A.	*Fixed cost:*			
	Bees	200.00	10	20.00
	Bee veil	25.00	3	0.75
	Hive tool	15.00	10	0.15
	Smoker	30.00	5	0.60
	Honey extractor	750.00	5	15.00
	Uncapping tray/knife	250.00	5	5.00
	Hive	327.00	10	32.70
	Hive stand	25.00	10	2.50
	Sub-total:	1622.00	—	76.70
B.	*Variable cost:*			
	Comb foundation sheet	150.00	1	150.00
	Hessian cloth	8.00	1	8.00
	Sugar (10 kg 8/- per kg)	80.00	1	80.00
	Acaricide and other drugs	2.00	1	2.00
	Sub-total:	240.00	—	240.00
	Total cost (A+B)	1862.00	—	316.70
II.	RETURNS			
	Honey (20 kg per hive @ Rs.60/ kg)	1200.00	—	1200.00
	Beeswax (0.5 kg @ Rs.75/kg)	37.50	—	37.50
	Total returns:	1237.50	—	1237.50
III.	NET RETURNS (II–I)	–624.50	—	920.80

Source: Verma, 1989b.

Table 5.3: Cash flow projection of beekeeping enterprise with Indian honeybee *Apis cerana* in Himachal Pradesh, India, 1987

Item	Years 1	2	3	4	5	6	7	8	9	10
A. CASH OUTFLOWS										
i) Bees*	50	50	50	—	—	—	—	—	—	—
ii) Villager's hive**	300	300	300	300	300	—	—	—	—	—
iii) Hive stand	50	50	50	50	50	—	—	—	—	—
iv) Bee veil	25	—	—	25	—	—	25	—	—	25
v) Hive tool	15	—	—	—	—	—	—	—	—	—
vi) Smoker	30	—	—	—	—	30	—	—	—	—
vii) Honey extractor	300	—	—	—	—	300	—	—	—	—
viii) Uncapping tray and knife	250	—	—	—	—	250	—	—	—	—
ix) Comb foundation sheet	80	160	240	320	400	400	400	400	400	400
x) Sugar (10 kg @ Rs.8/- per kg)	80	160	240	320	400	400	400	400	400	400
xi) Hessian cloth	16	32	48	64	80	80	80	80	80	80
xii) Acaricide	2	4	6	8	10	10	10	10	10	10
Total:	1198	756	934	1087	1240	1470	915	890	890	915

B. CASH INFLOWS										
i) Honey (8 kg per hive @ Rs.60/per kg)	960	1920	2880	3840	4800	4800	4800	4800	4800	4800
ii) Bees wax (0.30 kg @ Rs.75/- per kg)	22	45	68	90	113	113	113	113	113	113
Total:	982	1965	2948	3930	4913	4913	4913	4913	4913	4913
C. Net cash flow (B–A)	–216	1209	2014	2843	3673	3443	3998	4023	4023	3998
D. Cumulative cash flow	–216	993	3007	5850	9523	12966	16964	20987	25010	29008

* Two bee hives to be added up to three years and then those multiply on their own.

* 10 hives per household is an ideal size and these be raised over five years by increasing two hives each year.

Note: All costs and returns are calculated at constant price and constant honey yield per colony.
For details see Table 5.1.

Table 5.4: Ten years cash flow projection of honey production from European honeybee *Apis mellifera* in Himachal Pradesh, 1987

Item	Years									
	1	2	3	4	5	6	7	8	9	10
A. CASH OUTFLOWS										
i) Bees	400	400	400	—	—	—	—	—	—	—
ii) Langstroth hive	654	654	654	654	654	—	—	—	—	—
iii) Hive stand	50	50	50	50	50	—	—	—	—	—
iv) Bee veil	25	—	—	25	—	—	25	—	—	25
v) Hive tool	15	—	—	—	—	—	—	—	—	—
vi) Smoker	30	—	—	—	—	30	—	—	—	—
vii) Honey extractor	750	—	—	—	—	750	—	—	—	—
viii) Uncapping tray and knife	250	—	—	—	—	250	—	—	—	—
ix) Comb foundation sheet	150	300	450	600	750	750	750	750	750	750
x) Sugar (10 kg @ Rs.8/- per kg)	160	320	480	640	800	800	800	800	800	800
xi) Hessian cloth	16	32	48	64	80	80	80	80	80	80
xii) Acaricide	2	4	6	8	10	10	10	10	10	10
Total	2502	1760	2088	2041	2344	2670	1665	1640	1640	1665

B. CASH INFLOWS										
i) Honey (20 kg/colony @ Rs.60/per kg)	2400	4800	7200	9600	12000	12000	12000	12000	12000	12000
ii) Bees wax (0.5 kg) (1 kg per two colonies Rs.75/- per kg)	75	150	225	300	375	375	375	375	375	375
Total:	2475	4950	7425	9900	12375	12375	12375	12375	12375	12375
C. Net cash flow (II–I)	**–27**	3190	5337	7859	10031	9705	10710	10735	10735	10710
D. Cumulative cash flow	**–27**	3163	8500	16359	26390	36095	46805	57540	68275	78985

Note: The cash inflows and outflows are calculated at constant price and constant honey yield per colony. For details see Table 5.2.

etc. @ to 50 per cent to Scheduled Castes, Scheduled Tribes, Backward Classes and farmers covered under the Integrated Rural Development Programme. After taking into account the subsidy element, the cash flow would further improve. Similarly, subsidies at lower rates, i.e. 25 and 33 per cent, respectively are also provided by the government to small and marginal farmers.

Sensitivity analysis has been undertaken by reducing the returns by 50 per cent and maintaining the cost at the same level. The details regarding cost and returns for *Apis cerana* are given in Table 5.5 and *Apis mellifera* Table 5.6. It may be seen from Table 5.5 that by reducing the income by 50 per cent, the activity will incur a loss during first year of operation which will be recouped in the subsequent two years of operation which will be recouped in the subsequent two years of operation in the case of beekeeping with *Apis cerana*. In the case of *Apis mellifera*. However, after reducing the income by 50 per cent, the activity still generates a profit as the loss incurred in the first year of operation is recovered in the subsequent two years of beekeeping. Beekeeping with *Apis cerana* will generate profits from the third to the tenth year.

Table 5.5: Costs and returns of honey production in Himachal Pradesh, for beekeeping with *Apis cerana*

Sensitivity Analysis

Years	Total[1] costs	Total[2] returns	Total returns	Net[3] returns
1	1198	982	−216	−707
2	756	1965	1209	227
3	934	2948	2014	540
4	1087	3930	2843	878
5	1240	4913	3673	1217
6	1470	4913	3443	987
7	915	4913	3998	1542
8	890	4913	4023	1567
9	890	4913	4023	1567
10	915	4913	3998	1542

1. Includes both fixed and variable costs. For details see Tables 5.1 and 5.3
2. For details see Tables 5.1 and 5.3
3. A shortfall of 50 per cent assumed in the total returns.

Table 5.6: Costs and returns of honey and beeswax production in Himachal Pradesh for beekeeping with *Apis mellifera*
Sensitivity Analysis

Years	Total[1] Costs	Total[2] returns	Total returns	Net[3] returns
1	2502	2475	–27	–1264.5
2	1760	4950	3190	715
3	2088	7425	5337	1624.5
4	2041	9900	7859	2909
5	2344	12375	10031	3843.5
6	2670	12375	9705	3517.5
7	1665	12375	10710	4522.5
8	1640	12375	10735	4547.5
9	1640	12375	10735	4547.5
10	1665	12375	10710	4522.5

1. Includes both fixed and variable costs. For details see Tables 5.2 and 5.4
2. For details see Tables 5.2 and 5.4
3. A shortfall of 50 per cent assumed in total returns.

5.3 NEPAL

The rural people of Nepal have exploited honeybees for honey since time immemorial, and beekeeping is traditionally linked with crop farming and animal husbandry. Beekeeping with *Apis cerana*, in Nepal, is still a traditional household activity and accounts for an average honey yield of 5 to 6 kg per colony per year. However, some progressive beekeepers can obtain higher honey yields of 25 kg per colony from the native hive bee, *Apis cerana*. Other species of wild honeybees, *Apis dorsata/laboriosa* and *Apis florea*, are eratic honey yielders and have provided honey to the people living near the forest areas.

When the Terai and inner Terai were densely forested, *Apis dorsata* honey was a big source of forest revenue. Even today, forest dwellers hunt for its honey and sell it in the nearby rural markets. A professional hunter manages to collect up to 30 kg of honey per colony per year.

Two distinct races of the native, *Apis cerana*, i.e., yellow and dark ones, are found in Nepal. This species is kept and managed traditionally around human settlements, and honey is drawn by squeezing the combs. Attempts to introduce a few colonies of the European honeybee, *Apis mellifera*, have not been successful so far. Traditionally, *Apis cer-*

ana is kept in *Khope* hives (wall hives) or in mud hives. Attempts have also been made, through a UNICEF project, to introduce the popular Kenyan top bar hive for beekeeping with *Apis cerana* but with little success. Different types of movable frame hives modified from Newton B models of Indian make are now in common use (Kafle, 1990). Many of the modern hives in use are of poor quality and highly priced (Ham, 1990).

Various cultivated as well as wild plants provide mixed types of bee forage which vary in different agro-climatic belts of the country. In the Kathmandu valley alone, 180 plant species have been identified as pollen and nectar sources. Migratory beekeeping between the Terai and the mountain areas of the Kingdom can yield good results. Sacbrood virus disease killed more than 90 per cent of the colonies of *Apis cerana* in Nepal in 1983. However, this disease had a four-year cycle and since then the normal population of this native hive bee has been getting restored.

In Nepal, honey is in great demand and the price is about US$ 7 per kg. For the establishment of beekeeping on sound, scientific lines, there is a need to distribute properly designed bee hives to beginners, initiate training programmes and adopt management practices appropriate to beekeeping with native *Apis cerana*. In the past, many projects on beekeeping development were undertaken with varying success. The biggest one at present is the Beekeeping Training and Extension Support Project (BETRESP) being run by the Ministry of Agriculture, Nepal, in cooperation with Netherlands Development Organization (SNV-Nepal). The total cost of the project is US$ 862,100. This project is being run in 10 selected districts of the Kingdom. Under this programme, about 1,700 modern bee hives have been distributed to the farmers and honey production in the project area has been estimated as 28 MT. In the next five year plan, government of Nepal plans to distribute 4,000 additional bee hives of *Apis cerana* and raise honey production to 40 MT in project area. (K.K. Shrestha, personal communication).

The estimation of costs and returns from beekeeping with *Apis cerana* in Nepal are based on the information provided by Himalayan Bee Concern, a private beekeeping enterprise, and the HMG and SNV Beekeeping Training and Extension Support Project. These estimates are based on 1988 prices (Rathore and Verma, 1990). The annual installation and operational cost of one colony of *Apis cerana* kept in a movable frame Indian "Newton type hive" is 655 NER (Nepalese rupees) out of which Rs.430 is fixed cost and 225 is variable cost. An *Apis cerana* colony generates a net profit of Rs.1,795 in the first year of its operation (Table 5.7). Cash flow projections for estimates indicate that the enterprise will make a profit even during the first year

Table 5.7: Economics of beekeeping with Asian hive bee *Apis cerana* in Nepal, 1988

	Items	Cost (Rs.)	Life (years)	Cost/year/* colony (Rs.)
I.	COSTS			
A.	*Fixed cost:*			
	Bees	500.00	10	50.00
	Bee veil	75.00	3	25.00
	Hive tool	50.00	10	5.00
	Smoker	50.00	5	10.00
	Honey extractor	1000.00	5	200.00
	Uncapping tray/ knife	200.00	5	40.00
	Village hive	1000.00	10	100.00
	Sub-total:	2875.00	—	430.70
B.	*Variable cost:*			
	Comb foundation sheet	150.00	1	150.00
	Hessian cloth	10.00	1	10.00
	Sugar (6 kg 10/- per kg.)	60.00	1	60.00
	Acaricide and other drugs	5.00	1	5.00
	Sub-total:	225.00	—	225.00
	Total cost (A+ B)	3100.00	—	655.70
II.	RETURNS			
	Honey (8 kg @ Rs.300/kg)	—	—	2400.00
	Beeswax (0.5 kg @ Rs.100/kg)	—	—	50.00
	Gross income:	—	—	2450.00
III.	NET RETURNS (II–I) (Gross Income – Total Cost)	—	—	1795.00

Source: Himal Bee Concern, Kirtipur, Kathmandu.

* One U. S. Dollar = 29 Nepalese Rupees.

Table 5.8: Ten years cash flow projection for beekeeping enterprise with Asian hive bee *Apis cerana* in Nepal, 1988

Item	Years									
	1	2	3	4	5	6	7	8	9	10
A. CASH OUTFLOWS										
i) Bees	1000	1000	—	—	—	—	—	—	—	—
ii) Villager's hive	2000	2000	2000	2000	2000	—	—	—	—	—
iii) Bee veil	75	—	—	75	—	—	75	—	—	75
iv) Hive tool	50	—	—	—	—	—	—	—	—	—
v) Smoker	50	—	—	—	—	50	—	—	—	—
vi) Honey extractor	1000	—	—	—	—	1000	—	—	—	—
vii) Uncapping tray/knife	200	—	—	—	—	200	—	—	—	—
viii) Comb foundation sheet	300	600	900	1200	1500	1500	1500	1500	1500	1500
ix) Sugar	120	240	360	480	600	600	600	600	600	600
x) Hessian cloth	20	40	60	80	100	100	100	100	100	
xi) Acaricide	10	20	30	40	50	50	50	50	50	50
Total:	4825	3900	3350	3875	4250	3500	2325	2250	2250	2325

B. CASH INFLOWS										
i) Honey (8 kg/ colony @ Rs.300/ per kg)	4800	9600	14400	19200	24000	24000	24000	24000	24000	24000
ii) Bees wax (0.5 kg) at the rate of Rs.100/kg	50	100	150	200	250	250	250	250	250	250
Total:	4850	9700	14550	19400	24250	24250	24250	24250	24250	24250
C. NET CASH FLOW (B—A)	25	5800	11200	15525	20000	20750	21925	22000	22000	21925
D. Cumulative cash flow	25	5825	17025	32550	52550	73300	95225	117225	139225	161150

Note: All costs and returns are calculated at constant price and constant yield per colony. For details see Table 5.7.

of operation, and that the accumulative profit during a period of one decade would be over 1,61,150 NER (Table 5.8). Sensitivity analysis results suggest that the activity would a incur a loss only during the first year of operation (Table 5.9).

5.4 BANGLADESH

There are at present three species of honeybees in Bangladesh: *Apis dorsata*, *Apis cerana* and *Apis florea*. The Sunderban forests are the major natural habitat of *Apis dorsata* and the annual honey yield per colony may by up to 50 kg. *Apis dorsata* is found in other parts of the country also. The little or dwarf bee, *Apis florea*, yields only 1–3 kg of honey per annum but is of great economic value as pollinator of agricultural crops.

Apis cerana, the domesticated hive bee is native to Bangladesh and is akin in its biometric characters and body size, to *Apis cerana indica* found in southern India (Svensson, 1988). The average honey yield from *Apis cerana* varies from 4 to 10 kg per colony but there are reports that maximum yields up to 20 kg can be harvested. Such variations in yield offer great potential for the improvement of this native bee species through selective breeding and appropriate management technology (Dewan, 1987).

There are at present about 8,000 part-time and full-time beekeepers in Bangladesh maintaining about 10,000 *Apis cerana* colonies. In potential beekeeping areas, it is possible to keep as many as 10 colonies per square kilometre (Kevan, 1983). Beeswax is generally not harvested. All honey extraction is done by a small hand-turned extractor manufactured by the Bangladesh Institute of Apiculture (BIA). Honey quality in Bangladesh is generally very poor because of its high moisture content (25 to 40 per cent). However, there is a considerable possibility to reduce such a high moisture content by harvesting fully ripened honey in a scientific way. Beekeeping equipment and supplies and technical know-how is available through Bangladesh Small and Cottage Industries Corporation (BSCIC) and other national and international agencies such as Canadian University Service Overseas (CUSO), Bangladesh Institute of Apiculture (BIA) and Proshika Mano Unnayan Kendra (PROSHIKA) also.

Apart from many pests and predators, important bee diseases are Thai sacbrood, varroa mite and European foul brood. Frequent swarming, absconding, robbing and lack of facilities for mass queen rearing are other problems in beekeeping with *Apis cerana* in Bangladesh (Nash and Murell, 1981).

In Bangladesh, the vegetation is diverse and well-suited for bee forage. Most of the good pollen and nectar sources are litchi, jack fruit, lemon, *Acacia, Albizia*, coconut, drumstick, black berry, mango, *Eucalyptus*, Papaya, guava, etc. A variety of weeds such as Senecio, Bhait, brangals, *Leucus lavendifolia* are used by bees for pollen and nectar.

According to Svenssen (1988), a new design of beekeeping technology and a new management system based on the socio-economic and ecological conditions of Bangladesh, promise more hope for the several of poor and landless people in the country.

In Bangladesh, the economics of beekeeping with a low-cost traditional bar hive (TBH) and a movable frame Indian "Newton hive" have been compared. The estimation of the costs and returns for a traditional top bar hive is based on the data provided by Svensson (1988) and cost and return estimates for beekeeping by using a modern "Newton hive" by Mohamed (1984) and FAO report (1986). The costs and returns per colony of *Apis cerana* kept in "traditional top bar hives" and "Newton hives" are given in Tables 5.10 and 5.11, respectively.

These results reveal that the annual cost for the installation and operation of one top bar traditional hive and Newton hive has been estimated as Takka 110 and 282, respectively. An *Apis cerana* colony generates a net profit of Takka 370 per year from the top bar hives and Takka 483 from the Newton hives. The estimation of cash flow projections of honey and beeswax production during the first year of operation, there is a profit of Takka 760 by using top bar hives and a loss of Takka 1,216 with Newton hives. Subsequently, there will be profits made from both designs. The accumulated cash flow during the period of one decade has been estimated at over 34,040 and 42,069 Takka by using top bar hives and Newton hives, respectively. The loss incurred in the first year will be recouped in the following two years of operation with a profit of Rs.2,439 with Newton hives. With the traditional bark hive, there is a profit of Rs.760 even during the first year of operation (Tables 5.12. and 5.13).

Details of a sensitivity analysis have been given in Tables 5.14 and 5.15. By reducing the income by 50 per cent, the activity will incur a loss during the first two years with the use of Newton hives. In the case of the top bar hive, their is no loss.

5.5 PAKISTAN

Beekeeping is practised on a small scale, throughout Pakistan, except in the desert areas. Apart from a few progressive beekeepers who are familiar with modern technology, traditional methods of beekeeping are widely used. Therefore, in comparison to the developed countries, honey yield per colony is quite low.

Honey bee and insect pollinator populations in Pakistan are among the lowest in the world. As a result of this, yields of certain fruits,

Table 5.9: Costs and returns of honey and beeswax production in Nepal for beekeeping with *Apis cerana*

Sensitivity Analysis

Years	Total[1] costs	Total[2] returns	Total returns	Net[3] returns
1	4825	4850	25	−2400
2	3900	9700	5800	950
3	3350	14550	11200	3925
4	3875	19400	15525	5825
5	4250	24250	20000	7875
6	3500	24250	20750	8625
7	2325	24250	21925	9800
8	2250	24250	22000	9875
9	2250	24250	22000	9875
10	2325	24250	21925	9800

1. Includes both fixed and variable costs. For details see Tables 5.7 and 5.8
2. For details see Tables 5.7 and 5.8
3. A shortfall of 50 per cent assumed in total returns.

Table 5.10: Economics of beekeeping in Bangladesh* by using traditional top bar hive, 1988

	Items		Amount (Taka) per Colony (Taka 33 = US$ 1) 1988
I.	*EXPENDITURE*		
	Bee box		20.00
	Bees		20.00
	Extractor/Filter cloth		20.00
	Sugar		50.00
		Total Cost (T):	*110.00*
II.	*INCOME*		
	Honey		400.00
	Bees wax		80.00
		Total Income (T):	*480.00*
III.	*NET RETURN* per colony (II−I) = 480−110 =		370.00 T

* Table drawn from Borje Svensson, 1988. "Beekeeping Technology in Bangladesh—A Description of Past and Present Situation with Suggested Modifications", pp. 31–32.

Table 5.11: Beekeeping with *Apis cerana* in Bangladesh by using modern Newton hive, 1986

Items	Price (TK.)	Life (Years)	Cost/year/ Colony (TK.)
I. COSTS			
A. *Fixed cost:*			
Bees	100.00	10	10.00
Bee box	350.00	10	35.00
Queen gate	20.00	2	10.00
Queen excluder	150.00	5	30.00
Veil	150.00	3	5.00
Knife	20.00	2	2.00
Honey extractor	1000.00	5	20.00
Foundation	15.00	1	15.00
Contingencies	77.00	1	77.00
Labour	78.00	1	78.00
A. Total cost:	1960.00	—	282.00
B. RETURNS			
Items	Value (TK/kg)	Amount (kg)	Return/year/ (TK.)
Honey	50.00	15	750.00
Bees wax	60.00	0.25	15.00
Total returns:	110.00	—	765.00
Net return per colony (A–B)	1850.00	—	483.00

Source: FAO Agricultural Services Bulletin No. 68, 1986.

vegetables, fodders, and oilseed crops are adversely affected. All four species of the genus *Apis* are found in Pakistan. There are at present 14,000 colonies of the European bee, *Apis mellifera*, maintained in modern hives by progressive beekeepers. The number of native, *Apis cerana* and *Apis dorsata* colonies, may be between 40,000 to 55,000 and 65,000 to 75,000, respectively. *Apis cerana* colonies are usually kept in traditional hives. The major honey plants are cultivated crops and forest vegetation. Among them, *Brassica* spp., *Helianthus* spp., *Medicago* spp., *Panicum.*, spp., *Sorghum* spp., *Acacia* spp., *Albizia* spp., *Fraxinus* spp., *Eucalyptus* spp., *Plectranthus* spp., and *Dalbergia* spp., are the most important honey resources. At present, the bee flora in Pakistan can support 0.5 to 0.6 million colonies and produce 8,000–10,000 MT

Table 5.12: Ten years cash flow projection of honey production from Asian honeybee *Apis cerana* in Bangladesh using traditional top bar hive

Item	Years									
	1	2	3	4	5	6	7	8	9	10
A. CASH OUTFLOWS										
i) Bees	40	40	40	—	—	—	—	—	—	—
ii) Villager's hive	40	40	40	40	40	—	—	—	—	—
iii) Honey extractor/ filter cloth	20	—	—	—	—	20	—	—	—	—
iv) Comb foundation sheet										
v) Sugar	100	200	300	400	500	500	500	500	500	500
vi) Hessian cloth										
vii) Acaricide										
A. Total:	200	280	380	440	540	520	500	500	500	500

B.	CASH INFLOWS										
i)	Honey (8 kg/ colony @ TK.50/ per kg)	-800	1600	2400	3200	4000	4000	4000	4000	4000	4000
ii)	Bees wax (0.5 kg) (1 kg per two colonies TK.75/- per kg)	160	320	480	640	800	800	800	800	800	800
	Total:	960	1920	2880	3840	4800	4800	4800	4800	4800	4800
C.	NET CASH FLOW (B—A)	760	1640	2500	3400	4260	4280	4300	4300	4300	4300
	Cumulative cash flow	760	2400	4900	8300	12560	16840	21140	25440	29740	34040

Note: All costs and returns are calculated at constant price and constant yield per colony. For details see Table 5.10.

Table 5.13: Ten years cash flow projection of production from *Apis cerana* Bangladesh by using Newton hive, 1986

		Years									
	Item	1	2	3	4	5	6	7	8	9	10
A.	CASH OUT FLOWS										
i)	Bees	200	200	200	—	—	—	—	—	—	—
ii)	Bee box	700	700	700	700	700	—	—	—	—	—
iii)	Queen excluder	300	300	300	300	300	300	300	300	300	300
iv)	Knife	20	20	20	20	20	20	20	20	20	20
v)	Queen gate	40	40	80	80	120	80	120	80	120	80
vi)	Veil	150	—	—	150	—	—	150	—	—	150
vii)	Honey extractor	1000	—	—	—	—	1000	—	—	—	—
viii)	Comb foundation sheet	30	60	90	120	150	150	150	150	150	150
ix)	Contingencies	306	551	734	857	918	765	765	765	765	765
	Total:	–2746	–1871	–2124	+2227	+2208	+2315	+1505	+1315	+1355	+1465

B.	CASH INFLOWS										
i)	Honey (15 kg/ colony @ TK.50/ per kg)	1500	3000	4500	6000	7500	7500	7500	7500	7500	7500
ii)	Bees wax (0.5 kg) (1 kg per two colonies TK.75/- per kg)	30	60	90	120	150	150	150	150	150	150
	Total:	1530	3060	4590	6120	7650	7650	7650	7650	7650	7650
C.	NET CASH FLOW (B–A)	–1216	1189	2466	3893	5442	5335	6145	6335	6295	6185
D.	Cumulative cash flow	–1216	–27	2439	6332	11744	17109	23254	29589	35884	42069

Note: All costs and returns are calculated at constant price and constant yield per colony. For details see Table 5.11.

Table 5.14: Costs and returns of honey production from beekeeping with *Apis cerana* in Bangladesh using traditional top bar hive
Sensitivity Analysis

Years	Total[1] costs	Total[2] returns	Total returns	Net[3] returns
1	200	960	760	280
2	280	1920	1640	680
3	380	2880	2500	1060
4	440	3840	3400	1480
5	540	4800	4260	1860
6	520	4800	4280	1880
7	500	4800	4300	1900
8	500	4800	4300	1900
9	500	4800	4300	1900
10	500	4800	4300	1900

1. It includes both fixed and variable costs. For details see Tables 5.10 and 5.12.
2. For details see Tables 5.10 and 5.12.
3. A shortfall of 50 per cent assumed in total returns.

Table 5.15: Costs and returns of honey production from beekeeping with *Apis cerana* in Bangladesh by using Newton hive
Sensitivity Analysis

Years	Total[1] costs	Total[2] returns	Total returns	Net[3] returns
1	2746	1530	–1216	–1981
2	1871	3060	1189	–341
3	2124	4590	2466	171
4	2227	6120	3893	833
5	2208	7650	5442	1617
6	2315	7650	5335	1510
7	1505	7650	6145	2320
8	1315	7650	6335	2510
9	1355	7650	6295	2470
10	1465	7650	6185	2360

1. It includes both fixed and variable costs. For details see Tables 5.11 and 5.13.
2. For details see Tables 5.11 and 5.13.
3. A shortfall of 50 per cent assumed in total returns.

of honey per annum. such an expansion in the beekeeping industry can provide gainful employment for an additional 30 to 40 thousand persons. Since bee flora is not available throughout the year, in any region, migratory beekeeping between the lowland and highland areas is being practised with rewarding results (Ahmad, 1990). There are 12 different types of modern and traditional bee hives in use in Pakistan. Some low-cost hives, developed for beekeeping in remote areas, would popularize beekeeping with *Apis mellifera* among those who cannot afford to buy expensive equipment (Muzzafor, 1990). Wax moths, hornets, and mites are the serious pests, predators, and parasites that affect bee colonies in Pakistan. Sacbrood virus disease is a serious problem affecting *Apis cerana* colonies. Studies on the economics of beekeeping suggest that it is a reasonable profit-earning activity in Pakistan, both for part-time as well as full-time beekeepers. The current annual honey production for all different species of honeybees in Pakistan is about 640 MT. The wholesale price of honey at the producer and intermediary levels is 40 to 50 and 60 to 80 rupees per kilogramme, respectively. Honey in small cases and bottles is sold at the rate of 80–140 per kilogramme in city markets.

The North West Frontier Province (NWEP) of Pakistan is very suitable for beekeeping on account of its different ecological zones containing rich bee flora. It has 8.33 million hectares of land of which about 2 million hectares are cultivated. This province has the potential to produce 35 MT of honey per annum against the present low production of 2 MT only.

There are special "bee dens" full of *Apis cerana* colonies, in some specific valleys of the NWFP, where the practice of honey hunting and the collection of wild bee swarms of *Apis cerana* are very popular among the mountain farmers (Khan, 1990). Almost 85 per cent of *Apis cerana* colonies in NWFP were destroyed during 1981–82 due to acarine disease which was introduced from the *Apis mellifera* / *Apis cerana* colonies brought in by Afghan beekeepers. Now the exotic, *Apis mellifera*, is also becoming more popular among the beekeepers of this province, and this species is gradually replacing the native, *Apis cerana*. Afghan refugees brought with them hundreds of *Apis mellifera* colonies of Russian origin, and these have now multiplied into thousand over the past eight to nine years. The United Nations High Commission for Refugees also imported hundreds of *Apis mellifera* colonies from Australia for the Afghan refugees. Therefore, the NWFP now has *Apis mellifera* from Russia, Australia and Europe (Shahid, 1990).

The estimation of costs and returns for beekeeping with *Apis mellifera* for part-time beekeepers having five and 80 colonies and for full-time beekeepers operating 250 and 500 bee colonies have been worked out by Ahmad (1986, 1988). According to these estimates, only five

Table 5.16: Economics of beekeeping with *Apis mellifera* in Pakistan 1988* (Part-time beekeepers with five colonies in Langstroth hive, 1988)

Item	Amount (Pak. Rs.)**
I. CAPITAL EXPENDITURE	
Packages bees @ Rs.600 per 1/2 kg	60
Hives (wooden) @ Rs.500 each	50
Honey extractor	–
Nucleus hives each @ Rs.100	10
Comb foundation sheets @ Rs.50 kg.	100
Misc. tools	20
Total fixed cost:	240
II. VARIABLE COST	
Supplement feeding 15 kg per colony @ Rs.9/- per kg	135
Misc. expenses	20
Total variable cost:	155
III. TOTAL COST (I+II) =	395
IV. GROSS INCOME	
Honey 18 kg per colony @ Rs.50/- per kg.	900
Bees wax 1/4 kg per hive @ Rs.30/- per kg.	7.4
Total income	907.40
V. NET RETURN	
Return over variable cost = (IV–II) =	752.40
Return over total cost = (IV–III) =	512.40

* Table drawn from article by Ahmad, R. (1988).

** One U.S. Dollar = 20 Pakistan Rupees

colonies of *Apis mellifera* can be maintained at one place throughout the year, and in order to procure surplus honey yields from 80, 250 and 500 colonies of *Apis mellifera* they need to be migrated between the mountains and the plains to exploit fully the floral resources of the country. (Table 5.17). Since a wooden Langstroth hive is too expensive for the poor farmer, Pakistan Agricultural Research Council (PARC), Islamabad, has introduced low-cost hives made of cheaper material, such as hives made of cement movable frame, clay and chopped wheat straw "Multani mitti" (special clay), clay and rice husk. These low-cost hives have the dimensions of a Langstroth hive.

The costs and returns per colony of *Apis mellifera* kept in standard Langstroth hives and low-cost hives are given in Tables 5.16 and 5.18, respectively. These estimates reveal that the annual cost of installation and operation of one colony of *Apis mellifera* in a standard Langstroth hive and in a low-cost hive is Rs.395 and 319, respectively. Out of these total expenditure, the capital expenditure for operating one colony of *Apis mellifera* in a standard Langstroth hive and in a low-cost hive is Rs.184 and 240 and the variable costs are Rs.155 and 135, respectively. A bee colony generates a net profit of Rs.512 and 289, respectively.

Cash flow projections of honey and beeswax production are given in Tables 5.19 and 5.20. The data in these tables indicate that during the first year of operation, the entrepreneur will incur a loss of Rs.1,295 and 735 by using a Langstroth hive and a low-cost hive, respectively. Subsequently, he will earn profit during the using both types of bee hives. The accumulated profit during the period of 10 years has been estimated at over Rs.42,000 and 25,000 with Langstroth and low-cost hives, respectively. The loss incurred in the first year will be recovered in the following two years with both kinds of hives and there will be a profit of Rs.430 each with Langstroth and low-cost hives. Sensitivity analysis results suggest that by reducing the income by 50 per cent, the activity will incur losses during the first three years of operation and generate profit from four to 10 years (Tables 5.21 and 5.22).

Table 5.17 reveals that a beekeeper operating 80, 250, 500 colonies of *Apis mellifera* in standard Langstroth hives will earn a net profit of 20,475, 54,600 and 131,700, respectively, during the first year and 32,275, 91,525 and 205,400 in the third year, respectively (Ahmad, 1986, 1988.).

5.6 CHINA

There are at present more than 7 million honeybee colonies kept in modern hives in China. Out of these, 70 per cent are the European *Apis mellifera* and others are the native *Apis cerana*. The annual honey production is over 200,000 MT per year, and the total royal jelly and bee pollen production is 800 and 1,000 MT per year; respectively. In addition, beeswax and propolis are two other important hive products harvested. About 30 to 40 per cent of the these hive products are exported and the rest are used for domestic consumption. About 90 per cent of honey and all the royal jelly in China is produced from *Apis mellifera*.

The Institute of Apicultural Sciences, of the Chinese Academy of Agricultural Sciences, is mainly responsible for beekeeping research

Table 5.17: Investment and income from bee

Item	Low cost hives/ stationary colonies	Langstroth hives: Part-time beekeeper		Langstroth hives: Full-time beekeeper	
No. of European bee colonies	5	5	80	250	500
Capital expenditure	Amount in rupees				
Package bee @ Rs.600 per 1.5 kg	3,000	3,000	48,000	150,000	300,000
hives each @ Rs.500 & low cost @ Rs.30	150	2,500	40,000	125,000	250,000
Transport (one Suzuki pick-up)	—	—	—	62,000	62,000
Comb foundation machine	—	—	—	12,000	12,000
Honey extractor	—	—	6,000	7,000	8,000
Nucleus wooden hives @ Rs.100 and low cost Rs.10	50	500	4,000	10,000	20,000
Pollen traps each @ Rs.200	—	—	2,000	4,000	8,000
Comb foundation sheets @ Rs.50 per kg	500	500	8,000	25,000	50,000
Misc. tools	200	200	500	1,000	2,000
Total:	3,900	6,700	108,500	396,000	712,000
Cost of production					
Raw material (pollen and nectar)	Free gift nature				
Migration of colonies	—	—	5,000	15,000	30,000
Supplemental feeding 15 kg per colony @ Rs.9 per kg	675	675	10,800	33,750	67,500
Depreciation (10%) on equipment	40	320	5,250	22,100	36,200
Interest (15%) on capital exp.	585	1,005	16,275	59,400	106,800
Rent of store	—	—	2,400	4,800	7,200
Rent of apiary site in the form of honey	—	—	600	1,500	3,000
Bee attendant Rs.800 per month	—	—	9,600	28,800	57,600
Misc. expenses	—	100	1,600	5,000	10,000
Total:	1,300	2,100	51,525	170,350	318,300

keeping with *Apis mellifera* in Pakistan, 1988

Item	Low cost hives/ stationary colonies	Langstroth hives			
		Part-time beekeeper		Full-time beekeeper	
No. of European bee colonies	5	5	80	250	500
Capital expenditure		Amount in rupees			
Gross income					
Honey 12 kg in low cost @ 18 kg per wooden hive Rs.50 per kg	3,000	4,500	72,000	225,000	450,000
Royal jelly 5 kg per 100 colonies @ Rs.1500 per kg	—	—	6,000	18,750	37,500
Wax 1/4 kg per hive @ Rs.30 per kg	37	37	600	1,875	3,750
Pollen 1/2 kg per colony @ Rs.50 per kg	—	—	2,000	6,250	12,500
Package bees 15 kg per 100 colonies @ Rs.400 per 1 1/2 kg	400	400	3,200	10,000	20,000
Total:	3,437	4,937	83,800	261,875	523,750
Net income					
Income will be only from honey production in the first year, honey and package bees in the second year and honey, royal jelly, wax, pollen, and package bees during third year and onwards.					
First year	1,700	2,400	20,475	54,600	131,700
Second year	2,100	2,800	23,675	64,650	151,700
Third year	2,137	2,837	32,275	91,525	205,450

Source: Ahmad, 1988.

and extension activities. There are more than 100,000 apiaries in China, each having 30 to 80 bee hives. Beekeeping *Apis cerana* is practised mainly in the mountain areas (Zhenming, 1990).

Table 5.18: Economics of beekeeping with *Apis mellifera* in Pakistan using low cost hives, 1988

COSTS

Items	Price (Rs.)	Life (Years)	Cost/year/ Colony (Rs.)
I. CAPITAL EXPENDITURE			
Package bees 1/2 kg	600	—	60.00
Low cost hive	30	10	3.00
Nucleus hive	10	10	1.00
Comb foundation sheets	50/kg	5	100.00
Misc. tools	200	10	20.00
Total fixed cost:	—	—	184.00
II. VARIABLE COST			
Supplement feeding 15 kg sugar @ Rs.9/- per kg.	135	—	135.00
Total variable cost:	—	—	135.00
III. TOTAL COST (I + II) = 184 + 135 =			319.00
IV. GROSS INCOME			
Honey 12 kg per colony @ Rs.50/- per kg			600.00
Bees wax 1/4 kg per hive @ Rs.30/- per kg			7.50
V. TOTAL INCOME			607.50
VI. NET RETURN			
Return over variable cost = IV−II =			472.50
Return over total cost = IV−III =			288.50

Source: Ahmad, 1988.

Royal jelly is one of the most important hive products for which production technology has been developed in China after 1959. In southern China, it ranges from 0.3 to 0.5 kg per colony a year. Experiments are also being conducted to produce royal jelly from *Apis* *cerana* colonies. However, this native bee species produces only half the quantity of royal jelly in comparison to *Apis mellifera*. Since royal jelly changes in chemical composition during storage, markets for selling fresh royal jelly are being established. Royal jelly is also being used as a raw material in medicines, tonics, beverages and cosmetic products.

Production of pollen, as a commercial hive product, started in 1983. It is collected in plastic pollen traps at the entrance of the bee hive. Pollen is used in health foods, tonics, and medicines. Venom production started in 1953 in China, and is now used to cure arthritis and cancer. Only European honeybees, *Apis mellifera* produce propolis and this is used for medicinal purposes. Propolis production technology is still in the development stage in China (Guanhuang, 1990).

China, which is 9.6 million sq km in area, contains mountains, rolling hills, great plateaux, huge basins and vast plains: and it spans the north temperate, temperate, subtropical and tropical zones. The nectar plants characteristic of an area depend on the geographical and climatic conditions. The most important nectar plants are: *Eurya* spp., *Eucalyptus* spp., litchi (*Litchi chinensis*), longan (*Euphoria longan*), loquat (*Eriobotrya japonica*), rape (*Brassica napus*). milk vetch (*Astragalus sinicus*). vetches (*vicia* spp., especially *Vicia villosa*). orange (*Citrus* spp.), Chinese tallow tree (*Sapium sebiferum*), jujube (*Ziziphus jujuba*), cotton (*Gossypium* spp.), false acacia (*Robinia pseudoacacia*) chaste tree (*Vitex negundo*), sweet clover (*Meliltus* spp.), alfalfa *Medicago sativa*) buckwheat (*Fagopyrum esculentum*), sunflower (*Helianthus annuus*) and linden (*Tilia* spp.),

Since the late fifties the government departments have organized beekeepers to undertake long-distance migration of colonies in a planned way, moving to the various nectar flows and thus utilizing these plants fully. At present, the subtropical and tropical zones are the main areas for multiplying colonies of the Western bee (in winter and spring) which are used in other regions for the production of honey and other bee products. In the mountain area, however, beekeeping with the native *Apis cerana* is still quite popular (Liu Xianshu, 1985). No information on the economics of beekeeping as worked out for other countries of the Hindu Kush-Himalayan region is available for China.

5.7 BHUTAN

In Bhutan the valleys, lower and high hills with moderate climates are the most suitable areas for beekeeping. Bhutan is rich in its bee resources and all four species of the genus *Apis* are found there. The European honeybee, *Apis mellifera*, was introduced in the Bhumthang and Puntsholing areas in 1986 and 1987, respectively. The native,

Table 5.19: Ten years cash flow projection of honey production from European honeybee *Apis mellifera* in Pakistan using Langstroth hives, 1988

Item	Years									
	1	2	3	4	5	6	7	8	9	10
A. CASH OUTFLOWS										
i) Bees	1200	1200	1200	—	—	—	—	—	—	—
ii) Langstroth hive	1000	1000	1000	1000	1000	—	—	—	—	—
iii) Nucleus hive	200	200	200	200	200	—	—	—	—	—
iv) Misc. tools	200	—	—	—	—	200	—	—	—	—
v) Comb foundation sheet	200	400	600	800	1000	1000	1000	1000	1000	1000
vi) Sugar (15 kg 9/- per kg) for two colony	270	540	810	1080	1350	1350	1350	1350	1350	1350
vii) Misc. expenses	40	80	120	160	200	200	200	200	200	200
Total:	3110	3420	3930	3240	3750	2750	2550	2550	2550	2550

B. CASH INFLOWS										
i) Honey (18 kg/ colony @ Rs. 50/ per kg)	1800	3600	5400	7200	9000	9000	9000	9000	9000	9000
ii) Bees wax (1/4 kg) (1/2 kg per two colonies Rs. 30/- per kg)	15	30	45	60	75	75	75	75	75	75
Total:	1815	3630	5445	7260	9075	9075	9075	9075	9075	9075
C. NET CASH FLOW (B–A)	–1295	210	1515	4020	5325	6325	6525	6525	6525	6525
D. Cumulative cash flow	–1295	–1085	430	4450	9775	16100	22625	27150	35675	42200

Note: All costs and returns are calculated at constant price and constant yield per colony. For details see Table 5.16.

Table 5.20: Ten years cash flow projection of honey production from European honeybee *Apis mellifera* in Pakistan using low cost hives, 1988

Item	Years 1	2	3	4	5	6	7	8	9	10
A. CASH OUTFLOWS										
i) Bees	1200	1200	1200	—	—	—	—	—	—	—
ii) Langstroth hive	60	60	60	60	60	—	—	—	—	—
iii) Nucleus hive	20	20	20	20	20	—	—	—	—	—
iv) Misc. tools	200	—	—	—	—	200	—	—	—	—
v) Comb foundation sheet	200	400	600	800	1000	1000	1000	1000	1000	1000
vi) Sugar (15 kg 9/- per kg) for two colony	270	540	810	1080	1350	1350	1350	1350	1350	1350
Total:	1950	2220	2690	1960	2430	2550	2350	2350	2350	2350

B. CASH INFLOWS										
i) Honey (12 kg/ colony @ Rs. 50/ per kg)	1200	2400	3600	4800	6000	6000	6000	6000	6000	6000
ii) Bees wax (0.5 kg) (1 kg per two colonies Rs. 75/- per kg)	15	30	45	60	75	75	75	75	75	75
Total:	1215	2430	3645	4860	6075	6075	6075	6075	6075	6075
C. NET CASH FLOW (B–A)	–735	210	955	2900	3645	3525	3725	3725	3725	3725
D. Cumulative cash flow	–735	–525	430	3330	6975	10500	14225	17950	21675	25400

Note: All costs and returns are calculated at constant price and constant yield per colony. For details see Table 5.18.

Table 5.21: Costs and returns of honey and beeswax production from *Apis mellifera* in Pakistan by using Langstroth hives
Sensitivity Analysis

Years	Total[1] costs	Total[2] returns	Total returns	Net[3] returns
1	3110	1815	−1295	−2202.5
2	3420	3630	210	−1605
3	3930	5445	1515	−1207.5
4	3240	7260	4020	390
5	3750	9075	5325	787.5
6	2750	9075	6325	1787.5
7	2550	9075	6525	1987.5
8	2550	9075	6525	1987.5
9	2550	9075	6525	1987.5
10	2550	9075	6525	1987.5

1. Includes both fixed and variable costs. For details see Tables 5.16 and 5.19.
2. For details see Tables 5.16 and 5.19.
3. A shortfall of 50 per cent assumed in total returns.

Table 5.22: Costs and returns of honey and beeswax production from *Apis mellifera* in Pakistan by using low cost hives
Sensitivity Analysis

Years	Total[1] costs	Total[2] returns	Total returns	Net[3] returns
1	1950	−1815	−735	−1342.5
2	2220	2430	210	−1005
3	2690	3645	955	−867.5
4	1960	4860	2900	470
5	2430	6075	3645	607.5
6	2550	6075	3645	487.5
7	2350	6075	3525	687.5
8	2350	6075	3725	687.5
9	2350	6075	3725	687.5
10	2350	6075	3725	687.5

1. Includes both fixed and variable costs. For details see Tables 5.18 and 5.20.
2. For details see Tables 5.18 and 5.20.
3. A shortfall of 50 per cent assumed in total returns.

Apis cerana, is generally kept in primitive traditional hives by the farmers in southern Bhutan. In the northern parts of Bhutan, there is no beekeeping tradition, because harvesting honey from the nests of honeybees is considered a sin. However, such religious beliefs are changing gradually.

Major honey flow seasons in Bhutan are April-May and October-November. the annual average honey yield from *Apis mellifera* is 3 and 30 kg per colony respectively. Beeswax is the property of the Forestry Department. Traditional log hives are made from oakwood, and modern bee hives are made of blue pine wood. *Acarine* and *Tropilaelaps* mites as well as European foulbrood have been reported on *Apis mellifera*. Local people and tourists are the major consumers of honey which is sold at 50 Bhutanese Nu per kilogramme. There is no research and development programme in beekeeping. However, one Bhutanese national is receiving beekeeping training in Canada.

Apples, oranges, and cardamom are the major horticultural crops grown in Bhutan and occupy about 90 per cent of the total area under fruit crops. All these fruit crops require cross-pollination by honeybees for efficient and sufficient pollination. A conservative estimate of the number of hives needed exclusively for the pollination of horticultural crops, at present, is about 50,000, whereas the present number of bee colonies in modern hives is not more than 100.

Strategies for beekeeping development in Bhutan include exploration of bee genetic resources and zonation of beekeeping areas, survey of honey plant resources and preparation of floral calendars, management of bee colonies for pollination, migratory beekeeping schedules, establishment of extension-cum-demonstration apiaries, beekeeping training programmes. and assessment of the honey market situation (Verma, 1990b).

Introduction of modern beekeeping in Bhutan is very recent and no information on the economics of beekeeping is available. However, Bhutan is close to Nepal and Himachal Pradesh (northern India) is socio-economic and ecological conditions. Thus, it is reasonable to assume that the economics of beekeeping in Bhutan should not be very different.

5.8 BURMA

Large-scale importation of *Apis mellifera* into Burma was done under Food and Agriculture Organization (FAO) of the United Nations project after 1979. Prior of this, five colonies of *Apis mellifera* were imported from Australia and one of them was seriously affected with American foulbrood. Under the FAO project, 500 packages of the Italian bee *Apis mellifera ligustica* were introduced and by 1982, there were about 1,000 colonies of the European bee in this country (Morse 1982). Simultaneously, more than 50 persons from Burma received training in beekeeping with *Apis mellifera* in Ohio State University Agricultural Technical Institute at Wooster, Ohio in 1980 and 1981. Similarly, others were trained in beekeeping with *Apis mellifera* in other parts of the USA, Europe and Australia. Projects on beekeeping with *Apis mellifera* were started with the idea that by encouraging beekeeping they can convince at least some poppy growers that they can earn the same money or even more by adopting beekeeping. Besides FAO, the Drug Abuse Control Program of the U.S. State Department also financed the beekeeping training programme for Burmese nationals as a part of the strategy to check smuggling of illegal heroin into the world market from the "Golden Triangle" the area where Burma, Thailand and Laos join (Morse, 1982, Tew, 1980). According to Morse (1982), Burma has the potential to support about 10,000 colonies of *Apis mellifera*. The price of honey is about US$ 7.00 per kilogramme and besides helping in solving the serious problem of drug abuse, it can be an ideal alternate source of income to the farmers. Parasitic mites, ants, excessive temperatures and rainfall are some of the serious constraints for developing beekeeping with *Apis mellifera* in Burma.

5.9 CONCLUSIONS

Studies on the economics of beekeeping in Bangladesh show that beekeeping can be started with a very low investment and even the poorest farmer can go for it with the minimal support.

Economic estimates from Pakistan reveal that this enterprise can be taken up both at the household and commercial levels to generate substantially more profits and employment.

In Himachal Pradesh in India, this enterprise has a dual purpose of generating income and increasing horticultural output through pollination activities of honeybees. Native *Apis cerana* is being replaced with exotic *Apis mellifera* because the net profit doubles due to higher honey yield of the exotic bees. High profit from beekeeping with *Apis cerana* in Nepal is primarily because of the high price of honey in Nepal and not because of higher yield. If beekeeping with *Apis cerana* is managed at a commercial level, the profit may be quite high.

All these studies clearly show that beekeeping is a profitable enterprise and with great potential in the mountain areas where forage for the bees is available. Some other findings are as follows:

1) The initial investment in this enterprise is very low as compared to any other productive activity.

2) The returns are low with only one or two colonies but there is flexibility to increase up to a size of 10 colonies without much investment.

3) It can be taken up as a poverty-elevation programme with little support/subsidy in the initial years.

CHAPTER 6

Apicultural Practices

6.1 HONEY HUNTING

Honey collection from wild nests of *Apis laboriosa*/*Apis dorsata* is a very ancient art and still a common practice in the entire region of the Hindu Kush-Himalaya. Palaeolithic cave paintings in Spain, South Africa and India reveal that the art of honey hunting is 12,000 years old and one finds a lot of similarity between the ancient methods and those being used now by hill tribes in certain parts of Nepal and Tibet (Dams, 1978; Harnandez-Pacheco, 1924; Pager, 1973; Woodhouse, 1982; Gordon, 1960; Mathpal, 1978, 1984).

Honey hunting in China dates back to the Tsin-dynasty (265–419 AD). Harvesting of honey from nests of honeybees located in inaccessible steep mountain rocks was done by lowering the honey hunter down in a basket with the help of ropes so that he could reach as close to the bee nest as possible. At the time, it was the monopoly of ruling class in China to own the entire honey crop. In the thirteenth century, honey hunting was forbidden because a large number of deaths occurred due to the risky operation (Kelogg, 1967; Tang and Kelogg, 1963; and Svensson, 1977).

Breadbear (1986) reported Zamba, Wogmbra, Gaylegphug, Sarbhang, Bubja, Paro and Phuntsholing as major places of honey hunting operations in Bhutan. Surveys of these places revealed 20 to 32 nests of *Apis dorsata*/*Apis laboriosa* either inhabited by bees or in the form of empty damaged combs. These nests were generally located either on cliffs or in large forest trees especially myna trees, *Tetrameles nudiflora*, (Breadbear, 1986).

The two wild species of honey bees, *Apis laboriosa* and *Apis dorsata*, make their single comb nests in difficult mountain rock areas which are quite inaccessible to man. So it is only the very experienced, daring and knowledgeable persons, who have learnt the art of honey hunting from their ancestors, who can harvest honey from such colonies. Such honey-hunting methods involve killing the entire brood as well as large numbers of adult bees. As a result of this practice, and also due to mass deforestation, these two wild species of honeybees face the danger of extinction from the Hindu Kush-Himalaya.

In recent year, very interesting studies describing the methods of honey hunting as well as the socio-economic and religious factors involved in this practice have been reviewed by Strickland (1982) and Valli and Summers (1988). Harrer (1953) also described the honey hunting methods by the Nepalese in Tibet.

6.1.1 Honey-hunting Equipment

The equipment involved in honey hunting includes about a 50-metre-long bamboo-fibre ladder for descending to the site of the bee nest, a bamboo pole for cutting the nest comb, a bamboo basket for honey collection, a loose cap around the head and back of the honey hunter to save him from the attack of aggressive bees, two short sticks tied to a rope for lowering the brood comb, and wood and foliage cuttings to generate smoke to disorient and calm down the aggressive bees.

6.1.2 Honey-hunting Method

After performing certain religious rites considered necessary for the success of the honey-hunting operations, the leader of the honey-hunting team (usually an elderly villager with several years of honey-hunting experience) climbs to the top of the cliff, and from this point a bamboo ladder is suspended, after tightening it firmly to the trees at both the upper and lower ends. The leader descends the ladder. He holds a bamboo "reaching pole" about 3 cm long, to cut the honey comb. Another person somewhere between the cliff and the nest, manipulates the hanging ladder so that the honey hunter get as close to the bees nest as possible. At the base of the cliff, a fire is let to produce smoke which will calm down and disorient the bees from the nest. As a result of this, bees fly off and the golden comb becomes visible. A single comb nest of *Apis dorsata/laboriosa* consists of two parts, the portion attached to the cliff which is full of honey and is called the honey comb, and the lower crescent of the nest housing brood (the larvae and pupae), known as the brood comb. First the brood-containing part of the nest is removed. This is done by pushing two short sticks tied to a rope from the cliff, into this part of the comb, with the help of a bamboo pole. Once the brood comb-part has been separated from the honey comb, it is gently lowered with the help of the rope, and put into a basket for the extraction and processing of wax.

After the brood comb is separated, honey starts oozing out from the honey comb while it is still attached to the cliff, and several men gather at the base of cliff to get a taste of it. Finally, this part of the nest is broken off in parts with bamboo poles and the honey collection basket is swung to and fro guided to catch the honey chunks as they fall. When the basket is full, it is lowered to the ground, emptied and used again. Some wise and experienced honey hunters do not destroy the nest comb, completely leaving a part of it attached to the rock cliff for the next year's harvest. New combs would be built much faster on an old existing one. *Apis dorsata / laboriosa* are very quick in building new combs. This honey-hunting method involves teamwork and is a very risky task. A slight error on the part of the hunter could mean sure death.

Honey-hunting seasons in Nepal are Spring and Fall. According to Valli and Summers (1988) earlier honey hunters used to harvest as many as 600 combs per year. But now due to the decline in number of these wild nests of *Apis dorsata* and *Apis laboriosa,* the number has come down to 80 per year. In Nepal and also in other parts of the Hindu Kush-Himalaya, *Rhododendron anthopogon,* a species which grows near the tree line of the high altitude forest produces honey which is toxic to man and its consumption leads to cold sweats, vomiting and impaired vision (Valli and Summers, 1988). Honey hunters in Nepal through experience have come to know about it and they avoid taking such toxic honey. Its toxicity is tested by pouring a drop of the honey on the palm and if it tingles, then it may not be safe to eat. The scientific value of such a test is still a mystery.

Honey harvested by honey-hunting methods is distributed among the members of honey-hunting team in proportion to the risk and labour put in by each member. For example, the leader of the honey-hunting team gets the maximum share, this is followed by the mayor of the village who calculates each member's share. The next share goes to members who help in relaying the equipment, smoke the comb, and filter the honey. Besides, at the base of the cliff, other villagers are allowed to thrust out pots and pans to collect the "raining honey" from the comb because they also pay the tax to the Government which in turn permits honey hunting.

A part of the honey collected by honey hunters is used for family consumption and the remaining is bartered for grain, yoghurt, milk, chicken or even a day's work. In the year when a good amount of honey gets collected, it is sold in the village market at the rate of one U.S. Dollar per kilogramme.

The brood comb collected by the honey hunters is used for wax. First it is melted over a fire and then poured through bamboo strains into cold water and finally, it is shaped into bricks of two-and-a-half kilogrammes each. The beeswax is sold in Kathmandu market where it is used in the lost-wax process of casting bronze.

Keeping in view the great risk of life involved in honey hunting and also the declining number of *Apis dorsata / laboriosa* nests in the Hindu Kush-Himalayan region, the profession of honey hunting is now coming to an end.

6.2 TRADITIONAL BEEKEEPING

In different countries of the Hindu Kush-Himalaya, several different types of hives such as hollowed logs, wall recesses and boxes of various dimensions and designs are in use even today for beekeeping with *Apis cerana*. These traditional bee hives reflect the remnants of ancient bee knowledge and are the relics of honey-collection techniques being practised by mountain farmers through the centuries. Although these indigenous hives evolved under different beekeeping traditions and socio-economic conditions, they show remarkable similarities in shape and design. This may so because from the very early times, man attempted to keep bees as close to the natural conditions as was possible. Different types of traditional hives along with their advantages and disadvantages are discussed here.

6.2.1 Log Hive

The idea of using log hives originated when attempts were made by man to domesticate honeybees for harvesting honey. In India, the traditional log hives are used commonly at a higher altitude from about 2000 m above sea level (Kapil; 1971; Sharma, 1948; and Singh, 1962). In Burma, 30–35 cm long hollowed log hives are found in Kachin, Kaven and Keyer states. In Bhutan, traditional log hives are used in Gaylephung, Suri, Phuntsholing and Thimphu-Yusipang (Breadbear, 1986). Nepal has a long history of using log hives for beekeeping with *Apis cerana* and in recent years several attempts have been made to improve the design and dimensions of this traditional hive suited to the smaller body and colony size of *Apis cerana* (Kafle, 1990).

A traditional log hive is a simple structure without any frames, separate brood or super chamber. It is basically made by hollowing out a piece of tree trunk, closing both its sides and boring a small hole of suitable size along its length to serve as an entrance for the bees.

Among the most traditional log hives are horizontal and vertical log hives (Saubolle and Bachmann, 1979; Wadhi, 1961). The length of a hollowed horizontal log hive varies from 60 to 75 cm, and the entrance hole of 6 mm diameter or of pencil thickness is made in the middle of the log. The two open ends of the log are closed with a piece of tin or wooden plank or stone fixed with a mixture of cowdung and clay.

In these horizontal log hives, strips of old combs at two ends are fixed with melted wax or candle drippings. The space between the old combs from centre to centre is 3 cm which provides enough space for the free movement of bees. Each end of the log hive is provided with four to five such old combs strips and the central ones are left empty for the bees to build new combs themselves. In such a horizontal log hive, the bees build the combs parallel to the ends of the log. While harvesting honey, only the combs at the two ends of the log are removed and the central combs with the brood and honey are kept intact.

The vertical log hive is similar to the horizontal one except that it is kept in an upright vertical position instead of a horizontal position. The hive is generally placed on a piece of tin or flat stone with five to six holes, of pencil thickness above the base, which act as entrances for bees. The top of the vertical log hive is closed with a wooden or tin plank in which eight to 10 holes of one centimetre diameter are made through which the bees can freely move to the super box placed on the top of the vertical log. The super chamber may be in the form of a box, mud pot or altar. From the vertical top bar hive, honey is harvested from the super combs during the second year after bees have inhabited the hives, because in the first year, bees will fill the vertical log with brood, pollen and honey.

In China, traditional wooden log hives are used in some parts even today (Ooschmann, 1961). These, hives are 40 cm high, 30 cm in diameter, and open at both ends. As the colony strength increases, the volume of these hives can be increased by the addition of more wooden rings to the bottom and top, of the hives. Rings are tied with cords to keep these parts of the hive together and both the ends are closed with the help of wooden planks. However, honey yield from *Apis cerana* colonies kept in such hive as low as 5 kg/colony, which is only about one-fourth of that obtained from modern moveable frame hives (Ooschmann, 1961).

In Nepal attempts have been made to improve the design of these hives by adding top bars to them for holding the combs, on the same principle as used in the African top-bar hives which have proved quite successful in Tanzania and other parts of Africa for beekeeping with African races of *Apis mellifera*. Saubolle and Bachmann (1979) attempted to improve the design of the horizontal log hive by adding top bars and using discarded wood, matting or bricks for constructing the main body of the hive. Such hives are oblong in shape and each was provided with 30 top bars. From such hives, only the side top bars with combs are removed while harvesting the honey and the central ones are left undisturbed for brood rearing.

Further, improvement in top-bar hives was made by Gordon Temple who was working for a UNICEF beekeeping project in Nepal. Keeping in view the small population size as well as body size of the native hive bee *Apis cerana* as compared to the African hive bee, Gordon Temple reduced the size of top-bar log hive to two-third-linear. At both ends of the hive, he provided metal supports for hanging it above the ground so that ants, martens, small mammals and lizards would not disturb the bees. He also reduced the number of top bars from 30 to 20. Instead of in the middle, a rectangular bee entrance was made at one end of the log side and its size was regulated with an entrance block which served as queen excluder to check frequent swarming and absconding. As soon as the colony showed signs of absconding, the entrance blocks were put into position to prevent the queen from leaving the hive. Provision for feeding sugar syrup to the bees was also made by providing an external broadman-type feeder to this improved log top-bar hive. The design, specifications and measurement of the different parts of the African type top-bar hive is given in Fig. 6.1. With the help of Mr. Thomas from France, a centrifugal honey extractor was also designed in which top-bar combs from log hives could fit, but it never came in to practical use.

Crane (1984) during her visit to Nepal suggested changes in the design of the above top-bar hive. In African top-bar hives, there is no space between the top bars and this is done to avoid attacks of aggressive African honeybees when the hive is opened for inspection. However, the native hive bee, *Apis cerana* is very gentle to handle. Keeping this in view, Crane (1984), suggested that for improved ventilation of the log hive, narrower top bars should be used so that enough space is left between them. She also advised that a frame feeder be put inside the hive because the external feeder would enhance the chances of robbing. In order to save precious timber, the use of bamboo for constructing the top-bar hive was also suggested.

Speth (1986) prepared detailed instructions for constructing the top-bar log hive for beekeeping with *Apis cerana* in which a hollow log traditionally used could be changed into a top-bar hive. He suggested that the width of each top bar should be 30 mm and a 10 mm wide entrance in the middle to hive.

In Nepal, different agencies like UNICEF, the Agricultural Development Bank, and Kathmandu Agricultural Assistance Association launched an ambitious programme of beekeeping with the native hive bee *Apis cerana* in top-bar log hives. These agencies also started three-day training courses in different parts of Nepal for the popularization of top-bar log hives and distributed a large number of them to the farmers. However, after the termination of the UNICEF beekeeping project in Nepal, these top-bar log hives are now not in common in Nepal.

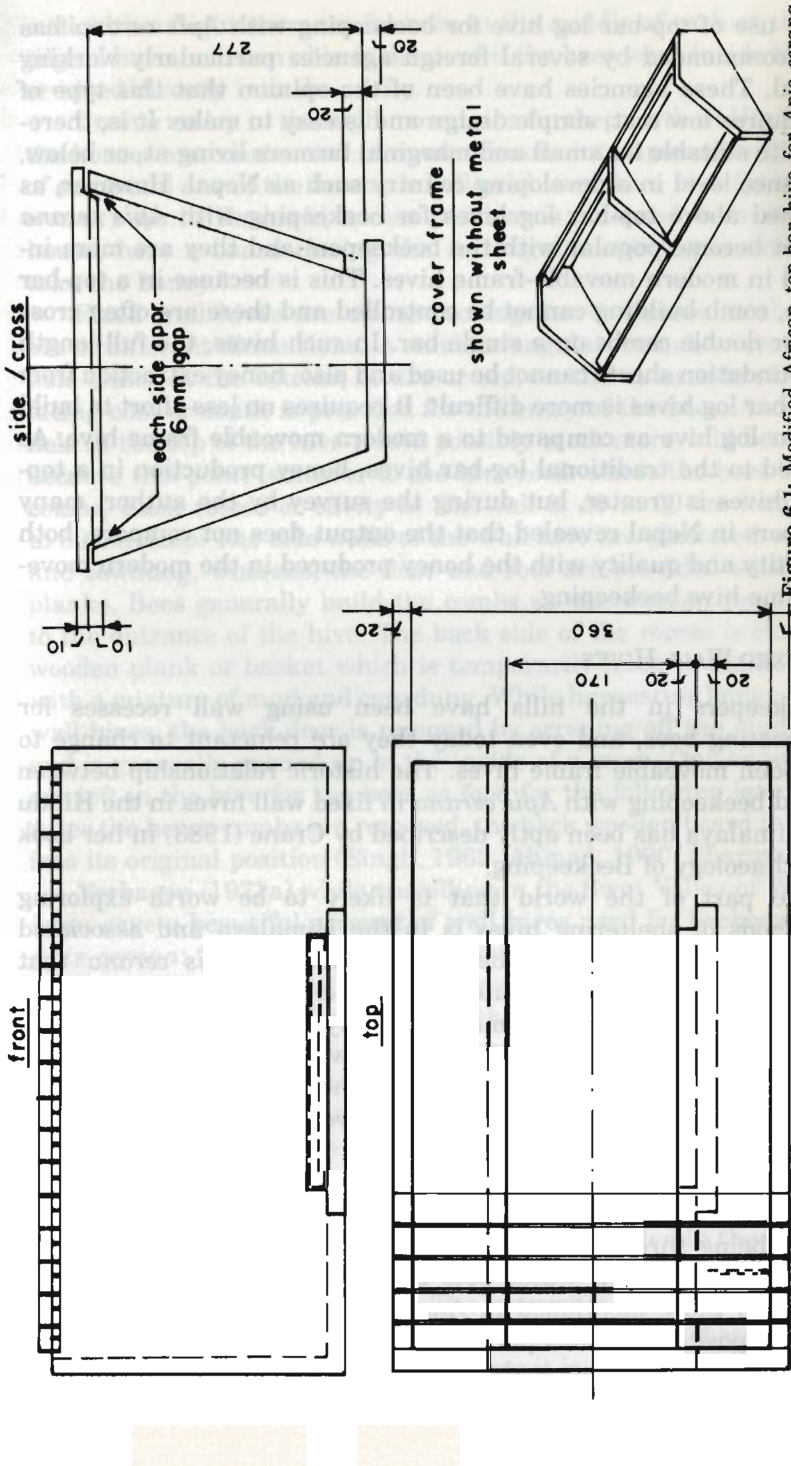


Figure 6.1: Modified African top-bar hive for *Apis cerana* (reduced size/for 18 frames + 1 queen excluder)

Source: Saubelle and Bachmann, 1979.

The use of top-bar log hive for beekeeping with *Apis cerana* has been recommended by several foreign agencies particularly working in Nepal. These agencies have been of the opinion that this type of hive requires low cost, simple design and is easy to make. It is, therefore, quite suitable for small and marginal farmers living at, or below, subsistence level in a developing country such as Nepal. However, as mentioned above top-bar log hives for beekeeping with *Apis cerana* have not become popular with the beekeepers and they are more interested in modern movable-frame hives. This is because in a top-bar log hive, comb building cannot be controlled and there are often cross combs or double combs on a single bar. In such hives, the full-length comb foundation sheets cannot be used and also, honey extraction from the top-bar log hives is more difficult. It requires no less effort to build a top-bar log hive as compared to a modern moveable frame hive. As compared to the traditional log-bar hives, honey production in a top-bar log hives is greater, but during the survey by the author, many beekeepers in Nepal revealed that the output does not compare, both in quantity and quality with the honey produced in the modern moveable frame hive beekeeping.

6.2.2 Fixed Wall Hives

Beekeepers in the hills have been using wall recesses for domesticating bees, and even today they are reluctant to change to the wooden moveable frame hives. The historic relationship between man and beekeeping with *Apis cerana* in fixed wall hives in the Hindu Kush-Himalaya has been aptly described by Crane (1983) in her book The Archaeology of Beekeeping:

"One part of the world that is likely to be worth exploring for methods of sheltering hives is in the Himalaya and associated mountain ranges. The bees here are strains of *Apis cerana* that can withstand the harsh climate about which rather little is known. Winters are cold but summers may give fairly good honey yields. Many of the valleys are isolated and traditional ways survive. In Kashmir, I have seen many houses with internal shelves in the thickness of mud walls containing rows of horizontal hives of mud, clay, wicker or wood, a flight entrance being provided for each to the outside. The wall warmed by the cooking hearth was always well stocked with hives. Honey is taken from the end of the hive inside the house, the shutters being thrown open to let flying bees escape. There are no glazed windows. I saw water pots embedded in walls on a similar principle to those mentioned in Anatolia except that alternate hive faced in opposite directions perhaps to reduce drifting.

"In Ladakh, a higher and more remote valley, a row of wooden doors was found to be filled between the upright beams of a house wall with a flight entrance for bees in the middle of each at the lower edge. I have not been able to discover if the bees were inside the doors or hived directly into the cavity.

"In one valley in the high mountains further north in Hindu Kush, the houses are constructed of wooden beams interspersed with courses of stone and one of the beams is hollowed to make a hive for bee (*Apis cerana*). As in Kashmir, access to them is obtained from inside the house, here a board closing the rectangular opening is removed to take the honey."

Fixed wall hives are either rectangular or square in shape and are of different dimensions. A small triangular, round, or rectangular hole either at the bottom, centre or top, on the outer side of the hive facing east or south is provided for the entry of the bees. An entrance hole at the top of the hive would possibly catch more wild bee swarms because this point is nearer to the hive roofs where the bees build the combs. Each recess or cavity in the wall is 40 to 60 cm long and 25 to 30 cm deep. The side walls of the wall hive are plastered with mud and cowdung, whereas, the floor and roof are provided with wooden planks. Bees generally build the combs on the wooden room parallel to the entrance of the hive. The back side of the recess is closed by a wooden plank or basket which is temporarily fixed to the house wall with a mixture of mud and cow-dung. While harvesting honey from the wall hives, the back door is removed by scraping off the mud plaster, and is generally opened up to the inside of a room. One or two combs are left in the hive for the bees as food for the following lean periods. After the honey combs are removed, the back wooden board is replaced into its original position (Singh, 1962; Ahmad, 1990; Sharma, 1948).

Verhagen (1971a) while travelling in the Swat Valley of West Pakistan gave a beautiful account of wall hives used for beekeeping with *Apis cerana*: "In Swat, a mountainous region at the foot of the Himalaya and which until recently was a little independent kingdom, there exists a form of beekeeping that is almost unique. The Pakistani says that Swat is the homeland of the bee. It is certainly the region which supplies the greater part of the table honey produced in Pakistan and where men and bees live together in a kind of bucolic symbiosis. In fact, when a farm is built in Swat, care is taken that cavities are made in the walls with an orifice the size of a finger, on the outside and a more or less rectangular window about 20 cm in length on the inside. After a swarm has been settled in the cavity, the large opening is sealed with a plank and mortar. Afterwards the small orifice on the outside is opened. The harvest is taken by removing the combs from the inside of the rooms. The location of these cavities or hives, (which can be seen easily because it is customary to mark these orifices with a ring of dark colour), is some times very unexpected.

"I have seen them in the wall of verandah, living room or kitchen of a home with the bees flying about without any hazard to the people including several boisterous children, and also various domestic animals."

In Afghanistan, *Apis cerana* is found in the southeast region comprising Jalalabad, Nouristan and Pactia. In these places, this native hive bee is kept in wall hives as in the Swat Valley of West Pakistan. However, in this region the design of the wall hive is somewhat different. Instead of making a cavity in the wall, hollow timber forms the main body of the hive. These timber hives are built into the house walls at the time of construction. Each hollow timber hive contains two colonies of bees, separated from the inside by a board and mortar, and each having an independent entrance (Verhagen, 1971b).

According to Ahmad (1984) wall hives are commonly used in Swat, Dir and Hazara, in Pakistan. In these places, some wall hives are also provided with moveable frames. A further development of wall hives in Pakistan is the "pitcher hive" made of clay. These are inserted into the housewall and the cavity is inhabited by bees. A clay lid acts as a covering for opening it from inside the house.

A preliminary survey reveals that *Apis cerana* colonies abscond/migrate less frequently from fixed wall hives than from modern moveable frame hives. This is possibly due to the fact that wall hives in the hills are generally more than six to eight feet above the ground. They are not easily accessible and are therefore not subjected to disturbance. Keeping this aspect in mind efforts should be made to design wall hives in such a way that moveable frames can fit into them, which would make the extraction of honey more easy and hygienic.

Besides curtailing absconding, other advantages of wall hives are that larger colonies can be accommodated in smaller spaced wall cavities, ample insulation to the bees is provided particularly in the winter season; and there is no interference from cattle, wild animals and other enemies.

However, the traditional or commonly used wall hives have several disadvantages also: increased chances of queen losses: robbing, frames getting glued, and difficulty in handling. Colony movement is difficult and expensive, and there is also the problem of proper ventilation.

6.2.3 Miscellaneous Traditional Hives

All sorts of boxes, clay pitchers, tree barks and mud receptacles of variable dimensions are used by beekeepers for rearing bees. These are generally suspended in a verandah or open corridor of a house immediately below the roof so that they are clearly visible to the swarms of bees. It has often been observed that *Apis cerana* colonies deserted their indigenous hives during the lean periods and at the onset of the next honey-flow season, then return to these hives. A survey carried out by Nakamura (1988), a Japan Overseas Corporation Volunteer, reveals that in certain parts of Nepal, more than 50 per cent of traditional hives are always empty and such beekeepers are referred to as "waiting beekeeper".

Villagers collect swarms of bees from branches, rock cavities or grass heaps in small bamboo baskets and generally sprinkle water or dust over the bees so that they may not fly off swiftly. Finally, these swarms are domesticated and housed in the vacant traditional hives.

In Burma, besides traditional log hives, the following other types are also in common use (Nyein, 1984):

1. Bamboo Hives: Hill tribes from the Dawna range of Karen state utilize bamboo stems as beehives. Such hives are hung vertically from the ceiling of a hut with the help of a rope.
2. Underground clay pot hives: Hill tribes from the Chil hills bury clay pitchers underground to protect the bees.
3. Underground cave hives: Hill tribes in Chin state of Burma practise another peculiar traditional method of using underground cave hives for beekeeping with *Apis cerana*. First, a hole is dug in the earthen slope and this is covered with a wooden board which has a small opening for the bees to enter. This is generally used for catching swarms of wild bees and a piece of old comb is kept near the entrance to attract such swarms.

6.2.4 Honey Harvesting from Traditional Hives

Honey is squeezed out of the comb by pressing it through a piece of cloth. It is either used for household consumption or taken to the market in pre-used earthen pitchers, bottles or other household utensils for sale. One often finds farmers sitting on the pavements of markets of the mountain cities or going from door to door to sell the honey. A survey revealed that honey collected through traditional methods is often adulterated with cheaper edible products like sugar.

The traditional methods of beekeeping explained above have several disadvantages, both to beekeepers and honey consumers. It is only a matter of chance that the above-mentioned indigenous and simple hives attract swarms of bees, and that colonies would be established in such hives. Thus, a farmer cannot help keep the desired number of hives through traditional beekeeping. In the traditional hives, frequent inspections of colonies to check the incidence of pests and diseases, re-queening, provision of artificial feeding during dearth periods and occasional cleaning is not possible. This often leads to frequent absconding/deserting of the hive, which is one of the most serious problems in beekeeping with *Apis cerana*.

Honey extracted by the traditional squeezing method is not pure as it contains brood extracts, parts of the bodies of bees, hive debris and dirt. Furthermore, a number of bees get killed leading to reduction in the colony strength. Also, bees have to waste lot of their energy in making a new comb since the old one is destroyed while squeezing honey out of it. Honey is generally stored in pre-used bottle, tins, earthen pitchers and is sometimes in advanced stage of fermentation, and is thus unfit for human consumption.

6.3 MODERN HIVE BEEKEEPING

6.3.1 Historical Perspectives

Modern hive beekeeping in the Hindu Kush-Himalaya has its origin in India during the later nineteenth century (1881–1884). In South India, it was Rev. Father Newton, who designed a small modern bee hive with moveable frames for beekeeping with *Apis cerana*. In the northern temperate region of India, Mr. John Douglas (1980) introduced modern bee hives to domesticate this native bee species. Before his modern bee hive came into use, Mr. Douglas unfortunately died but his experiences with beekeeping in northern India were published in the form of a book entitled *A Text Book of Beekeeping in India*. From 1882–1884, Sir Louis Dane, an Assistant Commissioner in Kulu (Himachal Pradesh) and a hobbyist beekeeper, kept bees in modern hives. Later, as Lieutenant Governor of Punjab, be introduced modern bee hives in his residence apiary at Barnes Court, Shimla, which is even today the official residence of the present Governor of the state. In 1909, the Punjab Beekeepers Association was formed at Shimla under the patronage of Sir Louis Dane. The Punjab Government in (1913) appointed Mr. F. S. Cousin, Lieutenant (retired) as an apiarist in the Department of Agriculture and Industries, with headquarters at Sanawar (Himachal Pradesh). Mr. Dorafeef, an engineer employed in the hydro-electric scheme, Joginder Nagar established an apiary (1930) at Kahul (Kulu in Himachal Pradesh). This apiary was looked after by Melisko, a Romanian, for about two years, and later by Litenkov, a Russian, who shifted this apiary to Raison (Kulu). In 1937, R. N. Muttoo formed an All India Beekeepers' Association and started publication of the Indian Bee Journal. On the recommendation of the Punjab Government and at the instance of Colonel Brayne, Commissioner Rural Construction, commercial bee farms with improved beekeeping equipment were established at Nagrota in district Kangra of Himachal Pradesh (1936) and one at Raison (Kulu) was shifted to its present site at Katrain (Himachal Pradesh) in 1939. After independence, Saradara Singh and P. L. Sharma made considerable efforts to develop beekeeping in the mountain parts of Himachal Pradesh and the Punjab. In 1953, the All India Khadi and Village Industries Board was formed which was reconstituted as Khadi and Village Industry Commission later. Under this commission beekeeping in mountain areas of northeast and northwest India received enough attention for its development in a coordinated manner. In the early sixties, A. S. Atwal and his research group working in Punjab Agricultural University, Ludhiana, introduced the European honeybee (*Apis mellifera ligustica*) successfully in the plains of the Punjab and submountainous areas of Himachal Pradesh (Verma, 1989b).

6.3.2 Evolution and Standardization of the Modern *Apis cerana* Bee Hive in India

For nearly 50 years (1880–1930), a hive designed by Father Newton was commonly used all over India for beekeeping with *Apis cerana*. However, the worker bees of *Apis cerana* in southern India are of much smaller body size and also the colony population size is smaller than bees of this species found at higher altitudes of northwest India. So the Newton hive was not suitable for beekeeping with *Apis cerana* in southern India as it was in the mountainous parts of Himachal Pradesh, Uttar Pradesh, Jammu and Kashmir. Consequently, *Apis cerana* colonies swarmed and absconded quite frequently from such hives. Moreover, honey yields obtained by using the Newton hive was only 5 kg per colony. Keeping in view these limitations of the Newton hive, Muttoo (1944, 1952, 1954, 1956) designed a new hive for larger sized *Apis cerana* as found in the higher altitudes of the Uttar Pradesh hills and named it the Joelikote Villagers' hive. This hive became quite popular not only in other mountainous parts but also in the plains of northern India. Simultaneously, as many as 15 different types of bee hives in different sizes came into existence for beekeeping with *Apis cerana* throughout India, and all were known as modified Newton or Villagers' hive.

Keeping in view this kind of multiplicity of hive designs at that time, a strong need was felt to evolve different definite standards of bee hives suited to different sub-species/geographic ecotypes of *Apis cerana* found in different climatic zones and beekeeping areas of the country. The first suggestion for the standardization of bee hives in India was made at the XIth All India Beekeepers conference held at Nandgat, Bombay, in 1949. This suggestion was repeated in subsequent annual meetings of the All India Beekeepers' Association and it was in 1956 that an "Apiary Industrial Selection Committee" was constituted as a part of the Indian Standard Institution (ISI) programme. In this committee, representatives of the following organizations were included (Kapil, 1971):

1) Khadi and Village Industry Commission (Beekeeping section), Bombay.
2) Bombay Village Industries Board, Bombay.
3) Department of Agriculture (Apiary Section) Government of Mysore.
4) Government Beekeeping Station, Joelikote, Uttar Pradesh.
5) Apicultural Development Officer, Mysore State,
6) All India Beekeepers Association, Rampur, Uttar Pradesh.

As a result of the recommendation of this committee, the following two types of bee hives (Type A and B) were adopted.

Type A: Modified Newton type of bee hive.

Type B: Modified Joelikote village type of bee hive.

This committee was also of the view that due to the different environmental conditions existing in a vast country like India, different sub species/ecotypes or races of *Apis cerana* may be found. Based on this assumption, each of the above hive types was further sub-divided into three sub-types depending upon the distance between the centres of two adjacent frames and also the different sizes of be space.

Besides prescribing the above standards, a frame size of 40.64 × 20.32 cm was also chosen as the standard, and through the use of dummy or division board, it was possible to convert this size of frame hive into a Newton, Joelikote or even a Langstroth type, depending upon the colony size of *Apis cerana*. However, the most important feature in all these types of bee hives is bee space, and the sizes recommended are 4.76 mm, 6.35 mm and 7.94 mm depending upon the sub species/race/ecotype of the bees (Kapil, 1971).

It has now been experimentally proved that the above proposed standards for different hives have worked very well in beekeeping with *Apis cerana* in India. For example, the Khadi and Village Industries Commission, Government of India has distributed thousands of both modified Newton types and Joelikote villager types to beekeepers. Joelikote has proved very successful for the larger and "hilly variety" of *Apis cerana*, whereas the Newton type is being successfully used for the smaller "plains variety" of this native bee species. Specifications for these bee hives, hive stands, comb foundation mill, comb foundation sheets as well as travelling bees box have been laid out by the Indian Standard Institution (1961, 1962, 1967, 1970 and 1981). Design and dimensions of various parts of type A and type B bee hives with 8 and 10 frames is given in Fig. 6.2 and Tables 6.1 to 6.4. Experimental data

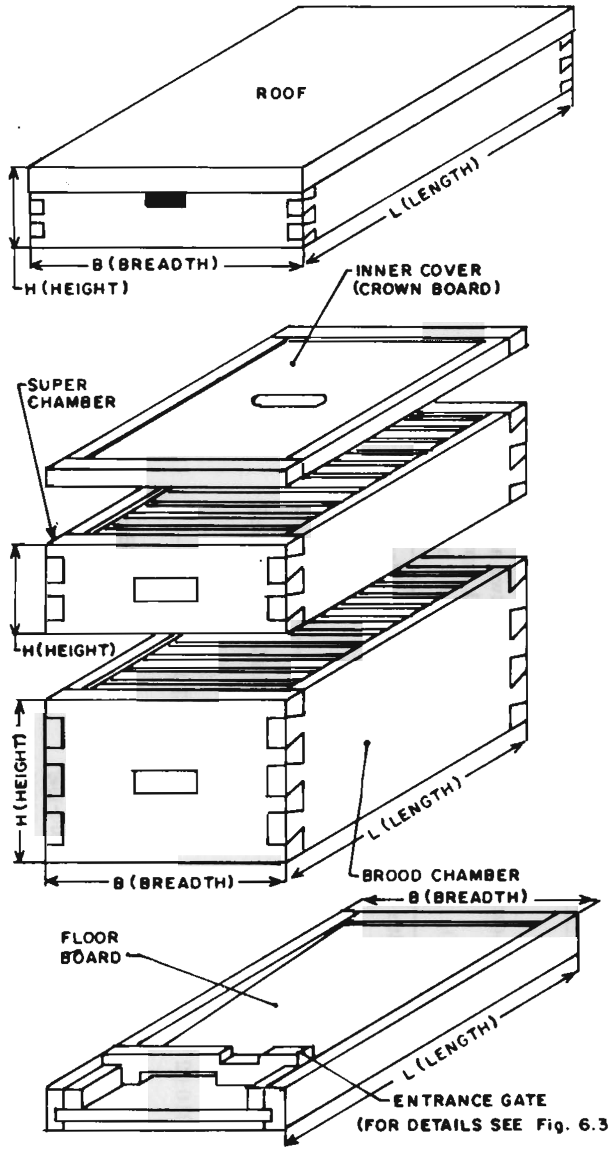


Figure 6.2: Indian beehives type A and B for *Apis cerana*. (For details of dimensions of various parts of type A and B bee hives with different number of frames, please see Tables 6.1 to 6.4).

Source: Indian Standard Institution, 1981

Table 6.1: Dimensions of various parts of *Apis cerana* type A beehives with ten frames (in mm)

Description	Distance between centres of two adjacent frames = 30 mm (bee space = 7 mm)			Distance between centres of two adjacent frames = 31 mm (bee space = 8 mm)			Distance between centres of two adjacent frames = 32 mm (bee space = 9 mm)		
	Length (L)	Breadth (B)	Height (H)	Length (L)	Breadth (B)	Height (H)	Length (L)	Breadth (B)	Height (H)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Floor board	361±2	356±2	50±2	361±2	366±2	50±2	361±2	376±2	50±2
Brood frame:									
Outside	230	—	165	230	—	165	230	—	165
Inside	210±2	—	145±2	210±2	—	145±2	210±2	—	145±2
Brood chamber:									
Outside	286±2	**356±2**	172	286±2	366±2	173	286±2	376±2	174
Inside	240	310	172	240	320	173	240	330	174
Super frame:									
Outside	230	—	85	230	—	85	230	—	85
Inside	210±2	—	65±2	210±2	—	65±2	210±2	—	65±2
Super chamber:									
Outside	286±2	356±2	92	286±2	366±2	93	286±2	376±2	94
Inside	240	310	92	240	320	93	240	330	94
Inner cover (crown board)	286±2	356±2	22	286±2	366±2	23	286±2	376±2	24

Roof (top):									
outside	328±2	398±2	100±2	328±2	408±2	100±2	328±2	418±2	100±2
Dummy board	230±2	—	165±2	230±2	—	165±2	230±2	—	165±2
Division board	236	—	One-end 182 Other end-194	236	—	One-end 183 Other end-195	236	—	One-end 184 Other end-196

Source: Indian Standards Institution 1981.

Table 6.2: Dimensions of various parts of *Apis cerana* type A beehives with eight frames (in mm)

Description	Distance between centres of two adjacent frames = 30 mm (bee space = 7 mm)			Distance between centres of two adjacent frames = 31 mm (bee space = 8mm)			Distance between centres of two adjacent frames = 32 mm (bee space = 9mm)		
	Length (L)	Breadth (B)	Height (H)	Length (L)	Breadth (B)	Height (H)	Length (L)	Breadth (B)	Height (H)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Floor board	361±2	296±2	50±2	361±2	304±2	50±2	361±2	312±2	50±2
Brood frame:									
Outside	230	—	165	230	—	165	230	—	165
Inside	210±2	—	145±2	210±2	—	145±2	210±2	—	145±2
Brood chamber:									
Outside	286±2	296±2	172	286±2	304±2	173	286±2	312±2	174
Inside	240	250	172	240	258	173	240	266	174
Super frame:									
Outside	230	—	85	230	—	85	230	—	85
Inside	210±2	—	65±2	210±2	—	65±2	216±2	—	63±2
Super chamber:									
Outside	286±2	296±2	92	286±2	304±2	93	286±2	312±2	94
Inside	240	250	92	240	258	93	240	266	94
Inner cover (crown board)	286±2	296±2	22	286±2	304±2	23	286±2	312±2	24

Roof (top):									
outside	328±2	338±2	100±2	328±2	346±2	100±2	328±2	354±2	100±2
Dummy board	230±2	—	165±2	230±2	—	165±2	230±2	—	165±2
Division board	236	—	One-end 182 Other end-194	236	—	One-end 183 Other end-195	236	—	One-end 184 Other end-196

Source: Indian Standards Institution 1981.

Table 6.3: Dimensions of various parts of *Apis cerana* type B beehives with ten frames (in mm)

Description	Distance between centres of two adjacent frames = 31 mm (bee space = 8mm)			Distance between centres of two adjacent frames = 32 mm (bee space = 9mm)		
	Length (L)	Breadth (B)	Height (H)	Length (L)	Breadth (B)	Height (H)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Floor board	431±2	366±2	50±2	431±2	376±2	50±2
Brood frame:						
Outside	300	—	195	300	—	195
Inside	280±2	—	175±2	280±2	—	175±2
Brood chamber:						
Outside	356±2	366±2	203	356±2	376±2	204
Inside	310	320	203	310	330	204
Super frame:						
Outside	300	—	105	300	—	105
Inside	280±2	—	85±2	280±2	—	85±2
Super chamber:						
Outside	356±2	366±2	113	356±2	376±2	114
Inside	310	320	113	310	330	114
Inner cover (crown board)	356±2	366±2	23	356±2	376±2	24
Roof (top):						
outside	398±2	408±2	100±2	398±2	418±2	100±2
Dummy board	300±2	—	195±2	300±2	—	195±2
Division board	306	—	One-end 213 Other-end 225	306	—	One-end 214 Other-end 226

Source: Indian Standards Institution 1981.

are available to prove that by adopting such standards, it has been possible to increase yield of honey by 22 to 32 per cent, and significantly reduce the absconding and frequent swarming of *Apis cerana* colonies (Kapil, 1971). Bisht et al. (1982) tested the comparative efficiency of the Joelikote Villager and Newton Bee hives on a heterogeneous mixture of the plains and hilly varieties of *Apis cerana*. As expected, the Joelikote Villager hive is superior and more productive with respect to brood rearing, and pollen and honey storage.

In the late fifties (1957–1959), when the above-mentioned hives were adopted, only the "plains and hilly variety" of *Apis cerana* were arbitrarily known, based on preliminary biometric investigations.

Table 6.4: Dimensions of various parts of *Apis cerana* type B beehives with eight frames (in mm)

Description	Distance between centres of two adjacent frames = 31 mm (bee space = 8mm)			Distance between centres of two adjacent frames = 32 mm (bee space = 9mm)		
	Length (L)	Breadth (B)	Height (H)	Length (L)	Breadth (B)	Height (H)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Floor board	431±2	304±2	50±2	431±2	312±2	50±2
Brood frame:						
Outside	300	—	195	300	—	195
Inside	280±2	—	175±2	280±2	—	175±2
Brood chamber:						
Outside	356±2	304±2	203	356±2	312±2	204
Inside	310	258	203	310	266	204
Super frame:						
Outside	300	—	105	300	—	105
Inside	280±2	—	85±2	280±2	—	85±2
Super chamber:						
Outside	356±2	304±2	113	356±2	312±2	114
Inside	310	258	113	310	266	114
Inner cover (crown board)	356±2	304±2	23	356±2	312±2	24
Roof (top): outside	398±2	346±2	100±2	398±2	354±2	100±2
Dummy board	300±2	—	195±2	300±2	—	195±2
Division board	306	—	One-end 213 Other-end 225	306	—	One-end 214 Other-end 226

Source: Indian Standards Institution 1981.

However, recent detailed biometric analysis of *Apis cerana* carried out by Ruttner (1987) and by Verma and Mattu, (1982), and Verma et. al. (1988a and b) with the help of computer-assisted multivariate analysis revealed that there are three different sub-species of *Apis cerana* found in India. Out of these, *Apis cerana cerana* is found in Jammu, Kashmir and Himachal Pradesh, and *Apis cerana himalaya* is found in northeast India. The third ecotype *Apis cerana indica* is found in South India. Keeping in view the body sizes of the three different races, the following trend was observed: *Apis cerana cerana* > *Apis cerana himalaya* > *Apis cerana indica*. Further, each race has further locally adopted population or groups called ecotypes which differ from each other again in body size and the sizes of bee space required in different hives would also vary. In the Kashmir Valley (India), beekeepers use the standard 10 frames Langstroth hive for *Apis cerana* (Mahindre, 1983).

Modern Hive Beekeeping with *Apis cerana* in Other Parts of the Hindu Kush-Himalayan Countries

Hive standards developed in India are now being used with slight modifications in other countries of the Hindu Kush-Himalaya such as Nepal, Pakistan, Afghanistan, Bangladesh, Bhutan and Burma for beekeeping with *Apis cerana*. However, in these countries the earlier Indian experiences of using different sizes and dimensions of bee hives are being repeated. For example, in the Kathmandu valley of Nepal, the author has observed four different types of box hives, varying in dimensions and designs, being used for beekeeping with *Apis cerana*. The number of moveable frames in such hives varies from 8 to 12. The dimensions of the "Godavari" moveable frame hive has been worked out by Saubolle and Bachmann (1979) and are given in Figs. 6.3A to 6.3L. In Nepal generally, champ or Tuniwood is used for constructing the hive.

In Bangladesh, wooden hives of different sizes and designs are in use for beekeeping with *Apis cerana*, and they are all diminutive versions of the Indian "Newton hive" (Kevan, 1983). Most bee boxes used are 13 × 10 × 7 inches or 11 × 11× 7 inches. CUSO (Canadian University Services Overseas) has recommended the "type A" eight-frame hives for the small sized *Apis cerana* found in the plains of Bangladesh. Generally, jackfruit wood is used for constructing the hives and, to a limited extent, teakwood is also used (Nash and Murrell, 1981).

In Burma, a modified mini Langstroth hive has been designed for beekeeping with *Apis cerana*. The dimensions of the different hive parts are as follow (Nyein, 1984).

Length of brood frame	=	300 mm
Breadth of brood frame	=	195 mm
Distance of two adjacent frames from centre to centre	=	31 mm
Bee entrance size	=	10–25 mm

In Bhutan, moveable frame hive beekeeping is practised to a very limited extent in Galylephug, Phuntsholing, Wangdephodrang, Paro, Thimpu, Yusipang and Bumthang. At each of these places, the number of hives varies from two to six suggesting that beekeeping with modern moveable frame hives is yet to be developed. (Breadbear, 1986).

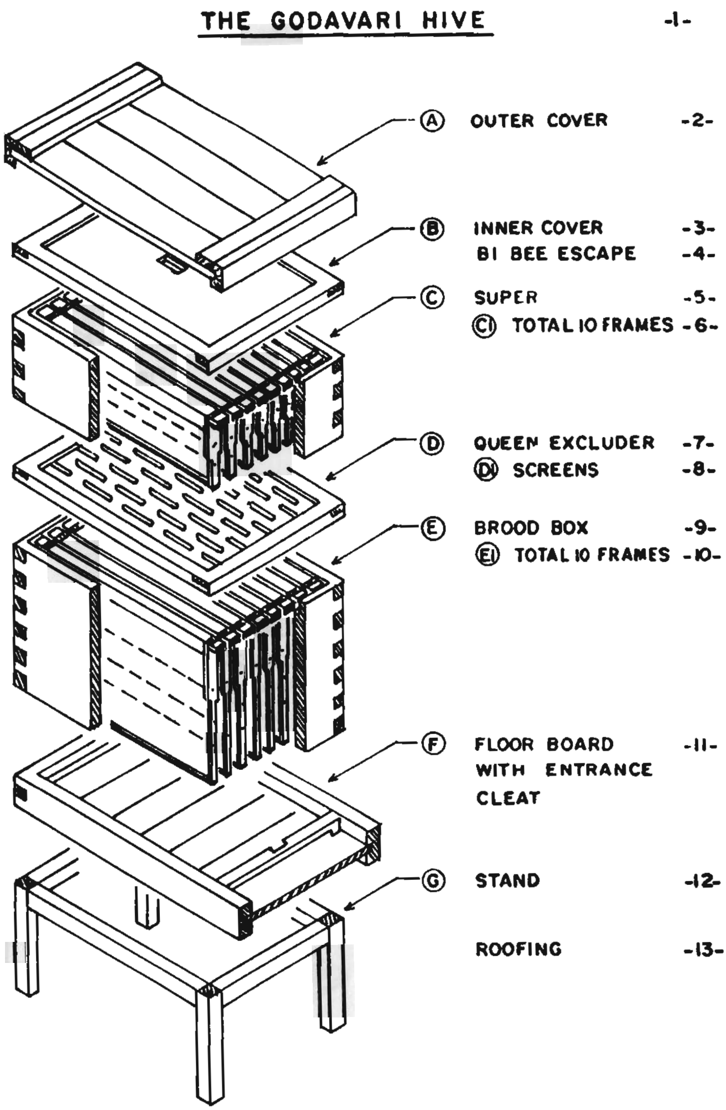


Figure 6.3A: Nepalese Godavari beehive for *Apis cerana* (For dimensions of various parts. Please see Figs. 6.3B to 6.3L).

Source: Saubolle and Bachmann, 1979.

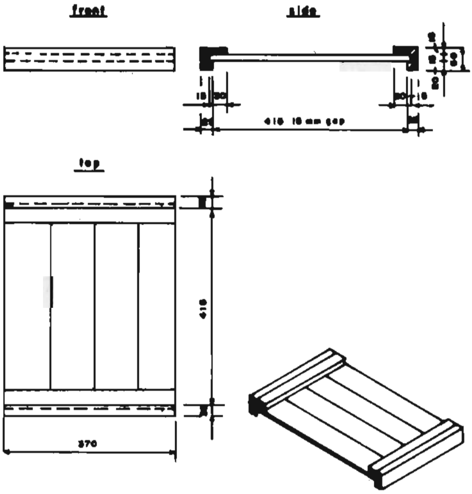


Fig. 6.3 B

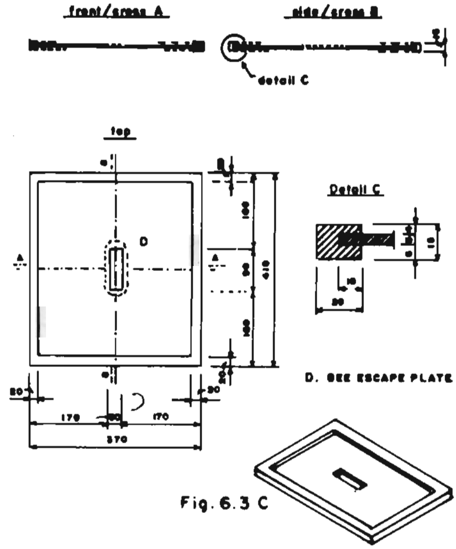


Fig. 6.3 C

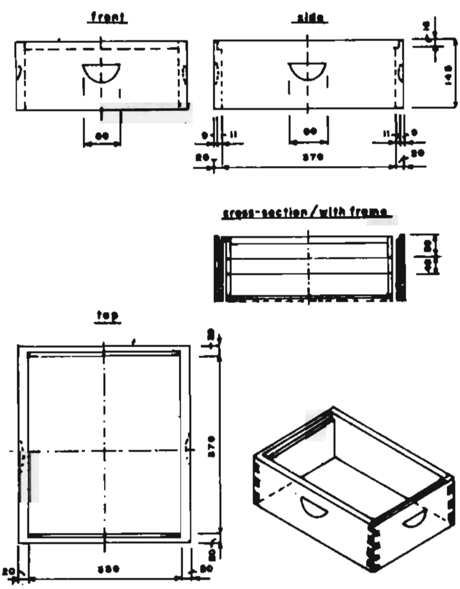


Fig. 6.3 D

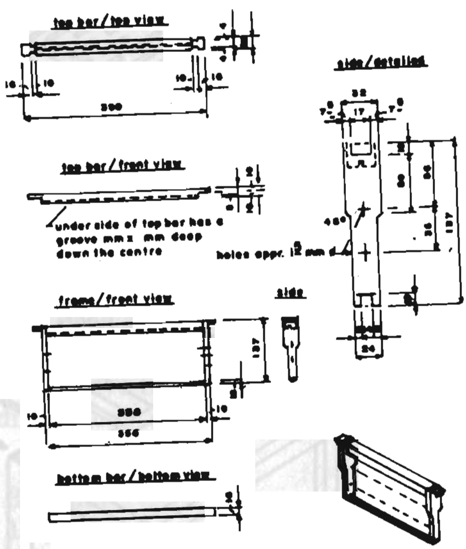


Fig. 6.3 E

Nepalese Godavari Beehive

Figure 6.3B: Dimension of different parts of top cover (roof)
Figure 6.3C: Dimension of different parts of inner cover
Figure 6.3D: Dimension of different parts of super chamber.
Figure 6.3E: Dimension of different parts of super frame.

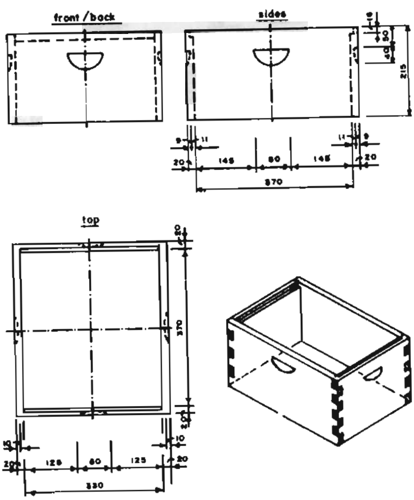


Fig. 6.3 F

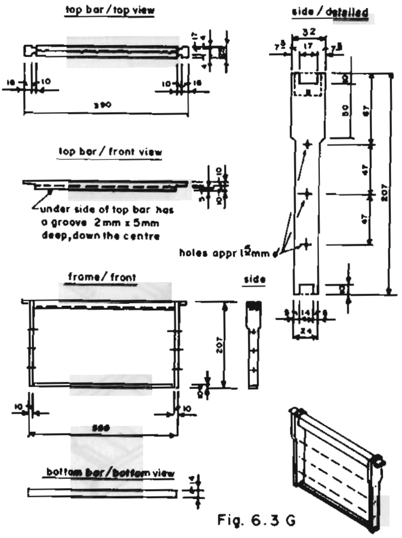


Fig. 6.3 G

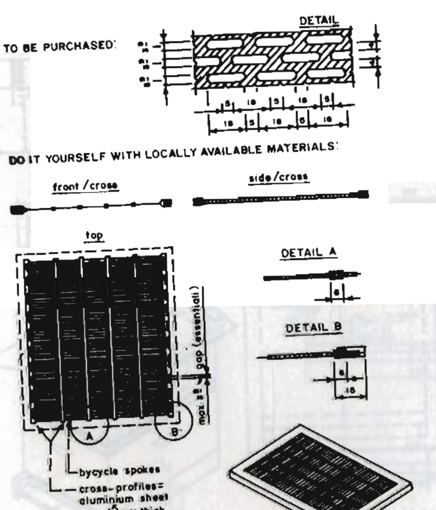


Fig. 6.3 H

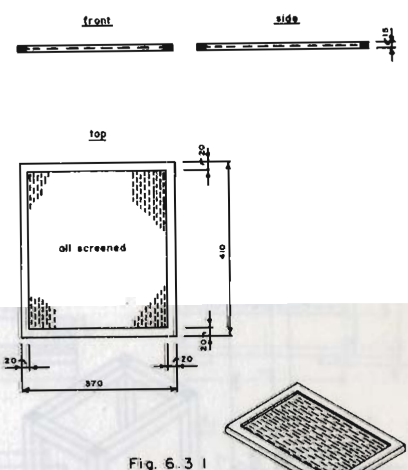


Fig. 6.3 I

Nepalese Godavari Beehive

Figure 6.3F: Dimension of different parts of brood chamber

Figure 6.3G: Dimension of different parts of brood frame.

Figure 6.3H: Dimension of different parts of queen excluder (screens)

Figure 6.3I: Dimension of different parts of queen excluder (frame).

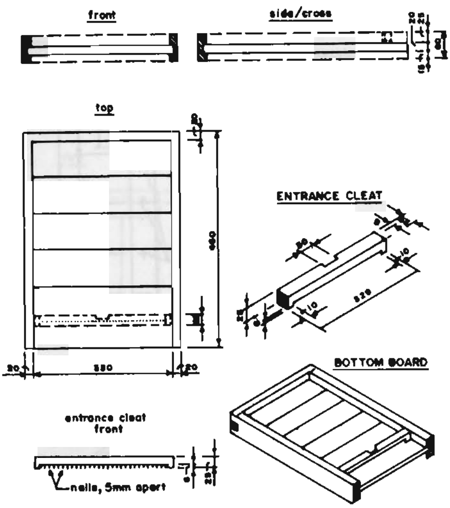


Fig. 6.3 J

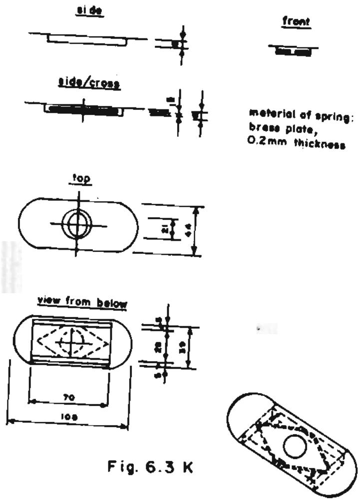


Fig. 6.3 K

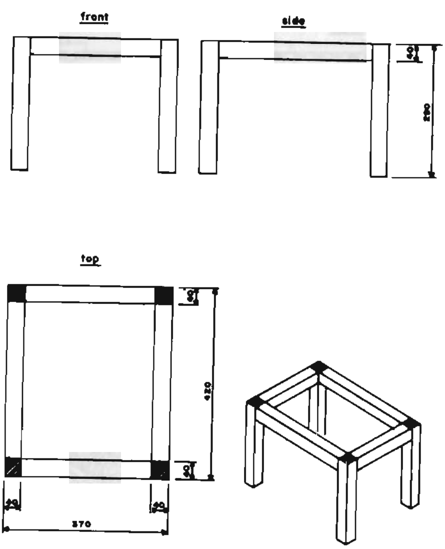


Fig. 6.3 L

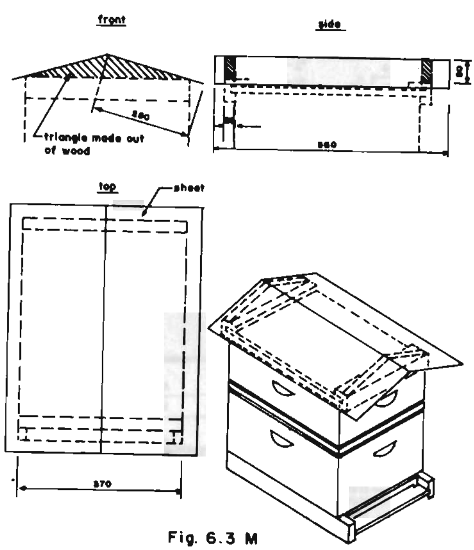


Fig. 6.3 M

Nepalese Godavari Beehive

Figure 6.3J: Dimension of different parts of bottom board

Figure 6.3K: Dimension of different parts of entrance gate

Figure 6.3L: Dimension of different parts of hive stand

Figure 6.3M: Dimension of different parts of roof.

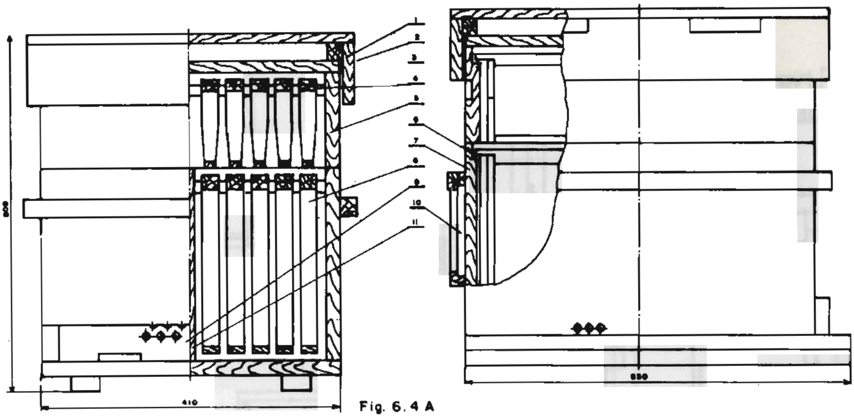


Fig. 6.4 A

Figure 6.4A: Chinese ten-frame standard beehive for *Apis cerana* (For dimensions of various parts of hive, please see Figs. 6B to 6J).

Source: Yuan et al. 1983.

1 — Top cover (roof); 2 — Inner cover; 3 — Screen;
2 — Super frame; 5 — Super chamber; 6 — Iron slip;
7 — Brood chamber; 8 — Brood frame; 9 — Entrance gate;
10 — Movable screen; 11 — Isolating plate.

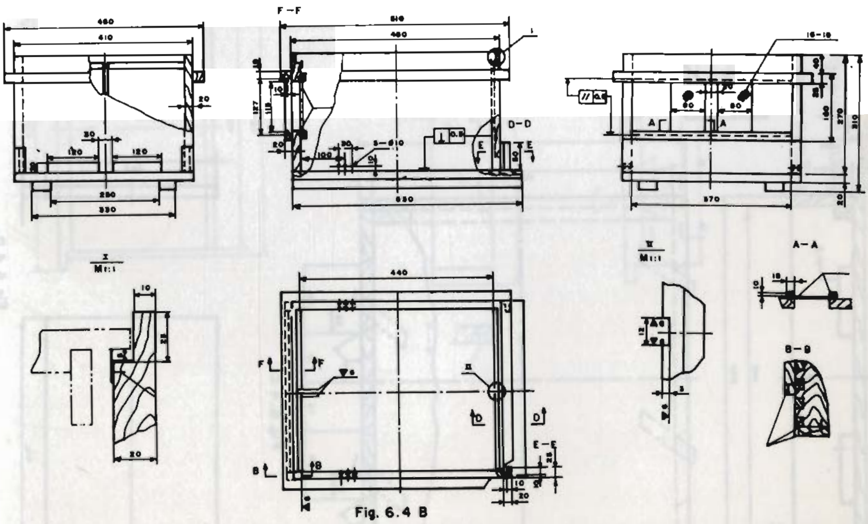


Fig. 6.4 B

Figure 6.4B: Dimensions of various parts of brood chamber.

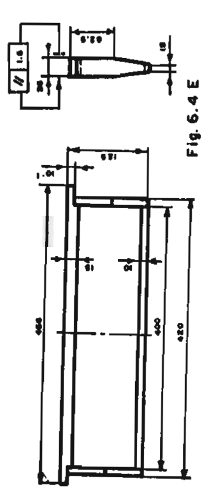


Fig. 6.4 E

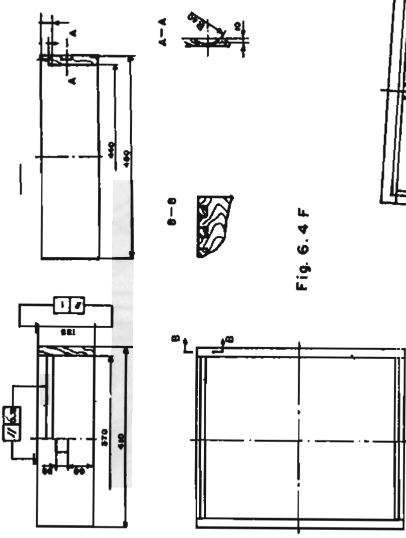
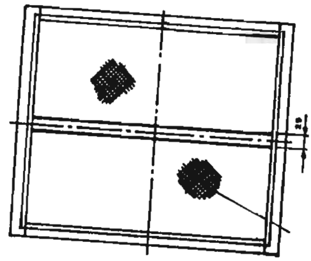


Fig. 6.4 F



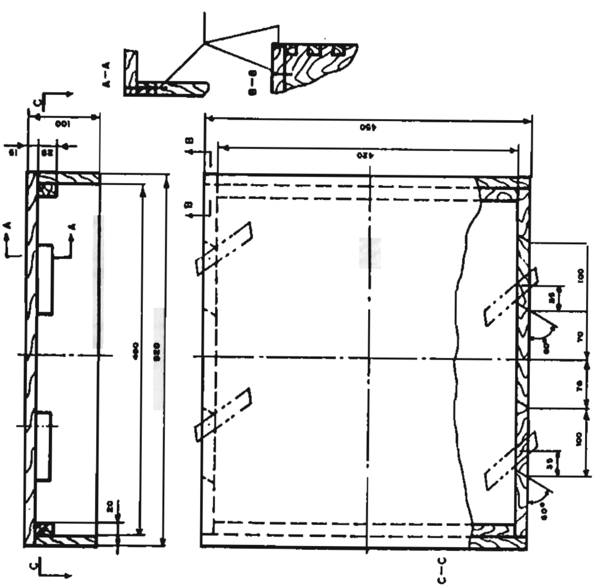


Fig. 6.4 C

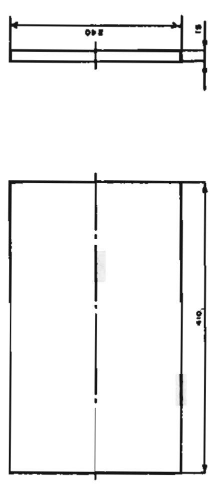


Fig. 6.4 D

Chinese *Apis cerana* Beehive

Figure 6.4C: Dimension of various parts of hive cover.

Figure 6.4D: Dimension of various parts of side cover.

Figure 6.4E: Dimension of various parts of super frame.

Figure 6.4F: Dimension of various parts of super chamber.

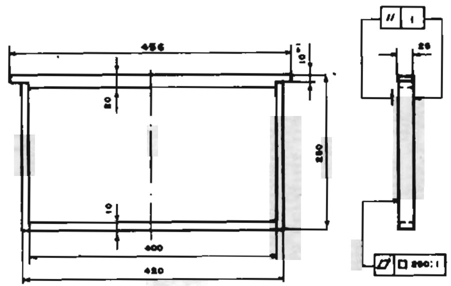


Fig. 6.4 G

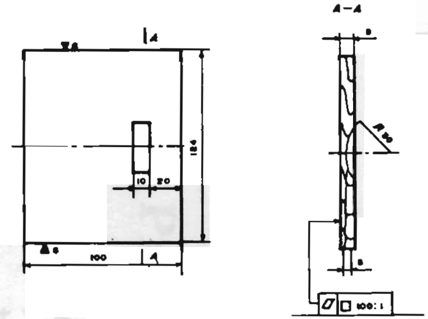


Fig. 6. 4 I

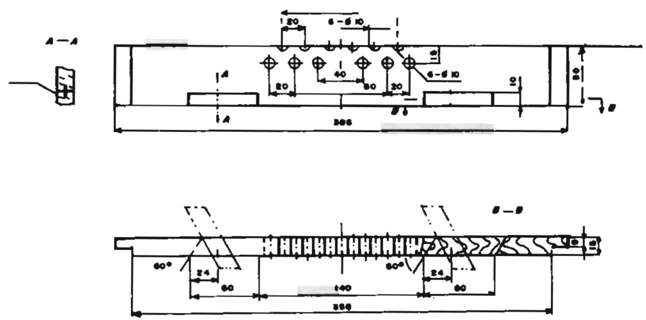


Fig. 6. 4 H

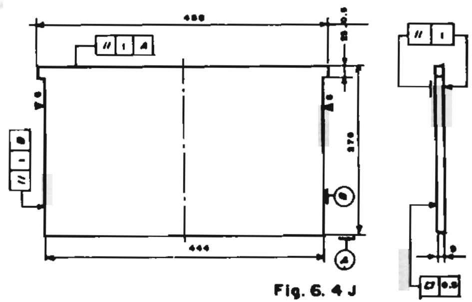


Fig. 6. 4 J

Chinese *Apis cerana* Beehive

Figure 6.4G: Dimension of different parts of brood frame.
Figure 6.4H: Dimension of different parts of entrance gate.
Figure 6.4I: Dimension of different parts of moving screen.
Figure 6.4J: Dimension of different parts of isolating plate.

In Pakistan, besides the use of wooden boxes, attempts have been made to construct cement or mud wall moveable frame hives by using the ingredients given on page 138 (Ahmad, 1988).

A.	Cement hive:	Cement	=	1 part
		Sand	=	3 parts
B.	Mud wall hive:	Clay	=	16 parts
		Chopped Wheat straw	=	1 part
		or		
		Multani mitti	=	6 parts
		Newspaper	=	11 parts
		Wheat flour	=	1 part
		Agave leaves	=	1 part

In China, *Apis cerana* kept in traditional bee hives yielded very little honey (5 kg/colony). So a great effort was made to introduce moveable frame hive beekeeping. As result of such an effort, the Chinese Ministry of Agriculture in collaboration with the Institute of Beekeeping, Chinese Academy of Agricultural Sciences and State Bureau of Standardization has proposed a "national standard" beehive for beekeeping with *Apis cerana* in the People's Republic of China. The ten-frame hive is adopted as standard throughout China. The design and specifications of this hive are given in Figs. 6.4A to 6.4J. The introduction of moveable frame hive beekeeping with *Apis cerana* has been most successful, and at present more than one million colonies of *Apis cerana* are being kept in such hives in China. The average honey yield per colony is 20 kg/annum.

However, *Apis cerana* beekeeping on such a large scale requires a lot of timber and beeswax. To meet this demand China, started a very ambitious programme of afforestation which has now ensured the supply of enough timber for the manufacture of wooden hive boxes. At the same time, attempts are being made to find suitable substitutes for wood which could be used for constructing the hives. One such alternate being tried is long immovable stone hives fitted with movable frames (Xianshu, 1985; Gong, 1983; Oschmann, 1961).

CHAPTER 7

Hive Products

7.1 HONEY

Honey is a natural sweet product of the bee hive, which has been treasured by man from ancient times. Due to its high medicinal and nutritional value, man derives great benefits from honey. The most common raw material for honey is nectar and other natural plant exudations. Nectar is a watery solution of sugars and originates in floral and extra-floral nectaries of plants. Bees also frequently make honey from honey dew which is a sweet secretion of insects.

The composition of honey determines its value as a nutritional and medicinal product. The major components of honey are the sugars. (about 80 per cent) and water (17 to 20 per cent) in which the sugars are dissolved. In addition, so far 181 different substances have been identified in honey and some of them are unique and do not exist anywhere else. These substances make up only a small part of the total components of honey. Important minor elements, are minerals, enzymes, lipids, amino acids, proteins, organic acids, etc. These minor components of honey determine its aroma, flavour and colour. Physico-chemical properties of honey are determined by major and minor elements. Several of these properties, viz. refractive index, density, viscosity, electric conductivity, surface tension, etc., are of great importance in the honey industry as they influence its keeping quality, granulation,. texture, etc.

Moisture content is the major factor which determines the keeping quality of honey. If the water content in honey is 20 per cent or more, it undergoes the process of fermentation and deteriorates in quality. Thus, fermentation, which is caused by a yeast, is the greatest enemy of honey. Due to fermentation, honey becomes sour and has a foamy layer on top. In advanced countries, honey fermentation is prevented by pasteurizing and storing it in sealed containers. However, such facilities are not available in the developing countries of South and Southeast Asia, and fermentation of honey is prevented by heating extracted honey for 30 minutes at 60°C and bottling it in airtight containers.

Honey also has a tendency to granulate during storage. This occurs because of its high glucose content which during prolonged storage undergoes a process of crystallization. Although, granulation does not affect the taste, such honey does not fetch good price in the market because consumers suspect that granulated honeys have been adulterated with the addition of table sugar, sucrose.

Granulation also accelerates the process of fermentation. Granulation can be controlled by heating honey to 77°C for five minutes and then cooling it rapidly to 57°C at which temperature it is bottled and immediately capped.

Honey should be stored at minimum possible temperatures to maintain its quality and texture. A detailed world-wide comprehensive review on honey has been compiled by Crane (1976).

7.1.1 Analytical Studies on Asian Honeys

Some analytical studies on Asian honeys made by different investigators are reviewed as follows:

1. *Physical characteristics*: One of the important optical properties of honey is its refractive index which provides an easy way of estimating the water or moisture content of honey, a value which determines whether and when honey will ferment at a given temperature. Latif et al. (1956) measured water content in honey samples from Pakistan, and it ranged from 14.3 to 18.6 per cent (average 16.4). In the Taiwan honeys, the water content varied from 20 to 24 per cent (Lin et al., 1977). Iwada et al. (1969) recommended that in Japanese honey, moisture content of 23 per cent for domestic and 21 per cent for imported honey was considered adequate. Aso et al. (1960) and Arai et al. (1960) reported moisture content in Japanese honey as 20.5 and 20.4, respectively. A number of investigators have reported the moisture content of Indian honeys, as 20.9 per cent in samples from all over India (Phadke, 1967a); 17.2–19.1 per cent in Mahabaleshwar honey (Phadke, 1962, 1967b); 19.2 per cent in Madras honey (Giri, 1938); 25.2–28.4 per cent in Travancore honey (Nair et al., 1950); 20.5 per cent in Calcutta honey (Mitra and Mathew, 1968) and 16.6–26.4 per cent in samples from all over India (Mallick, 1958). Narayana (1970) reported that Indian honeys have a higher moisture content and acidity than foreign honeys. Mahajan (1984) determined moisture content of 15 honey samples from the Shimla hills of Himachal Pradesh which ranged from 16.45 to 20.45 per cent (average 18.85 per cent). These values were lower than those observed from other parts of India. The average moisture contents in multifloral, *Plectranthus* and *Eucalyptus*

honeys were 18.33, 19.45 and 19.25 per cent, respectively (Table 7.1). Six samples of honey stored for one year did not show a significant increase in moisture content. The moisture content of summer samples (18.65 per cent) also did not differ significantly from those of autumn (18.57 per cent). However, Perti and Pandey (1967) reported average moisture content of summer and rainy season honeys from *Apis dorsata* colonies as 17.0 and 25.9 per cent, respectively.

Accordingly to Mahajan (1984), the average specific gravity, viscosity, surface tension and electrical conductivity at 30°C for honey samples of *Apis cerana* colonies from the Shimla hills were 1.425, 37.764, 106.219 and 0.219, respectively (Table 7.1). These physico-chemical characteristics did not show significant differences in their values for both major honey flow seasons (May–June and October–November). After a storage period of one year at room temperature (15–20°C), there was an increase in the moisture content, surface tension, electrical conductivity, and a decrease in refractive index, specific gravity and viscosity due to the hygroscopic nature of honey.

A correlation matrix worked out by Mahajan (1984) for the above honey samples revealed that some of these physico-chemical properties were positively or negatively correlated with each other (Table 7.2). For example, refractive index showed positive correlation with specific gravity ($r = 0.977$, $P < 0.01$); viscosity ($r = 0.807$, $P < 0.01$); surface tension ($r = 0.596$, $P < 0.01$). Similarly, specific gravity showed significant positive correlation with viscosity ($r = 0.725$, $P < 0.001$); surface tension ($r = 0.512$, $P < 0.01$). Electrical conductivity showed positive correlation with phosphate ($r = 0.516$, $P < 0.01$); potassium ($r = 0.642$, $P < 0.01$); magnesium ($r = 0.720$, $P < 0.01$); iron ($r = 0.827$, $P < 0.01$); and manganese content ($r = 0.653$, $P < 0.01$).

2. *Sugars, amino acids and vitamins*: Sugars constitute by far the largest portion of dry matter in honey and are responsible for such physical properties as viscosity, hygroscopicity and granulation.

Latif et al. (1956) investigated samples of Pakistan honey, which had sugar percentages as follows: reducing sugars (71.1–76.9), fructose (39.01–53.81), glucose (21.7–34.2) and sucrose (1.9–2.75). According to Mallick (1958) reducing sugars in Indian honeys varied from 53.9 to 78.4 per cent, and five samples, possibly from a sugar producing area, had more than 10 per cent sucrose. Fieh's test for invert sugar gave a positive result for two years. Kalimi and Schonie (1964) confirmed the increase of higher sugars and decrease of mono-saccharides during honey storage at 28 to 30°C for six to 12 months. These authors also reported that the total sugar content of unifloral honeys varied from 74.7 to 80 per cent and reducing sugars from 72 to 78 per cent of the total. Phadke (1967a, b) found the average value of non-reducing sugars,

Table 7.1: Physico-chemical analysis of honey samples of *Apis cerana* colonies from northern India

Honey type	Refractive index at 20°C	Moisture percentage at 20°C	Specific gravity at 30°C	Viscosity (poises) at 30°C	Surface tension (dynes/cm) at 30°C	Electrical conductivity (mho/cm × 10^{-4})	Ash percentage	Phosphate PO_4 (ppm)	Potassium K^+ (ppm)	Calcium Ca^{++} (ppm)	Magnesium Mg^{++} (ppm)	Iron Fe^{++} (ppm)	Manganese Mn^{++} (ppm)	Zinc Zn^+ (ppm)
1) *Multifloral*														
Range	1.486	16.450	1.409	13.482	98.899	0.029	0.08	30	519	37	9	1.5	0.50	2.3
	–1.496	–20.450	–1.436	–111.807	–121.137	–0.328	–0.76	–262	–3125	–1376	–250	–11.3	–11.4	–103.0
Mean	1.491	18.330	1.425	37.764	106.219	0.219	0.44	118.50	1441.40	339.80	106.00	5.33	3.41	16.41
2) *Unifloral*														
A) *Plectranthus*														
Range	1.488	19.250	1.415	15.076	105.609	0.016	0.06	44	147	52	11	1.9	0.20	1.5
	–1.489	–19.650	–1.419	–26.423	–107.917	–0.246	–0.66	–299	–2614	–250	–237	–6.8	–9.2	–3.8
Mean	1.488	19.450	1.417	20.749	106.763	0.131	0.36	136.50	1380.50	151.00	124.00	4.35	4.70	2.65
B) *Eucalyptus*														
Range	1.488	18.850	1.414	27.712	105.489	0.043	0.08	34	237	52	5	2.3	0.45	1.6
	–1.490	–19.650	–1.419	–28.292	–105.849	–0.050	–0.46	–79	–1394	–74	–92	–4.8	–2.2	–2.7
Mean	1.489	19.250	1.416	28.00	105.669	0.047	0.27	56.50	815.50	63.00	48.50	3.55	1.33	2.15

Source: Mahajan, 1984.

Table 7.2: Correlation matrix of various physicochemical characterstics of honeys of Shimla Hills extracted from *Apis cerana* colonies

Honey type	Refractive index	Specific gravity	Viscosity (poises)	Surface tension (dynes/cm) at 30°C	Electrical conductivity (mho/cm × 10^{-4})	Phosphate PO_4 (ppm)	Potassium K (ppm)	Calcium Ca (ppm)	Magnesium Mg (ppm)	Iron Fe (ppm)	Manganese Mn (ppm)	Zinc Zn (ppm)
Refractive index		0.977**	0.807**	0.596**	–0.219	0.258	0.253	0.568**	0.105	-0.016	0.115	–0.326*
Specific gravity			0.725**	0.512**	–0.077	–0.369*	–0.362*	0.550**	0.249	0.146	0.241	–0.361*
Viscosity (poise)				0.804**	–0.313**	0.061	0.135	0.859**	–0.080	–0.234	–0.103	–0.162
Surface tension (dyne/cm)					–0.124	0.029	–0.300	0.012	–0.107	–0.246	–0.103	–0.034
Electrical Conductivity (mho/cm ×10^{-4})						0.516**	0.642**	0.013	0.720**	0.827**	0.653**	–0.049
Phosphate PO_4 (ppm)							0.951**	0.196	0.928**	0.708**	0.963**	–0.025
Potassium K (ppm)								0.290	0.938**	0.762**	0.923**	–0.031
Calcium Ca (ppm)									0.151	0.046	0.082	–0.081
Magnesium Mg (ppm)										0.748**	0.959**	–0.012
Iron Fe (ppm)											0.788**	–0.127
Manganese Mn (ppm)												–0.144
Zinc Zn (ppm)												

Source: Mahajan, 1984. *$p<0.05$ = Significant; **$p<0.01$ = Highly significant.

glucose, fructose as 70.2, 33.4 and 36.5 per cent, respectively in Indian multifloral honeys, whereas, in Mahabaleshwar (India), these percentage of glucose and fructose varied from 31.2 to 38.3 and 35.2 to 43.3, respectively (Phadke, 1967b). Other authors also analysed honey samples for their sugar contents from Calcutta (Mitra and Mathews, 1968), Travancore (Nair et al., 1950) and Madras (Giri, 1938). These authors showed regional differences in percentages of total sugars, glucose, fructose and sucrose, etc.

Latif et al. (1956) analysed five honey samples of *Apis dorsata* from Pakistan and showed that average percentages of reducing sugars, glucose, fructose and sucrose in these samples, were 69.2, 27.0, 42.2 and 1.43, respectively (Table 7.3). Phadke (1968) carried out such analyses on Indian honeys extracted from 20 nests of *Apis dorsata* and concluded that total reducing sugars averaged 69.5 per cent, whereas, the percentages of glucose, and fructose in these samples varied from 29.8 to 33.8 and 34.6 to 39.9, respectively. Similar sugar content analyses extracted from *Apis dorsata* colonies from Travancore and Calcutta were carried out by Mitra and Mathew (1968) and Nair et al. (1950) which represented interregional differences.

The total reducing sugars, glucose, and fructose in honey samples extracted from *Apis florea* nests in India averaged 71.2, 32.3 and 38.9 per cent, respectively. Latif et al. (1956) reported lower total reducing sugars but higher fructose content in *Apis florea* honey samples from Pakistan (Table 7.3). Giri (1938) studied 12 samples of Indian honeys for acid phosphatose activity and reported that this enzyme was effective over pH ranges from 3.5 to 6.5; and at a temperature of 35°C.

Deodikar and Phadke (1966) concluded that the Fieh test for presence of hydroxymethyl furfural (HMF) in honey should be regarded as quantitative rather than qualitative. According to HMF contents honeys may be graded as follows:

HMF contents μ gm/gm of honey	Grade
0–10	I
11–20	II
21–30	III

Phadke and Nair (1968) further suggested that 30 μ gm of 5-hydroxymethyl furfural per gramme would be reasonable value for honeys produced in tropical climate.

The amino acid composition of Indian honey from *Apis cerana* colonies revealed that lysine, arginine, proline, valine, methionine, isoleucine and leucine along with asparatic acid, glutamine, serine, glycine, histidine and alanine were present (Kalimi and Schonie, 1964).

Table 7.3: Composition of Pakistan honey

	Moisture per cent	Reducing sugar per cent	Levulose per cent	Dextrose per cent	Sucrose per cent	Ash per cent	Formic acid per cent
Honey Analysis of Government Sample							
Government Apiaries:-							
1. Lyallpur							
(a) Capped honey ...	16.6	71.1	40.5	33.8	2.04	0.220	0.115
(b) Uncapped honey ...	20.6	58.56	30.78	30.34	4.90	...	0.103
(c) Clover flow ...	15.6	76.0	48.85	27.20	2.75	...	0.138
(d) Blended honey ...	18.6	76.8	50.0	31.05	2.5	...	0.161
(e) Brassica flow ...	21.2	73.84	44.15	33.44	2.18	0.148	0.0977
2. Sialkot ...	14.3	76.90	41.4	34.2	2.0	0.268	0.138
3. Chattar ...	15.5	69.8	39.01	33.9	1.66	0.112	0.078
4. Hassanabdal ...	17.6	74.5	48.8	30.53	1.09	0.32	0.069
5. Murree ...	16.56	76.6	53.88	27.07	1.56	...	0.069
Honey Analysis of Three Species of *Apis*							
(1) *Apis florea* F. ...	17.4	62.92	40.38	28.26	1.8	0.183	
(2) *Apis dorsata* F. ...	16.2	69.23	42.23	27.00	1.43	0.158	
(3) *Apis indica* F. ...	16.4	73.53	42.8	32.5	2.12	0.113	

Source: Latif *et al.* 1956

The content of vitamins such as riboflavin, niacin, thiamine and ascorbic acid in Indian honeys from *Apis cerana* colonies varied from 12 to 54; 442 to 798, 8 to 22, 2000 to 3400 μ gm per 100 gm of honey. These authors also found that after storage of honey at 28–30°C for one year, 20 per cent of the vitamins were lost (Kalimi and Schonie, 1965).

Various characteristics of honey are influenced to some extent by its mineral composition. Ash represents the amount of dry matter present in honey. Latif et al. (1956) showed that the ash content in samples of Pakistan honey ranged from 0.11 to 0.32 per cent. In Indian honeys, the ash content ranged from 0.03 to 0.52, 0.014 to 0.048, 0.03 to 0.46 and 0.11 to 0.25 in *Apis cerana* honey samples from Calcutta, Mahableshwar, Madras and all India representative samples. According to Mahajan (1984), white or light coloured honey samples of *Apis cerana* from Shimla hills showed lower ash content (0.06–0.9 per cent), whereas, darker coloured honey samples were higher (0.33–0.76 per cent) in ash content (Table 7.1). The total ash content in *Apis dorsata* honeys from the Philippines, Pakistan and India averaged 0.17, 0.26 and 0.39 per cent, respectively (Minh et al., 1971; Latif et al., 1956; Phadke, 1968). In *Apis florea* honey samples, ash content varied from 0.48–0.54 with an average of 0.52 (Phadke, 1968).

Singh et al. (1975) determined the ash content in samples of Indian honeys by the cationic exchange method and also determined the quantity of acid liberated. The ash values calculated from this formula showed a close agreement with the sulphated ash content of samples determined by conventional methods. Kalimi and Schonie (1964) showed that the amount of sodium, phosphorous, iron and magnesium in ash extracted from Mahableshwar ranged from 18.2 to 45.4, 17.2 to 34.2, 169–389 and 47 to 122 ppm, respectively. Mahajan (1984) reported an average ash content of 0.04 per cent in *Apis cerana* honey samples from the Shimla hills. The average concentrations of phosphate, potassium, calcium, magnesium, iron and zinc in these samples were 118, 1432, 265, 109, 5–3, 3.71 and 11.9 ppm, respectively. She also found that electrical conductivity showed significant positive correlation with most of the minerals such as potassium, magnesium, iron and manganese content (Tables 7.1 and 7.2).

7.1.2 Honey Production and Marketing Strategies in China

There is an increasing demand for honey in the world market. This is because of the higher living standards and greater interest in natural foods particularly in developed countries. The world production of honey shows a decreasing trend particularly in the developed countries (Table 7.4). A shortage of hive products in the world market offers new sales opportunities for exports.

A honey market report prepared by International Trade Centre, UNCTAD/GATT (1986) revealed that world production of honey was estimated at over 997,157 MT in 1984, and only less than 20 per cent of this entered the world trade. There are at present fifteen countries in the world which account for 90 per cent of world honey exports. Among these, China is the only country in this region which is the biggest exporter of honey in the world (Table 7.6). Keeping in view the major role of China in world honey trade, past history and present policies of production and export in China are reviewed as follows:

Table 7.4: Honey production in China, Asia and World

Years	Honey production in China (MT)	Honey production in Asia (MT)	Honey production in World (MT)	Percentage of total Asian production in China	Percentage of total World production in China
1975	227609	26335	874808	84.79	26.01
1976	238481	23206	960465	84.35	24.82
1977	247316	25426	943903	85.16	26.20
1978	247313	20491	973023	84.17	25.41
1979	110495	43186	873738	68.74	12.64
1980	80764	51028	821965	62.89	9.82
1981	115600	62513	885302	65.06	13.05
1982	136605	69695	965557	68.19	14.14
1983	143605	56643	990862	70.28	14.49
1984	160605	48115	997157	73.38	16.10
1985	—	—	—	—	—
1986	—	—	—	—	—
1987	204000	—	—	—	—
1988	186500	—	—	—	—

Source: International Trade Centre UNCTAD/GATT. 1986
USDA Foreign Agricultural Service, 1988.

Significance of honey in Chinese history: In some Hindu Kush-Himalayan countries, honey was known as the earliest known sweetening food source. Surprisingly, this is not true for China, where honey came into use later than many other forms of sweet foods. The role of honey in Chinese history has been reviewed by Kellog, 1967 and Kellog and Tang, 1963. A brief description of their work is as follows:

Ancient writings (Chow Dynasty, 1122–205 BC) reveal that the earliest sweet food in China was maltose, extracted from fermented grains of rice and wheat. The use of the word "honey" in the Chinese language was mixed up with maltose. For example, old Chinese dic-

Table 7.5: Quality of Chinese honey

Honey Grade	Percentage of Total	Major Plant Sources
Superior and	—	Citrus and Pipa
I	20	Milkvetch, Acacia, Water melons, Lenden and Citrus
II	70	Rape-seed
III	10	Cotton, Palm tree

U.S.D.A. Foreign Agricultural Service, 1988.

Table 7.6: Honey production and export by China

Years	Honey production in (MT)	Honey export	Percentage of total domestic production exported	Percentage of total Asian exported	Percentage of total World production exported
1975	227609	26083	11.46	99.04	17.369
1976	238481	22117	9.27	95.30	12.106
1977	247316	25120	10.16	79.09	14.224
1978	247313	20111	8.13	98.14	10.98
1979	110495	42608	36.56	98.66	21.560
1980	80764	49296	61.03	96.60	23.541
1981	115600	60205	52.08	96.30	24.482
1982	136605	66256	48.50	95.06	26.289
1983	143605	53202	37.05	93.92	20.245
1984	160605	45059	28.05	93.64	16.725
1985	—	—			
1986	—	80589			
1987	204000	66381	39.94		
1988	—	70000 (projected)			
1989	over 200000	70000			

USDA Foreign Agricultural Service, 1988.
International Trade Centre UNCTADD/GATT, 1986.

tionaries describe honey as "sweet maltose produced by bees". They also termed honey as a "close" or "secret" valuable food because it was stored by bees in closely spaced combs of dark nests. It was only during the third century B.C. that honey was recognized as a separate distinct individual sweetening source and one can read in the literature statements like "this taste is not like maltose or honey".

In the fourth century B.C., Prince Yueh bartered honey for a piece of land and also presented it as a gift to the Prince of Wu. In 25 A.D., Emperor Kwan, while ascending the throne, gifted cattles and honey to one of his friends. These examples suggest that in olden times, honey was considered as a precious, luxurious and highly priced commodity in China. In the beginning of the first century A.D., one finds frequent examples in the literature about honey being imported into China from the West and being bartered for precious commodities like silk.

In China, the Government encouraged beekeeping and honey production in as early as 300 A.D. At that time, the agriculture minister of the empire used honey to polish his pots and pans. During TS' dynasty (265–419 A.D.), a Government proclamation stated "Beekeepers can collect ten measures of honey as a maximum: if any persons can collect two pints more, he will be rewarded with ten bushels of rice."

In China, the first use of honey as medicine was mentioned in "Materia Medica of Shen men Shih" written during the period 25 to 110 A.D. Later, Dr. Chang Chi recommended the use of honey as a laxative in his medicinal book "Shang Lung". The role of honey in promoting long life has been advocated in the Chinese system of medicine since ancient times, and even today it is considered a valuable "drug of longevity".

In earlier times, honey was named as "ground honey", "wood honey", "bamboo honey" or "stone honey", depending upon whether the honey nest was located on the earth, tree or rocks, respectively.

Although China today is one of the top producers of honey in the world, but for a common man, it is still a luxury item which is scarcely available and highly priced. It is generally used for medicinal purposes and occasionally mixed with tea or taken as a refreshing drink on a hot day.

Recent trends in honey production in Peoples Republic of China

The present honey production policy in China has been reviewed by USDA, Foreign Agricultural Service, 1988; International Trade Centre, UNCTAD/GATT, 1986; Zhenming, (1990); Wongsiri et al. (1986); Xianshu, (1985); Schumacher, 1969, 1979, and 1980.

After the USSR, China is the second largest honey producer in the world. Tables 7.4 and 7.6 show the recent trends in honey production in China. According to a recent report published by USDA Foreign Agricultural Service (1988), China produced a total 204,000 MT of honey in 1987 from about 8,320,000 colonies. Out of this quantity, 166,200 MT was produced in modern commercial apiaries and the remaining 38,000 MT through traditional methods. In 1987, there were 6,820,000 bee colonies kept in modern bee hives for commercial honey production, and the average honey production per hive was 24.5 kg. There are about 24 species of plants (See chapter 9) which act as major sources of honey in China, and these occupy a total area of 22 million hectares which can provide good forage for over 30 million bee colonies. Projected commercial honey production in China by the year 1990 will be 1,86,500 MT from 7 to 9 millions bee colonies. Chinese honey is well known because of its good aroma and high dextrose content. But sometimes it contains sediments of loose-soil in the honey. Of the total honey produced in China, 20 per cent is classified as first grade, 70 per cent as second grade and the remaining 10 per cent as third grade honey (Table 7.5).

As in other parts of the world, honey production in China has fallen significantly in recent years as compared to the middle and late seventies when its production was maximum (Table 7.4). During the peak honey production years (1975–1979), China produced about 84–85 per cent of the total Asian production, and 25 per cent of the total world production. However, in recent years, these figures have come down to 60–70 per cent of the total Asian production and 13–14 per cent of the total world production (Table 7.4).

However, the Central Government and regional agencies in China are determined to promote beekeeping in China on a large scale. It plans to establish new commercial apiaries in Hubei, Sichuan, Heilongjiang, Hunan, Henan, Shaanxi, Zhejiang, Fujian, Jiangsu and Annui provinces with a total investment of 1.82 million US dollars, and has the target of increasing honey production by 13,000 MT per annum (USDA Foreign Agricultural Service, 1988). Unlike many developed countries of the world, where the new major thrust is on increasing the yield per hive, in China the policy is to increase the production by increasing the number of colonies.

China has both full-time commercial beekeeping enterprises and part-time small-scale beekeeping farmers. The majority of apiaries in China are household apiaries each with 50 to 80 bee colonies. The average size of an apiary in China is about 30 bee colonies. Whenever beekeeping is practised on a commercial scale, migratory beekeeping is very common. Bee hives are moved to good honey flow and suitable climatic zones either in trucks or by train. In China, honey production is primarily for export purposes, to increase the state income. For each ton of honey exported, it can import 3.5 tons of steel and 6 tons fertilizers (Svensson, 1977).

In 1987, 60 per cent of the total commercial honey produced in China was consumed in the domestic market in the following market segments:

Table honey	= 38 per cent
Chinese medicine	= 47 per cent
Food and beverage industries	= 15 per cent.

Honey export from China

China is the largest honey exporter in the world (Table 7.6). The Chinese have achieved this distinction because honey experts and economists in China are aware that:

i) There is a growing demand for honey in the developed countries of Europe, Japan and the USA, thus there exist a large, ready, and potential market for this hive product which can easily earn hard currency.

ii) Honey exported from China matches the international standards in quality, consistency and packing.

iii) Chinese honey meets standards of foreign food laws.

iv) Honey pricing policy is consistent and competitive.

In China, honey export is handled by provincial branches of the China Native Products Import/Export Corporation which is under the control of the central office in Beijing. This corporation has foreign offices in countries to which the major produce is exported such as to the USA, Japan, etc. After production, the quality is thoroughly checked by a state official, and an export certificate is furnished which accompanies the shipment. Honey is packed in new steel drums which are laquered green-red. These drums have the capacity of 640 litres net, and the smaller ones have a 200 litre capacity.

China's honey exports were maximum in 1986 when it exported 80,589 MT of honey, but in 1987 the export declined to 66,381 MT. A projected export quota for the year 1988 was marked about 70,000 MT. (Table 7.6).

The declining trend for China's export of honey may, due to more attractive domestic markets, as a result increase in the standard of living and can afford to pay higher prices. On the other hand, prices of honey in international markets are dropping and so is demand. For example, EEC now buys honey from the USSR at a very attractive competitive price, and similarly honey prices in the USA in recent years have fallen off, as a result, higher priced Chinese honey is in less demand. Japan is the only market for Chinese honey ready to pay top dollar prices.

7.1.3 Honey Production and Trade in the Hindu Kush-Himalayan Countries other than China

In the Indian subcontinent, honey has been referred as man's earliest food, and it has been valued throughout successive civilization. There are references to honey in the Vedas, the Ramayana, the Book of Proverbs, the Quoran and many other ancient books. In ancient times, it was common practice in this region to accept honey and beeswax by the ruling class for the payment of taxes and tributes. It has been considered as the most valued food at all important occasions including birth and death rites, and festivals. All ancient literature of the Hindu Kush-Himalayan region give details of honey as man's first food and the first available sweet. Information on honey production and trade in the Hindu Kush-Himalayan countries is reviewed in Table 7.7.

1. India

The FAO 1986 figures for total honey production in India is 18,000 MT. About half or more of this quantity of this total production is harvested from wild colonies of *Apis dorsata* and *Apis cerana* from forests and other areas. Keeping in view the total area of the country as well as the potential for beekeeping development in India, it has been estimated that there is enough bee forage in terms of cultivated crops and wild plants in India to support more than 5 million bee colonies (Thakar, 1976). This would mean substantial and reliable income to the tribal and rural population in the country. Most of the marketed honey in India is used for household purposes. Its use as table honey varies from 88 to 95 per cent of the total consumption. The remaining honey is used in bakery, confectionery and cereal foods. In India, it is also used in baby food, tobacco, pharmaceutical and cosmetic industries. In the past, (1977–1982), Malaysia, France, Nepal, the Netherlands, Singapore, Sri Lanka, Yeman and the Arab Republic have been the main importers of Indian honey. Among them Singapore had been a regular importer. However, the total amount of honey exported to these countries is almost negligible, i.e., about 3 tons per year (Joshi, 1982). Nepal had been importing honey from India earlier but now it is mainly China and Australia who export honey to Nepal.

In the past, traditional unhygienic methods of harvesting honey rendered the product unmarketable, even after a short period of time. The tropical and humid climate in many of the honey-producing areas was another serious constraint which affected the keeping quality of honey. However, in recent years, steps taken by the Government of India with regard to honey processing and marketing has removed these bottlenecks. The recent establishment of a separate ministry for processing food materials creates ways to facilitate processing and marketing of honey. The Government of India in 1988 removed the excise duty on equipment manufactured for use in the beekeeping industry. Honey-processing equipment and machinery would naturally be the major beneficiary of this policy (Tonapi, 1988). Himachal Pradesh is the only area in Southeast Asia which has announced support price for honey. The Indian Standard Institution (ISI) has laid down specifications for the different types of honey produced in India. These are summarized in Table 7.8.

2. Pakistan

In Pakistan, the annual production of honey from different species of honey bees is about 640 tons. About 14 to 18 per cent honey comes from domesticated hive bees *Apis mellifera* and *Apis cerana* kept in modern moveable frame bee hives, and the rest of the honey is harvested mainly from wild *Apis dorsata* colonies and also from *Apis cerana* colonies kept in traditional hives as well as those found in the wild state. The amount of honey harvested from wild *Apis florea* colonies is negligible but is of great medicinal value (Ahmad, 1990). The bulk of the honey in Pakistan from wild *Apis dorsata* colonies is harvested by using a very crude squeezing method. Such honey is very high in moisture content and it granulates and ferments very quickly. Sometimes, it is only a matter of few days, that the whole lot of such honey gets spoilt and becomes unfit for human consumption. The main reason for this poor standard of honey is ignorance. Honey hunters and traditional beekeepers have very little knowledge about the extraction and processing of honey. It has been estimated that through such crude methods of honey extraction, about 15 to 20 per cent of the total honey produced in Pakistan is lost (Ahmad, 1986). Some of the specifications for honey from Pakistan are given in Table 7.8.

3. Bangladesh

In Bangladesh, the average honey yield per colony of *Apis cerana* is quite low, i.e., 4 kg per colony. Honey is harvested quite frequently; sometimes, even every week. There are about 5,000 to 10,000 colonies of *Apis cerana* kept in different types of hives by about 8,000 beekeepers. The average number of bee colonies owned by a beekeeper is one or two. The Sunderbans in Bangladesh are major honey-producing areas and in these forests, concentration of *Apis dorsata* colonies is very high. More than 95 per cent honey in Bangladesh is consumed as table honey and the rest is used for medicinal and pharmaceutical purposes. Honey is stored and packed in plastic containers. This country also imports honey from Australia. Domestic honey is sold at prices between 3 and 4 US dollar per kilogramme (Svensson, 1988).

Table 7.7: Honey market situation in Hindu Kush-Himalayan region

	Bangladesh	*Bhutan*	*China*	*India*	*Nepal*	*Pakistan*
Consumers of honey	Local people + tourists + pharmaceutical	Local people + tourists	Local people	Local people + pharmaceutical	Local people + tourists + pharmaceutical	Local people + pharmaceutical
Price of honey per kg in US$	3.0	3.0	3.0	3.0	2.5–11.0	2.25
Trading system	Nil	Non-existent	Well developed	Honey co-operatives	Non-existent	A few honey co-operatives
Availability of honey	Scarce	Scarce	Scarce	Scarce	Scarce	Scarce
Consumer demand versus local supply	Demand is greater than supply	Demand is greater than supply	Demand is greater than supply	Demand is greater than supply	Demand is greater than supply	Demand is greater than supply
Honey import	Australia	Indian origin	Nil	Negligible Europe	China, Australia	–
Honey export	Negligible	Nil	Japan etc.	Negligible	Nil	Negligible
Honey containers	Plastic & glass bottles	Glass bottles	Glass or Plastic bottles	Glass or Plastic bottles	Glass or Plastic bottles	Glass or Plastic bottles
Annual honey production	30 tons	Negligible	204000 tons	18000 tons	26	640 tons

Average yield/ colony	4 kg with *Apis cerana*	3–5 kg with *Apis cerana*	24.5 kg with *Apis mellifera* 20–30 with *Apis cerana*	5–8 kg with *Apis cerana* 18 kg with *Apis mellifera* 30 kg with *Apis dorsata*	15 kg with *Apis cerana*	3–5 kg with *Apis cerana* 18 kg with *Apis mellifera*
Market segments:						
Table honey (%)	95	95	38	88–95	95	90–95
Pharma-ceutical (%)	5	5	47 5 food and beverage industries	5–12	5	5–10
Honey harvesting methods	Both by centrifugal extraction & squeezing	Both by centrifugal extraction & squeezing	Mainly by centrifugal extraction	Both by centrifugal extraction & squeezing	Both by centrifugal extraction & squeezing	Both by centrifugal extraction & squeezing

Source: Compiled from multiple sources.

Table 7.8: Specifications for different types on honey in India* and Pakistan**

Sr. No.	Characterstic	Indian Extracted Honey			Indian squeezed honey	Indian *Carvia callosa* honey	Pakistani honey	International standard
		Special grade	A Grade	Standard grade				
1.	Minimum specific gravity at 27°C	1.41	1.39	1.37	1.37	1.4	—	—
2.	Maximum moisture percent by mass	20	22	25	25	20	18.6	21
3.	Minimum total Reducing sugars percent by mass	70	65	65	65	60	71.1	65
4.	Maximum sucrose percent by mass	5.0	5.0	5.0	5.0	10	2.75	5
5.	Minimum fructose-glucose ratio	1.0	1.0	1.0	1.0	1.0	1.40	—
6.	Maximum ash percent by mass	0.5	0.5	0.5	0.5	0.5	0.32	0.6
7.	Maximum acidity expressed as formic acid present	0.2	02	0.2	0.2	0.2	0.69	—
8.	Fiehe's test	Negative	Negative	Negative	Negative	Negative	—	—

9.	Minimum Total count of pollens and plant element/gm honey	—	—	—	50000	50000	—	—
10.	Minimum Topical Density at 660nm	—	—	—	0.3	0.3	—	—

*Source: Indian Standard Institution, 1975a, 1977 a,b

**Latif *et al.*, (1956)

4. Nepal

In Nepal, local farmers harvest honey from traditional hives during spring (March–April), pre-monsoon (June–July) and autumn (October–November) seasons. In each of these honey-flow seasons, honey is harvested after every two or four weeks after the bees have occupied the hive in the lowland areas. In the highland areas, because of the temperate climate, beekeepers can harvest honey only once or twice a year. The quantity of honey harvested from traditional hives from both highland and lowland areas is quite low, 2 kg from *Apis cerana* hives. However, there are now progressive *Apis cerana* beekeepers in the Kathmandu valley of Nepal, who use modern moveable frame hives and the average honey yield from such *Apis cerana* hives is 15 kg per colony per year.

Local beekeepers sell domestic honey at different prices depending upon the demand for honey in a particular region. For example, in mountainous parts and in the western region, where the demand exceeds supply, honey is more expensive as compared to the Terai and eastern regions, where villagers grow sugar cane. Honey is consumed by the beekeepers as well professional honey hunters themselves as a food or for other purposes. Most of the villagers in Nepal chew honey along with the comb, whereas other honey consumers, who must buy honey directly from beekeepers or the market, use it for medicinal and religious purposes and seldom for table consumption.

In Nepal, the prices of honey vary considerably, 2 to 20 US$ per kilogramme. Nepal imports honey from China, Europe and Australia and the price of exported honey is the highest, 20 US$ per kilogramme. Keeping up with this trend, some progressive beekeepers in the Kathmandu valley also sell their domestic *Apis cerana* honey at a rate which is competitive with foreign honey. However, squeezed honey from wild colonies is sold at a very low price of about 2 US$ per kilogramme (Wadhi, 1961, Crane 1984, Strickland, 1982 and Nakamura, 1989).

5. Bhutan

In Bhutan, the local people and tourists are the main consumers of honey. Demand is much greater than supply, and Bhutan imports honey from India. The price of honey in Bhutan is about 50 Nu (3 US$ per kilogramme). There is no trading system for honey in Bhutan.

7.1.4 Suggestions for Improvements of Honey Processing and Marketing

Except for China, there is hardly any policy being adopted in other countries of the Hindu Kush-Himalaya for the scientific processing and marketing of honey. With the introduction of the European honeybee, *Apis mellifera*, into some of the countries of the Hindu Kush-Himalayan region, honey production is likely to increase tremendously, and the processing and marketing problems are likely to become more serious. It is time that the different Governments take up these problems so that the beekeeping industry in the region can develop on scientific lines in a planned way. Some of the suggestions for the improvements of honey processing and marketing are:

1. There is a need to recognize that centrifugally extracted apiary honey is distinct from the honey collected by traditional squeezing methods. The former should be processed and marketed as "table or medicine honey", whereas squeezed honey should be used for industrial purposes.
2. There should be different price policies for table and squeezed honey.
3. Honey should be recognized as a natural and primary food product like fruits, vegetable, etc. There is a need to increase honey consumption as a nutrient food than as medicine. For this purpose, wide publicity through the media is required to popularize honey to different categories of consumers.
4. Since quality is one of the major considerations of the importers, it is essential that the honey be pure, clean and uniform. Consequently, all producing countries should lay major emphasis on quality control which is at present lacking in the Hindu Kush-Himalayan countries.
5. While exporting honey, it should be kept in mind that the developed countries are potential markets for honey export, and in these countries they prefer fresh, light coloured, liquid and unifloral honey.
6. In the Hindu Kush-Himalayan countries, honey is still packed in an odd assortment of glass bottles. In a country like India, high density polymers, which meet the requirements for international honey markets, are now available and should be used for packing honey.
7. New suppliers and smaller exporting countries as is the case in the countries of this region, should establish regular trade channels through reliable agents/importers or packers in the target markets.
8. National honey boards in individual countries of the Hindu Kush-Himalayan region should be established on a pattern similar to the United States National Honey Board to look after all aspects of honey handling from hive to market.

9. Smaller countries of the Hindu Kush-Himalayan region should also follow the example of China and India, where specifications for quality control of honey in terms of its physico-chemical properties have been laid out.
10. Marketing strategies for honey should be planned in such a way that soon after it is harvested, the storage and transport time is reduced to an absolute minimum. This problem has specific relevance in marketing of honey in the mountain region where the honey is produced at a considerable distance from the consumer market.
11. Honey cooperatives for the processing and sale of honey and other hive products should be formed because it is too expensive for an individual beekeeper to purchase and install honey-processing equipment and machinery.

7.2 BEESWAX

Beeswax has been widely used for several commercial purposes for many centuries. Egyptians were the first to use beeswax for the preservation of their dead. Romans made extensive use of beeswax for writing, modeling, candles, and in the preparation of salves and medicines (Eckert and Shaw, 1976). One early example is its presence in a Ninth Century Viking ship found at Oseberg (Sebelien, 1913).

Beeswax is secreted by the four pairs of wax glands of the worker bees located on the ventral side of their abdomen, and it is synthesized in their body from the reducing sugar. It is generally secreted in the form of wax scales, and it has been estimated that about 1.5 million wax scales are required to produce one kilogramme of wax (Coggshall, 1949; Snodgrass, 1925; Phadke et al., 1969). There are contradictory reports in the literature regarding the amount of honey actually consumed by bees during wax production. According to Eckert and Shaw (1976), for the production of 1 kg of beeswax about 34 kg of honey is consumed. However, Phadke et al. (1969, 1971) reported that only 10 to 15 kg of honey is needed. Whitcomb (1946) reported that 7.5 to 10 kg of honey is consumed.

In the Hindu Kush-Himalayan region, wax is extracted by melting the combs in hot water. Wax accumulates on the water surfaces, and is then strained or filtered to remove the gross impurities, and allowed to solidify in tins or moulds. This traditional method of wax extraction, however, is gradually being replaced by modern solar extraction methods, wherever modern beekeeping with moveable frame hives is practised. Solar wax extractors are now commonly available and it is a cheaper and better method of wax extraction. Indian Standard Institution (1977c) has laid down the specifications for solar beeswax extractors.

According to an FAO (1986) report, China is the largest producer of beeswax in the world. In 1982, it produced 12,800 MT of beeswax, whereas, the world total production was 43,400 MT beeswax during this year. However, there were no net import and export figures available for this country. At present, India is producing about 15 to 20 MT of beeswax. Earlier, India used to export wax to the USA, the Federal Republic of Germany, the UK, France and Japan. However, most of the beeswax now produced is utilized in domestic markets. At present, Nepal and Bhutan export beeswax to India (Joshi, 1982).

In the Hindu Kush-Himalayan region, beeswax is produced from *Apis cerana* and *Apis dorsata / laboriosa*. It has been estimated (Phadke et al., 1969) for *Apis dorsata* colonies that on an average a commercial honey yield of 100 kg corresponds to a wax production of 1 to 2 kg. The yield from *Apis cerana* is rather small. The beeswax collected from the Hindu Kush-Himalayan bees is different in physico-chemical properties as compared to *Apis mellifera* beeswax. It is not acceptable to the European export market mainly because the largest user of bees wax is the cosmetic industry which uses formulae that have been designed from *Apis mellifera* beeswax. In this region, beeswax is mainly used for comb foundation sheets, in the batik industry and in casting bronze. Now, the cosmetic industries in Asian countries, especially Japan and India, use formulations designed for the wax produced by native bees. (FAO, 1986). Specifications for different types of beeswax produced in India are given in Table 7.9.

Beeswax from *Apis mellifera* has been a subject of intensive investigation. It consists of a mixture of different classes of components and each of these classes is itself a mixture of a series of compounds. The major constituents of *Apis mellifera* beeswax are

Hydrocarbons	=	14%
Monoesters	=	35%
Diesters	=	14%
Triesters	=	3%
Hydroxy monoesters	=	4%
Hydroxy polyesters	=	8%
Free acids	=	12%
Acid polyesters	=	2%
Free alcohols	=	1%
Unidentified	=	6%

More than 300 individual components of beeswax have been identified. Among these, the predominant are: C_{40} (6%), C_{46} (8%),

Table 7.9: Specifications for Indian beeswax

	Apis mellifera	*Apis cerana*	*Apis dorsata*	*Apis florea*	*Apis sp.* mixed
Colour	–	–	–	–	Dark yellow brown
Specific gravity at 22.2°C	0.9520	0.9659	0.9541	0.9461	0.960–0.980
Melting point 0°C	62.5	64.8	59.6–66.7	63.0	61–65
Refractive index at 72°C	1.4398–1.4451	1.4431	1.4409	1.4417	–
Saponification cloud point	—	85–105	62.1	—	85–105
Specific heat (cel gm)	—	—	—	—	0.484
Conductivity (... $cm^{-1} \times 10^6$)	—	1.36	1.66	1.37	—
Specific resistance ... $cm^{-1} \times 10^6$	—	0.73	0.60	—	—
Dielectric constant K at 1000 cycles	—	1.43	1.76	1.26	—
Maximum iodine value	—	10.00	—	—	10.00
Maximum acid value	—	8.0	—	—	10.0
Maximum ash percent	—	0.2	—	—	0.5
Maximum total volatile matter percent by mass	—	0.75	—	—	0.75
Maximum insoluble matter in benzene per cent by mass	—	1.0	—	—	—
Maximum matter soluble in water per cent by mass	—	0.5	—	—	—

Source: Phadke *et al.* 1969
Latif *et al.* 1960
Indian Standard Institution, 1975b.

C_{48} (6%), monoesters and C_{24} acid (6%). All these exceed 5 per cent of the total (Tulloch, 1980).

The comparative composition of beeswax extracted from different species of honey bees is given in Table 7.10.

Table 7.10: Partial composition of single samples of Asiatic beeswaxes, determined by GLC relative to internal standards

Components	*Apis dorsata*	*Apis cerana*	*Apis florea*
Hydrocarbons	9	11	15
Monoesters	23	28	31
Free acids	2	3	3
Hydroxy monoesters	12	?	?
Total volatile	46	42	49

Source: Tulloch, 1980

Commercially beeswax is important for the cosmetic, industrial beekeeping purposes. The major part of world beeswax production is consumed by the cosmetic industry. It is mainly *Apis mellifera* beeswax which is used for the manufacture of cold creams, lipsticks, lip pomades and various lotions.

Beeswax has several other industrial uses. For example, it is exclusively used for the manufacture of church candles and it is also an important ingredient in polishes, engraving materials, castings, dental equipment, ornaments and confectioneries (Poncini, 1987).

In the Hindu Kush-Himalayan region, it is only India, China and Pakistan which use extracted beeswax for the manufacture of comb foundation sheets. In addition, it has value as an ingredient of folk medicines in the pharmaceutical industry. In this region, beeswax production from *Apis dorsata / laboriosa* offers great untapped potentials. It is mainly the ignorance of the producer of beeswax that at present only insignificant quantities are being collected and sold in the local market. Beeswax production technology is simple to follow. The investment for collection, refining, grading and packing are comparatively low and finished products fetch a good price. Thus, it is an important income-generating activity. Market information on beeswax is not available for the correct assessment of its production and various commercial uses. There is also a need to check adulteration of beeswax with other artificial ingredients.

7.3 POLLEN

At present, China is the only country in the Hindu Kush-Himalayan region which produces about 1,000 MT of pollen per annum. Commercial production of pollen in China started in 1983 (Guanhuang, 1990). The Hindu Kush-Himalayan region, because of its diversity and richness of natural flora, offers great potential for harvesting pollen as a surplus hive product. It is almost a free resource and can be collected with minimum investment. It will go waste in nature if not utilized.

Honeybees are the most efficient micro-manipulators of pollen in nature. Pollen can easily be harvested by putting a pollen trap at the entrance of the hive. A pollen trap is a single or double grid device through which the bees entering the hive must scramble, and in this way pollen pellets from their hind legs get knocked off and fall into a tray. It has been estimated that one colony of *Apis mellifera* uses about 50 kg of pollen in a year as a source of proteins, fats, minerals and other substances. Proteins are essential for honeybees in the build up and repair of body tissues, egg production and brood rearing. During a good pollen flow season, it is possible to harvest about 0.5 to 1 kg of pollen per day from one hive of *Apis mellifera*. However, the pollen collection behaviour of *Apis cerana* has been studied in less detail.

Pollen collected by honeybees has many commercial uses which have not been fully exploited in this region. In ancient times, pollen was used for human consumption by the Greeks, Egyptians, Persians and Chinese. Maximum use of pollen is more for feeding the bees during slack seasons when it is not available from the flowering plants. For bees feed it is blended with soybean flour or sugar. It is also used as a dietary supplement for domestic animals. Pollen is now becoming popular for human consumption as nutritional and therapeutic dietary supplements. It is used for treating human sterility because of the presence of gonadotrophic harmones (Ridi et al., 1969). Pollen is also recommended for the proper functioning of human prostrate glands (Traub, 1973). Keeping in view the growing demand for vegetarian food both in the developing and developed countries, the use of pollen as a protein supplement in the human diet will become more important. Pollen is also used for desensitizing persons affected with pollen allergy.

Currently, several experiments are being conducted for the use of pollen in controlled orchard pollination. It may be applied by brush, duster, gun, blower, aircraft or honeybees, and as a result of this practice, the fruit or seed set is enhanced significantly. A device called "pollen insert" has been specially designed for controlled pollination of fruit orchards where sufficient pollinizer varieties are lacking (Jaycox, 1969). Air-dried pollen can be stored for a year at ordinary room temperature but it gradually loses its palatability and nutritive value. In the Hindu Kush-Himalayan region, it has been noticed that many temperate fruit orchards, do not bear sufficient fruit because of inadequate pollination. In such orchards, the use of pollen under controlled conditions as explained above will greatly help in solving the problem of insufficient pollination.

7.4 ROYAL JELLY

Royal jelly is a milky white secretion which is produced from the hypopharyngeal glands of young worker bees. It is secreted exclusively to feed the queen bee throughout her larval and adult life, and also young worker and drone larvae. According to Witherell (1979), the chemical composition of royal jelly as compiled from different sources is:

Moisture	= 66%
Protein	= 12.34%
Total lipid (fat)	= 5.46%
Total reducing substance	= 12.49%
Ash (mineral)	= 0.82%

It is very rich in vitamins B and C, and is lacking in vitamin E. Royal jelly contains 10-hydroxy decanoic acid which has an antibiotic and anti-tumour activity.

China is the only country in the Hindu Kush-Himalayan region which had developed the technology for the production of royal jelly. Total royal jelly production in this country is 800 MT per year. Before 1957, royal jelly in China was produced from queenless colonies on a small scale. Commercial production of royal jelly from queenright colonies started in 1959. A relatively strong colony of *Apis mellifera* in southern China at present produces 0.5 to 1 kg of royal jelly (maximum 2 kg), whereas, in northern China 0.3 to 0.5 kg of royal jelly per colony is produced. This difference in the yield of royal jelly per colony is due to the longer bee activity period (six months). Thus royal jelly production in China is now one of the important components of the beekeeping industry, (Guanhuang, 1990). The wholesale price of royal jelly was about US$ 100 per kilogramme in 1985.

7.4.1 Production Technology

Royal jelly production technology in China as described by Guanhuang (1990) is as follows: A queenright colony is separated into brood chamber and production (Super) chamber by means of the queen excluder. The brood chamber contains the queen, sealed brood and some empty combs, whereas, the production chamber is provided with one to two frames of unsealed larval brood, sealed brood and the combs with honey and pollen stores. For royal jelly production, a large number of nurse bees are needed, and this is achieved by transferring sealed brood combs to the brood chamber. One royal jelly-producing frame with 80 to 100 cups is placed in the production chamber at a time. After 60 to 72 hours of grafting, about 300 mg royal jelly is produced in each queen cell cup. These queen cell cups are regrafted for the production of more royal jelly. Chinese bee scientists have developed special plastic grafting needles and plastic queen cell cups for the production of royal jelly. Beekeepers in rural areas often use sterile brushes to collect royal jelly in a clean bottle and then store it in a refrigerator. However, in big commercial bee farms, royal jelly is collected from the cups by electrical suction.

In China experiments are also being conducted to collect royal jelly from *Apis cerana* colonies. However, the amount of royal jelly produced by this native bee species is much lower than *Apis mellifera*. This difference may be due to the smaller size and activity of the hypopharyngeal glands of individual worker bees, smaller colony size, as well as a concentration of more nurse bees in the brood chamber than in the production chamber in *Apis cerana* as compared to *Apis mellifera*. Since royal jelly gets spoilt with time, it cannot be stored for an indefinite period. In order to overcome this problem, markets for royal.jelly are being developed near the production unit so that it can readily be sold while it is fresh. Further, royal jelly is now mixed with medicine, tonics, beverages, and cosmetic products without any chance of changes in its chemical composition. "Beijing Royal Jelly" extract has now become famous all over the world as a tonic.

7.5 BEE VENOM

Bee venom is stored in the poison sac of the sting apparatus and is injected into the skin of the victim by a pair of barbed lancets. A bee sting on the human body should always be scraped away and never pulled out, because through the latter process, more venom is pumped into the wound. After stinging, a worker bee usually dies on the same day or soon after. A honeybee sting is more poisonous than a wasp's (Benton and Heckman, 1969). For hypersensitive persons, even a single sting can cause death if they are not given timely medical treatment. Under normal circumstances, it may require 500 stings over a short period of time to cause death by direct toxicity.

Bee venom is acidic in nature and its specific gravity is 1.1313 (Beck, 1935). It contains a complex array of chemically and pharmacologically active substances. Among them the major ones are: histamine, dopamine, melittin, apamin, mast-cell destroying (MCD)-peptide, minimine, and the enzymes phospholipase A and hyaluronidase (Hodgson, 1955; Beard, 1963; Habermann, 1972; Munjal and Elliott, 1971). A comparison of venom composition of *Apis cerana japonica* and *Apis mellifera* is given in Tables 7.11 and 7.12.

Table 7.11: Peptide contents in the venom sac of *Apis mellifera* and *Apis cerana japonica**

Species	No. bees	Melittin	Apamin	MCD-peptide
Apis mellifera	21	310 ± 59	6.8 ± 1.5	5.5 ± 1.2
Apis cerana japonica	26	108 ± 34	1.6 ± 0.6	—

* Contents are expressed as μg/sac (mean ± SD)
Source: Inoue, H. and Nakajima, T. 1985.

Table 7.12: Amine contents in the Venom Sac of Bumble Bees and Honeybees*

Species		DOPA	Nad	DA	His	SHT
*Apis mellifera**	21	—	388 ± 168	643 ± 375	1425 ± 431	12 ± 5
Apis cerana japonica	12	—	154 ± 60	142 ± 69	24 ± 20 (7)	—
*Bombus diversus**	7	215 ± 151 (6)	344 ± 182	352 ± 169	16 (2)	—
*Bombus ardens**	6	547 ± 351 (5)	298 ± 94	1126 ± 704	637 ± 295	41 ± 38

* Contents are expressed as ng/sac (mean ± SD). Figures in the parentheses are number of bees examined.

Source: Inoue, H. and Nakajima, T. 1985.

In order to extract sufficient bee venom for scientific and medical uses, a special electrical grid which elicits the stinging response is placed near the entrance of the hive. This grid produces a mild electrical shock, and the bees who land on it react by stinging a sheet of nylon taffeta below this grid. The venom is collected on the glass plate located below the taffeta where it dries and is removed after scraping with a blade. In India and China, indigenous electric venom collectors have been designed, and through them it is possible to collect pure venom without causing injury to the bees.

Bee venom has several medical uses. It can cure rheumatoid arthritis, and is also used for the desensitization of patients allergic to bee stings. In recent years, bee acupuncture therapy for the treatment of various human disorders has come into wide use.

7.6 PROPOLIS

Pro and Polis are two Greek words which mean before and city, respectively. Propolis is a resinous substance collected by forager bees to seal the hive crevices and reduce its entrance point. It is gathered from the sticky and gummy exudations of trees and buds such as alders, poplars and some conifers. Propolis is collected mainly by *Apis mellifera* and not by *Apis cerana*. Because of its sticky nature, it contaminates beeswax and causes difficulty in removing frames at the time of honey harvesting or during inspection of the hive. However, recent discoveries have shown that this product is quite valuable because of its anti-bacterial and anti-fungal properties. These anti-microbial properties are due to the presence of flavones and related compounds. Many of these flavonic components have already been identified (Popravko, 1969). In addition, propolis also contain 30 per cent waxes, 55 per cent resins and balsams, 10 per cent etheral oils and 5 per cent pollen (Cizmark and Matel, 1970, 1973).

In China, research work is in progress for the commercial production of propolis. It is recovered from the hive by direct scrubbing. In Japan, total yield from a hive is about 50 g. In China, it is mainly an export item, and a very small quantity is used for medicinal purposes (Guanhuang, 1990).

One of the commercial products under trial in China is "Propolis soap" because of its anti-microbial properties. However, western bee scientists believe that pharmaceutical uses of propolis needs further investigation.

CHAPTER 8

Honeybee Resources: Biology and Management

8.1 GEOGRAPHIC DISTRIBUTION OF ASIAN HONEYBEES

Out of the four species of the genus *Apis* found in Asia, *Apis cerana, Apis dorsata* and *Apis florea* are sympatric, and the exotic species *Apis mellifera*, the European bee, is allopatric in distribution. Sakagami et al. (1980) reported *Apis laboriosa* from the Himalaya as another new distinct honeybee species even larger then *Apis dorsata*, but these findings of the Japanese researchers need further confirmation.

The geographic distribution of *Apis* species in the Oriental region was extensively reviewed by Maa (1953). According to him, the primary distribution centre was in the Malayan sub-region, where not only the number of species was greater than elsewhere, but also the various degrees of specialization co-existed. He further suggested that the sub-genus *Sigmatapis* included honeybees from the Oriental, Palaeractic and Manchurian sub-regions. In all, he described more than 10 species. Michener (1974) reported a very wide distribution of *Apis cerana* in southeast Asia, extending from Ceylon and India to Japan and south-east to Moluccas. Kellogg (1938) discussed the distribution of *Apis cerana* in China. He considered the bees in China to be a variety of *Apis indica* and different from the Japanese variety. *Apis indica pernoi* was the largest variety of Oriental honeybee found in Fukan Province of southeast China. According to Sakagami (1959), the native *Apis cerana* in Japan was being replaced by the exotic European honeybee *Apis mellifera*, but still the former species was found in the mountainous regions both in the wild state and also in hives. Sakai and Matsuka (1982) reported wide occurrence of *Apis cerana* throughout Japan except in the northernmost island of Hokkaido. Distribution of *Apis cerana* in various parts of Afghanistan, Philippines and Sri Lanka have been given by Schneider and Djalal (1970); Morse and Laigo (1969b); and Fernando (1979), respectively.

The distribution of honeybees in different parts of India have been studied by various investigators from time to time. Hussain (1939 a,b) claimed that honeybees originated in India. He described three species of honeybees from India, rock bee *(Apis dorsata)*, indigenous bee *(Apis indica)* and pigmy bee *(Apis florea)*. Rahman and Singh (1940a) reported *Apis cerana indica* from all over India. These authors distinguished the smaller and yellowish plain strains and larger and darker hill strains of this species. Rahman (1944) for the first time showed the presence of *Apis cerana indica* at a height of 3030 to 3333 metres in a wild state. Muttoo (1944, 1956) claimed India to be the place of origin of the genus *Apis*. He described the following species of honeybees in India: *Apis indica, Apis dorsata, Apis florea*. The hill variety of *Apis indica* was named as *Apis indica gandhiana*. Sharma (1945) described the distribution of *Apis indica* in the plains of northern India and reported the absence of this species from the Rajputana desert. Lal (1945) and Khan (1947) described three different species of honeybees in India, and two strains of *Apis florea* (one smaller and another bigger strain) were reported from Bhopal. Deodikar (1959) while studying the ecotypes of *Apis cerana* found a gradual variation in some characters such as body size, tongue length and number of hamuli. The value of these characteristics were sometimes akin to the European bee, *Apis mellifera*. He also showed differences in the genitalia of *Apis cerana* from the northern and southern regions of India. Narayanan et al. (1960 a,b and 1961 a,b) suggested the existence of three races of *Apis cerana* in India which were distinguished as Himalayan, the Gangetic plains, and the South Indian plains races. Singh (1964) reported *Apis cerana, Apis dorsata* and *Apis florea* at elevations of 2424, 1515–2424 and 606–757 metres, respectively.

Ruttner (1985, 1986, 1987) recently reviewed the geographic distribution of *Apis cerana* (Fig. 8.1). According to him this species is found in a very wide area comprising mainly southern and eastern Asia. In the west it extends from Afghanistan up to the Philippines in the east and in the north from Ussuria to Java in the south. Thus, *Apis cerana* is found not only in the tropical and sub-tropical regions of Asia, but also in cooler climate such as Siberia, northern China and higher altitudes of the central Asian Mountains (Koeniger, 1976b).

8.2 *APIS CERANA*

8.2.1 MORPHOMETRICS

One of the prerequisites for the improvement of the beekeeping industry with the native hive bee *Apis cerana* in the Hindu

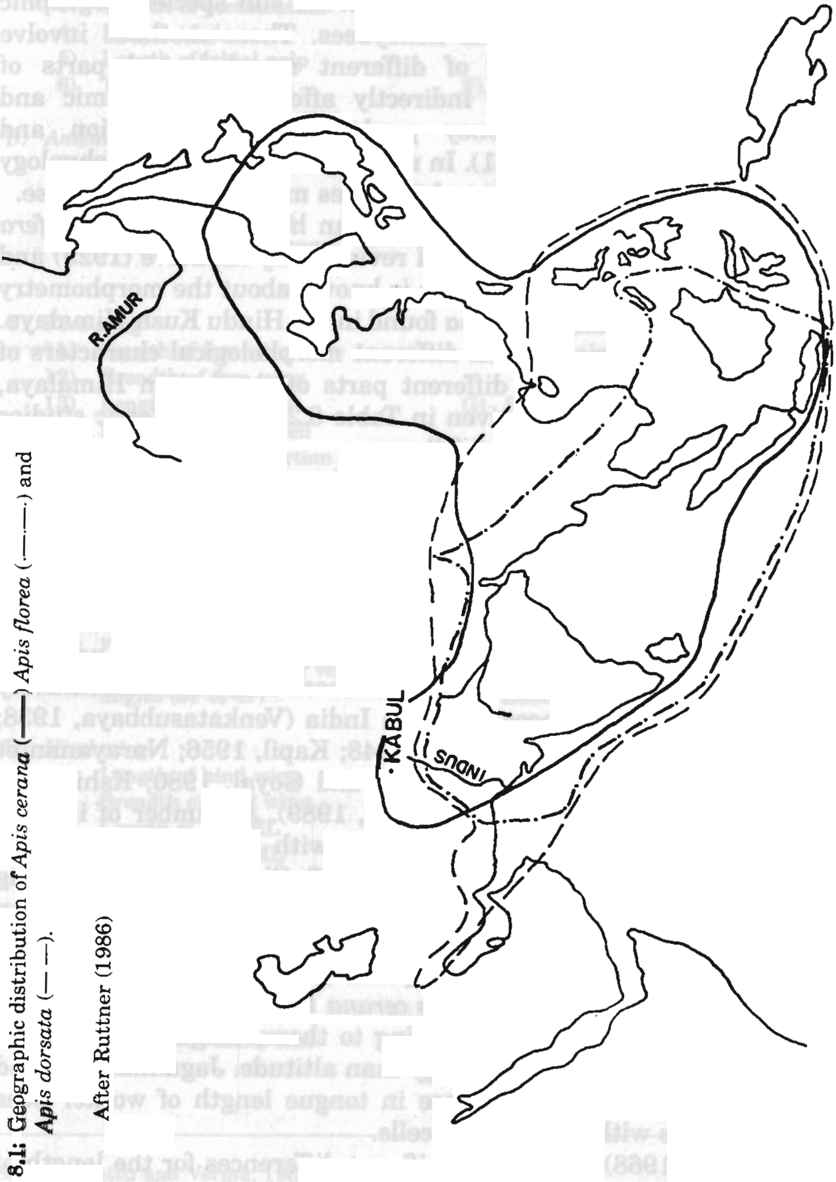


Figure 8.1: Geographic distribution of *Apis cerana* (——) *Apis florea* (·—·—·) and *Apis dorsata* (— — —).

After Ruttner (1986)

Kush-Himalaya is the identification of the different natural sub species/ecotypes of this native bee species in the region, and their further genetic improvement by selection and breeding. Morphometric methods are important research tools which are now being used extensively for the identification of different sub species/geographic ecotypes of different species of honeybees. These methods involve measurements and analyses of different morphological parts of honeybees which directly or indirectly affect such economic and biological characters as honey production, wax secretion and pollination activities (Table 8.1). In recent years, computer technology has made such measurements and analyses more rapid and precise.

Morphometric studies on the European honeybee, *Apis mellifera* have been made in great detail and reviewed by Alpatove (1929) and Ruttner (1987). However, very little is known about the morphometry of the native hive bees *Apis cerana* found in the Hindu Kush-Himalaya. Comparative biometric data on different morphological characters of *Apis cerana* collected from different parts of the Indian Himalaya, Nepal and South India are given in Table 8.2. The biometric studies on *Apis cerana* are reviewed as follows:

1) Tongue

Tongue length is an important character, upon which depends the quantity of nectar gathered from certain flowers (Fig. 8.2). Studies on the biometry of *Apis cerana* have been done in different parts of India: Mysore, Madras, Kulu, Allahabad, Srinagar, Bihar and Ludhiana. These studies reveal that the bees of northern India have a relatively longer tongue than the bees southern India (Venkatasubbaya, 1938; Ratnam, 1939; Rahman and Singh, 1948; Kapil, 1956; Narayanan et al., 1960 a,b, 1961 a,b; Jagannadham and Goyal, 1980; Kshirsagar and Ranade, 1981; Mattu, 1982; Singh, 1989). A number of investigators have tried to correlate the tongue with altitudinal variations (Narayanan et al., 1961 a,b; Fernando, 1979; Singh, 1989). According to these authors, bees at higher altitudes have longer tongues than those at lower altitudes. On the other hand, Mattu and Verma (1983) could not establish any significant positive relationship between the altitude for the worker bees of *Apis cerana* from the Himachal region of the northwest Himalaya. According to them, tongue length is influenced more by flower morphology than altitude. Jagannadham and Goyal (1980) observed an increase in tongue length of worker bees reared in combs with larger sized cells.

Morimoto (1968) observed significant differences for the length of glossa and labial palp in different samples of the Japanese honeybee, *Apis cerana japonica* and Italian honeybee, *Apis mellifera ligustica.*

Table 8.1: List of morphological characters

A) *Tongue*
1) Length of prementum
2) Breadth of prementum
3) Length of postmentum
4) Length of glossa
5) Length of labial palp
6) Total tongue length

B) *Antenna*
7) Length of scape
8) Length of pedicel
9) Length of flagellum
10) Total length of antenna

C) *Fore wing*
11) Length of fore wing
12) Breadth of fore wing
13) Length of radial cell
14) Breadth of radial cell
15) Length of basal portion of radial cell
16) Length of apical portion of radial cell
17) Length of 1st abscissa of vein M_{3+4} in cell 2_m (a)
18) Length of 2nd abscissa of vein M_{3+4} in cell 2_m (b)
19) to 29) Different wing venation angles (31 to 41)

D) *Hind wing*
30) Length of hind wing
31) Breadth of hind wing
32) Length of vein RL
33) Length of vein ML
34) Length of vein VL
35) Length of vein IL (indica vein)
36) Number of hooks (hamuli)
37) Extent of hamuli
38) Length of jugal lobe
39) Length of vannal lobe

E) *Hind Leg*
40) Length of femur
41) Length of tibia
42) Length of metatarsus
43) Breadth of metatarsus

F) *Tergites*
a) *Third tergite*
44) Length of light band
45) Length of dark band
46) Total length of tergite

b) *Fourth tergite*
47) Length of light band
48) Length of dark band
49) Total length of tergite

G) *Sternites*
a) *Third sternite*
50) Length of wax mirror
51) Breadth of wax mirror
52) Distance between wax mirror
53) Total length of sternite

b) *Sixth sternite*
54) Length of sternite
55) Breadth of sternite

H) *Biometrical indices*
i) Premental index
ii) Glossopremental index
iii) Labiopremental index
iv) Fore wing A index
v) Fore wing B index
vi) Radial cell A index (Radial index)
vii) Radial cell B index
viii) Cubital index (a/b)
ix) Hind wing A index
ix) Hind wing A index
x) Hind wing B index
xi) Jugovannal index
xii) Metatarsal index
xiii) Sixth sternite A index

Source: Mattu and Verma, 1983, 1984 b,c.

Table 8.2: Morphometric comparison among northeast, central

S. No.	Character		Kashmiri bee (K)	Himachali bee (H)	Uttar Pradesh bee (UP)	Nepali bee (N)
1	2		3	4	5	6
A.	*Forewing*					
1.	Length of radial cell	Mean	3.182±0.003	3.012±0.002	2.989±0.009	2.959±0.003
2.	Breadth of radial cell	Mean	0.423±0.001	0.404±0.001	0.434±0.004	0.420±0.003
3.	Length of basal portion of radial cell	Mean	1.247±0.002	1.198±0.002	1.188±0.006	1.145±0.002
4.	Length of apical portion of radial cell	Mean	1.947±0.003	1.849±0.002	1.883±0.005	1.802±0.003
5.	Length of forewing	Mean	8.749±0.007	8.498±0.005	8.371±0.025	8.225±0.022
6.	Breadth of forewing	Mean	3.065±0.003	2.847±0.002	2.786±0.008	2.788±0.027
7.	Length of 1st abscissa	Mean	0.567+0.001	0.537+0.001	0.490+0.003	0.489+0.002
8.	Length of 2nd abscissa	Mean	0.158±0.001	0.143±0.001	0.163±0.004	0.150±0.003
9.	Angle 31 of forewing	Mean	32.850±0.110	32.180±0.059	31.440±0.275	32.302±0.091
10.	Angle 32 of forewing	Mean	107.690±0.177	107.490±0.194	107.303±0.453	104.609±0.176
11.	Angle 33 of forewing	Mean	95.690±0.172	93.830±0.178	91.791±0.311	93.048±0.135
12.	Angle 34 of forewing	Mean	17.850±0.091	19.340±0.100	20.211±0.130	21.248±0.107
13.	Angle 35 of forewing	Mean	90.500±0.137	88.360±0.104	90.695±0.342	95.541±0.295
14.	Angle 36 of forewing	Mean	43.230±0.166	43.530±0.144	46.900±0.219	47.635±0.173
15.	Angle 37 of forewing	Mean	96.920±0.213	98.180±0.187	100.510±0.421	99.359±0.172
16.	Angle 38 of forewing	Mean	81.160±0.173	82.280±0.134	80.278±0.271	80.989±0.187

northwest Himalayan and South Indian *Apis cerana*

S. Indian bee (SI)	North Eastern bee (NE)	K-NE (PD)	H-NE (PD)	UP-NE (PD)	N-NE (PD)	SI-NE (PD)
7	8	9	10	11	12	13
2.705±0.004	2.884±0.002	9.37**	4.25**	3.51**	2.53**	−6.62**
0.389±0.001	0.393±0.001	7.09**	2.72**	9.45**	6.43 *	−1.03**
0.999±0.003	1.133±0.002	9.14**	5.43**	4.63**	1.05**	−13.41**
1.705±0.002	1.752±0.002	10.01**	5.25**	4.42**	2.77**	−2.76**
7.382±0.009	8.225±0.008	5.99**	3.21**	1.74**	0	−11.42**
2.694±0.003	2.834±0.002	7.54**	0.46**	−1.72**	−1.65**	−5.20**
0.466+0.002	0.519+0.001	8.47**	3.35**	−5.92**	−6.13**	−11.37**
0.140±0.001	0.146±0.001	7.59**	−2.10**	10.43**	2.67**	−4.29**
31.700±0.074	31.681±0.071	3.56**	1.55**	−0.77**	1.92**	0.06**
105.898±0.144	109.458±0.160	−1.64**	−1.83**	−2.01**	−4.64**	−3.36**
95.364±0.113	93.964±0.100	1.80**	−0.14**	−2.37**	−0.98**	1.47**
20.020±0.047	19.675±0.053	−10.22**	−1.73**	2.65**	7.40**	1.72**
91.264±0.116	88.257±0.125	2.48**	0.12**	2.69**	7.62**	3.29**
47.746±0.130	47.261±0.114	−9.32**	−8.57**	−0.77**	0.79**	1.02**
98.594±0.151	102.319±0.160	−5.57**	−4.22**	−1.80**	−2.98**	−3.78**
75.639±0.139	80.054±0.111	1.36**	2.71**	0.28**	1.15**	−5.84**

Table 8.2 (Cont'd. . .)

S. No.	Character		Kashmiri bee (K)	Himachali bee (H)	Uttar Pradesh bee (UP)	Nepali bee (N)
1	2		3	4	5	6
17.	Angle 39 of forewing	Mean	13.050±0.073	15.040±0.062	15.549±0.108	14.720±0.070
18.	Angle 40 of forewing	Mean	75.590±0.205	74.610±0.180	80.181±0.368	77.976±0.201
19.	Angle 41 of forewing	Mean	32.450±0.205	31.330±0.099	29,495±0.267	31.354±0.132
B)	*Hindwing*					
20.	Length of vein RL	Mean	1.481±0.002	1.440±0.002	1.401±0.012	1.357±0.003
21.	Length of vein ML	Mean	1.222±0.003	1.221±0.002	1.070±0.012	1.141±0.004
22.	Length of vein VL	Mean	1.266±0.003	1.195±0.003	1.231±0.007	1.239±0.003
23.	Length of vein IL	Mean	0.428±0.003	0.386±0.002	0.344±0.013	0.329±0.003
24.	Breadth of hindwing	Mean	1.751±0.002	1.653±0.002	1.663±0.011	1.646±0.002
25.	Length of hindwing	Mean	6.419±0.006	5.785±0.009	5.863±0.035	5.686±0.002
26.	Number of hamuli	Mean	19.480±0.099	19.350±0.072	18.075±0.221	17.456±0.080
27.	Extent of hamuli	Mean	1.297±0.002	1.241±0.002	1.148±0.005	1.142±0.003
28.	Length of jugal lobe	Mean	1.824±0.005	1.748±0.003	1.650±0.009	1.644±0.005
29.	Length of vannal lobe	Mean	1.238±0.003	1.204±0.002	1.172±0.007	1.268±0.002
C)	*Hind Leg*					
30.	Length of femur	Mean	2.583±0.003	2.468±0.001	2.330±0.015	2.325±0.004
31.	Length of tibia	Mean	3.206±0.004	3.091±0.003	2.891±0.016	2.906±0.006
32.	Length of metatarsus	Mean	2.010±0.002	1.942±0.002	1.827±0.010	1.783±0.004
33.	Breadth of metatarsus	Mean	1.104±0.002	1.085±0.001	1.075+0.007	0.967±0.002

S. Indian bee (SI)	North Eastern bee (NE)	K-NE (PD)	H-NE (PD)	UP-NE (PD)	N-NE (PD)	SI-NE (PD)
7	8	9	10	11	12	13
14.107±0.060	12.959±0.051	0.70**	13.84**	10.93**	11.96**	8.14**
77.506±0.143	81.526±0.157	−7.85**	−9.27**	−1.68**	−4.55**	−5.19**
31.483±0.104	33.650±0.119	−3.70**	−7.41**	−14.09**	−7.32**	−6.88**
1.234±0.002	1.325±0.001	10.53**	7.99**	5.42**	2.36**	−7.37**
1.076±0.002	1.189±0.002	2.70**	2.62**	−11.12**	−4.21**	−10.50**
1.140±0.002	1.193±0.002	5.77**	0.17**	3.09**	3.71**	−4.65**
0.337±0.003	0.393±0.003	8.18**	−1.81**	−14.24**	−19.45**	−16.62**
1.633±0.002	1.627±0.002	7.08**	1.57**	2.16**	1.15**	0.37**
5.303±0.004	5.615±0.006	12.53**	2.94**	4.23**	1.25**	−5.88**
18.146±0.052	18.243±0.050	6.35**	5.72**	−0.93**	−4.51**	−0.53**
1.090±0.002	1.149±0.002	11.41**	7.41**	−0.09**	−0.61**	−5.41**
1.640±0.003	1.724±0.002	5.48**	1.37**	−4.48**	−4.87**	−5.12**
1.052±0.002	1.143±0.001	7.67**	5.07**	2.47**	9.86**	−8.65**
2.120±0.003	2.306±0.002	10.72**	6.56**	1.03**	0.82**	−8.77**
2.604±0.003	2.885±0.002	10.01**	6.66**	0.21**	0.72**	−10.79**
1.638±0.002	1.790±0.002	10.95**	7.83**	2.03**	−0.39**	−9.28**
0.940±0.001	0.995±0.001	9.87**	8.29**	7.44**	−2.90**	−5.85**

Table 8.2 (Cont'd. . .)

S. No.	Character	Kashmiri bee (K)	Himachali bee (H)	Uttar Pradesh bee (UP)	Nepali bee (N)
1	2	3	4	5	6
D)	*Tongue*				
34.	Length of prementum	Mean 1.323±0.005	1.313±0.004	1.355±0.007	1.328±0.002
35.	Breadth of prementum	Mean 0.786±0.002	0.782±0.001	0.692±0.010	0.704±0.004
36.	Total Tongue length	Mean 5.355±0.023	5.307±0.019	4.893±0.044	4.762±0.023
37.	Length of Labial palp	Mean 2.752±0.011	2.550±0.005	2.194±0.018	2.101±0.008
38.	Length of postmentum	Mean 0.273±0.001	0.303±0.001	0.268±0.004	0.253±0.004
39.	Length of Glossa	Mean 2.846±0.015	2.782±0.015	2.523±0.035	2.383±0.017
E)	*Tergites*				
i)	*Third tergite*				
40.	Width of light band	Mean 0.953±0.006	1.024±0.005	1.097±0.021	1.765±0.008
41.	Width of dark band	Mean 0.968±0.005	0.779±0.005	0.804±0.012	0.606±0.007
42.	Total width tergite	Mean 2.098±0.002	1.978±0.003	1.783±0.017	1.794±0.003
ii)	*Fourth tergite*				
43.	Width of light band	Mean 0.662±0.004	0.657±0.002	0.766±0.017	0.756±0.006
44.	Width of dark band	Mean 1.205±0.003	1.097±0.003	0.957±0.016	0.924±0.001
45.	Total width tergite	Mean 2.064±0.003	1.898±0.002	1.749±0.013	1.717±0.008
F)	*Sternites*				
i)	*Third sternite*				
46.	Breadth of wax mirrors	Mean 2.274±0.003	2.004±0.003	1.892±0.010	1.820±0.003
47.	Distance between wax mirrors	Mean 0.316±0.001	0.210±0.002	0.243±0.005	0.158±0.003
48.	Length of wax mirrors	Mean 1.241±0.002	1.520±0.001	1.099±0.022	1.082±0.002

S. Indian bee (SI)	North Eastern bee (NE)	K-NE (PD)	H-NE (PD)	UP-NE (PD)	N-NE (PD)	SI-NE (PD)
7	8	9	10	11	12	13
1.240±0.002	1.345±0.002	−1.66**	2.44**	0.74**	−1.28**	−8.47**
0.689±0.002	0.646±0.001	17.81**	17.39**	6.65**	8.24**	6.24**
4.727±0.007	4.661±0.004	12.96**	12.17**	4.74**	2.12**	1.40**
2.165±0.004	2.132±0.002	22.53**	16.39**	2.83**	−1.48**	1.52**
0.326±0.002	0.240±0.001	12.09**	20.79**	10.45**	5.14**	26.38**
2.889±0.005	2.758±0.003	3.09**	0.86**	−9.31**	−15.74**	4.53**
0.792±0.006	1.094±0.006	−14.80**	−6.84**	0.27**	38.02**	−38.13**
0.753±0.004	0.553±0.005	42.87**	29.01**	31.22**	8.75**	26.56**
1.05560.003	1.696±0.002	19.16**	14.26**	4.88**	5.46**	−9.00**
0.664±0.003	0.749±0.005	13.14**	14.00**	2.22**	0.93**	−12.80**
0.844±0.004	0.870±0.005	27.80**	20.69**	9.09**	5.84**	−3.08**
1.509±0.003	1.663±0.002	19.43**	12.38**	4.92**	3.15**	−10.21**
1.711±0.003	1.944±0.003	14.51**	2.99**	−2.75**	−6.81**	−13.62**
0.256±0.002	0.280±0.001	11.39**	−33.33**	−15.23**	−77.22**	−9.38**
0.959±0.002	0.936±0.002	24.58**	38.42**	14.83**	13.49**	2.40**

Table 8.2 (Cont'd...)

S. No.	Character		Kashmiri bee (K)	Himachali bee (H)	Uttar Pradesh bee (UP)	Nepali bee (N)
1	2		3	4	5	6
49.	Total width sternite	Mean	2.599±0.003	2.430±0.002	2.353±0.010	2.265±0.011
ii)	*Sixth sternite*					
50.	Depth of sternite	Mean	2.401±0.004	2.325±0.002	2.215±0.011	2.221±0.003
51.	Breadth of sternite	Mean	2.912±0.003	2.589±0.003	2.551±0.011	2.507±0.004
G)	*Antenna*					
52.	Length of scape	Mean	1.244±0.003	1.079±0.003	1.160±0.008	1.143±0.003
53.	Length of pedical	Mean	0.237±0.001	0.235±0.001	0.233±0.006	0.231±0.003
54.	Length of flagellum	Mean	2.719±0.003	2.536±0.003	2.394±0.014	2.386±0.009
55.	Total length of antenna	Mean	4.311±0.003	4.109±0.003	3.735±0.018	3.690±0.008

R.V = Range of variation
C.V = Coefficient of variation
*, P<0.05 = Significant
**, P<0.01 = Highly significant
PD = Percentage difference

K = Kashmiri bees were collected from sight different localities of Kashmir region (Mattu, 1982)
H = Himachali bees were collected from twelve different localities of Himachal region (Mattu, 1982)
UP = Uttar Pradesh bees were collected from six different localities of U.P. region (Sharma, 1988)
N = Nepali bees were collected from nine different localities of Nepal region (Sharma, 1988)
SI = South Indian bees were collected from fourteen different localities of South India (Leelamma, 1988)
NE = North-Eastern bees were collected from sixteen different localities of North-east Himalayan region (Singh, 1989)
All the mean values are in mm except wing venation angles, which are in degrees.

S. Indian bee (SI)	North Eastern bee (NE)	K-NE (PD)	H-NE (PD)	UP-NE (PD)	N-NE (PD)	SI-NE (PD)
7	8	9	10	11	12	13
2.015±0.003	2.261±0.003	13.01**	6.95**	3.91**	0.18**	−12.21**
1.983±0.002	2.123±0.002	11.58**	8.69**	4.15**	4.41**	−7.06**
2.353±0.003	2.566±0.004	11.88**	0.89**	−0.59**	−2.35**	−9.05**
1.102±0.001	1.068±0.001	14.15**	1.02**	7.93**	6.56**	3.09**
0.217±0.001	0.223±0.001	5.91**	5.11**	4.29**	3.46**	−2.76**
2.261±0.003	2.486±0.002	8.57**	1.97**	−3.84**	−4.19**	−9.95**
3.582±0.004	3.778±0.002	12.36**	8.06**	−1.15**	−2.38**	−5.472**

On the other hand, Mattu and Verma (1983) found no significant differences in various characters of the tongue except for the length of postmentum in *Apis cerana* samples collected from the northwest Himalaya. Fernando (1979) also reported no significant variations in the length of prementum in different bee populations of Sri Lanka. However, Akahira and Sakagami (1959a) established a significant positive correlation between altitude and length of postmentum in *Apis cerana*, though they did not find any relationship between the altitude and length of the prementum and glossa. Moreover, no significant correlation was found between the tongue length and number of hamuli (Narayanan et al., 1960 a,b and 1961 a,b; Mattu, 1982; Singh, 1989), forewing length and hind leg length (Mattu, 1982). Singh (1989) and Kumari (1987) reported that all the parameters of the tongue were significantly smaller in the *Apis cerana* samples collected from the Manipur region of northeast India and Andaman island as compared to those from the Kashmir and Himachal regions of the northwest Himalaya. The tongue length of *Apis cerana* (queen bee) from Pondicherry was reported as 3 mm (Maa, 1953) and from Pune 3.830 mm (Kshirsagar, 1973). According to Sakai (1958), drone bees of the Japanese bee, *Apis cerana japonica* had significantly shorter tongues than the Italian bee, *Apis mellifera ligustica*.

Intraspecific comparison for the different characters of the tongue showed the following trend:

Apis dorsata > *Apis mellifera* > *Apis cerana* > *Apis florea* (length of tongue and prementum); *Apis mellifera* > *Apis dorsata* > *Apis cerana* > *Apis florea* (breadth of prementum, length of postmentum, glossa and labial palp) (Mattu, 1982; Sharma, 1983; Bhandari, 1983; Singh, 1989; Kumari, 1987).

2) Antenna

The antenna is the centre of many different types of sense perception in insects (Fig. 8.3). Different samples of *Apis cerana* collected from the northwest Himalaya showed a significant positive correlation between the length of antenna and altitude. Those at higher altitudes have longer antennae than those at lower altitudes (Mattu and Verma, 1983). The same trend was observed by Kshirsagar (1976) for this species. Akahira and Sakagami (1959b) did not find any relationship between the altitude and antenna length in the Japanese bee *Apis cerana japonica*. However, Singh (1989) established a significant positive correlation between the altitude and various parts of the antenna, except length of pedicel, in bees collected from northeast India. According to Mattu and Verma (1983) the length of antenna was greater in workers bees during the summer than other seasons of the year due to seasonal variations.

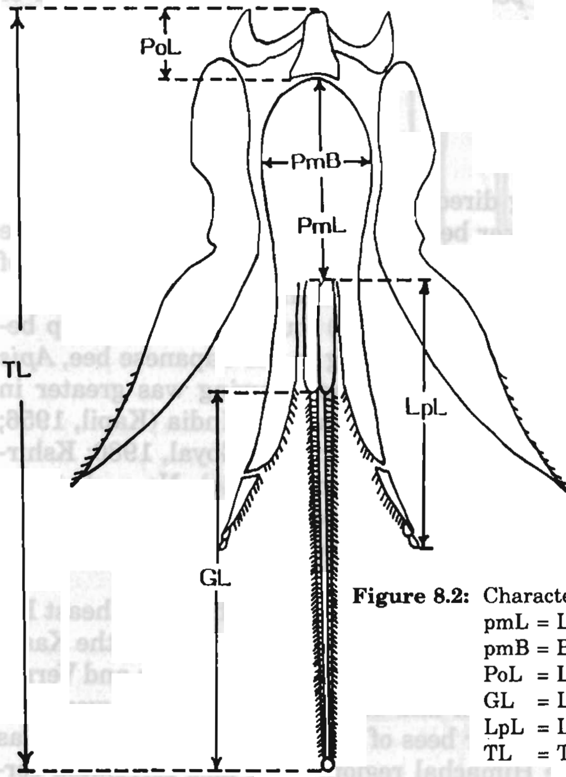


Figure 8.2: Characters measured for the tongue
pmL = Length of prementum
pmB = Breadth of prementum
PoL = Length of postmentum
GL = Length of glossa
LpL = Length of labial palp
TL = Total tongue length

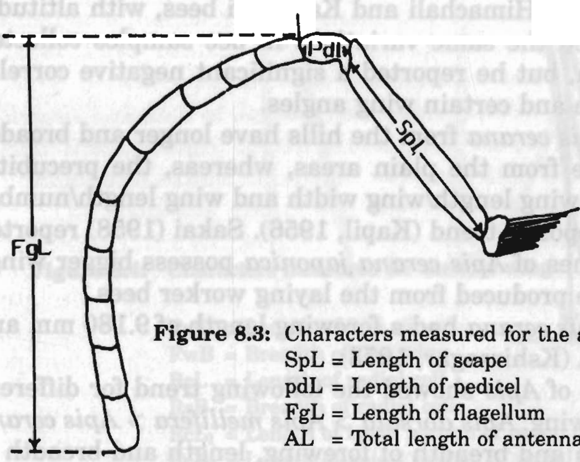


Figure 8.3: Characters measured for the antenna
SpL = Length of scape
pdL = Length of pedicel
FgL = Length of flagellum
AL = Total length of antenna

The queen bee of *Apis cerana* from Indore showed an average antennal length of 4.10 mm (Kshirsagar, 1973). In different species of *Apis*, the length of scape, pedicel, flagellum and the total length of antenna showed the following trend: *Apis dorsata* > *Apis mellifera* > *Apis cerana* > *Apis florea* > (Mattu, 1982; Sharma, 1983; Bhandari, 1983; Singh, 1989; Kumari, 1987).

3) Forewing

The size of the forewing directly affects the flight ability of bees (Figs. 8.4 and 8.5). The worker bees of *Apis cerana* collected from the hills had had bigger forewings as compared to those in the plains of India (Kapil, 1956; Kshirsagar, 1976; Mattu and Verma, 1984c; Singh, 1989), but Akahari and Sakagami (1959b) found no relationship between the altitude and size of the forewing in the Japanese bee, *Apis cerana japonica*. Moreover, the size of the forewing was greater in the bees of northern India than those of southern India (Kapil, 1956; Jain, 1967; Kshirsagar, 1976; Jagannadham and Goyal, 1980; Kshirsagar and Ranade, 1981; Mattu and Verma, 1984c). No such trend was found with regards to cubital index. Length of forewing was significantly more in bees collected during autumn than in other seasons of the year (Mattu and Verma, 1984a).

Singh (1989) reported that the Manipuri bees of the northeast Himalaya have shorter and narrower forewings as compared to the Kashmiri and Himachali bees of the northwest Himalaya. Mattu and Verma (1984c) reported that the length and breadth of radial cell were significantly greater in the worker bees of *Apis cerana* from Kashmir as compared to those of the Himachal region. They also correlated certain wing angles in the Himachali and Kashmiri bees, with altitude. Singh (1989) observed the same variations in bee samples collected from northeast India, but he reported a significant negative correlation between altitude and certain wing angles.

Drone bees of *Apis cerana* from the hills have longer and broader forewings than those from the plain areas, whereas, the precubital index, cubital index, wing length/wing width and wing length/number of hooks show the opposite trend (Kapil, 1956). Sakai (1958) reported that the normal drones of *Apis cerana japonica* possess bigger wings as compared to those produced from the laying worker bees.

Queen bees of *Apis cerana* had a forewing length of 9.180 mm and breadth of 3.170 mm (Kshirsagar, 1973).

Different species of *Apis* showed the following trend for different character of the forewing: *Apis dorsata* > *Apis mellifera* > *Apis cerana* > *Apis florea* (length and breadth of forewing, length and breadth of radical cell). With regards to the second abscissa, the following trend was observed: *Apis mellifera* > *Apis florea* > *Apis cerana* > *Apis dor-*

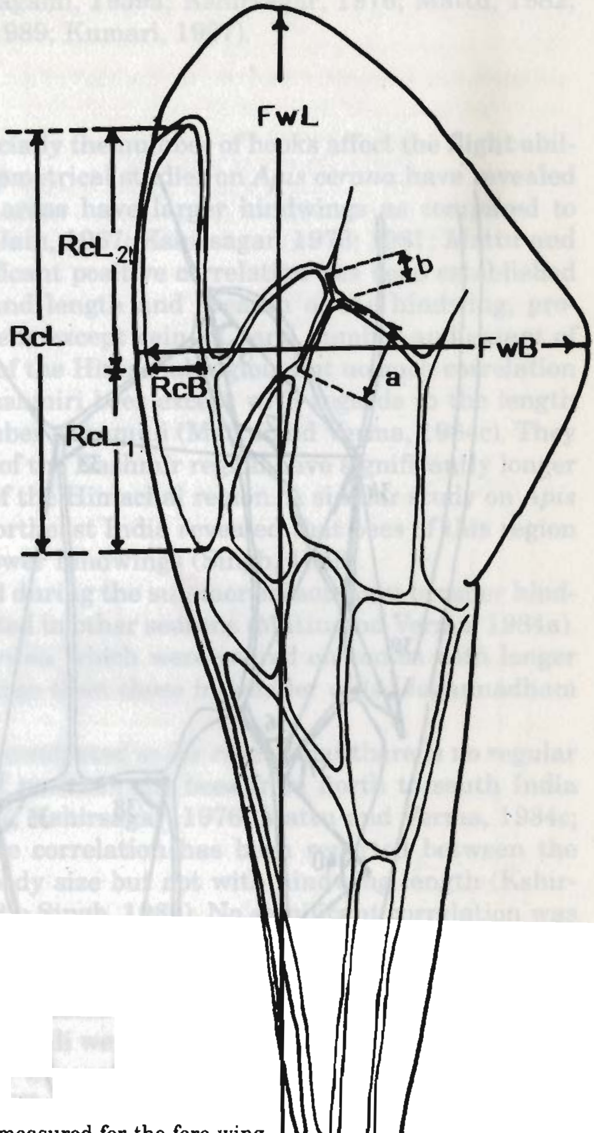


Figure 8.4: Characters measured for the fore wing

PwL = Length of fore wing
FwB = Breadth of fore wing
RcL = Length of radial cell
RcB = Breadth of radial cell
RcL_1 = Length of basal portion of radial cell
RcL_2 = Length of apical portion of radial cell
a = Length of 1st abscissa of vein M_{3+4} in 2nd median cell
b = Length of 2nd abscissa of vein M_{3+4} in 2nd median cell

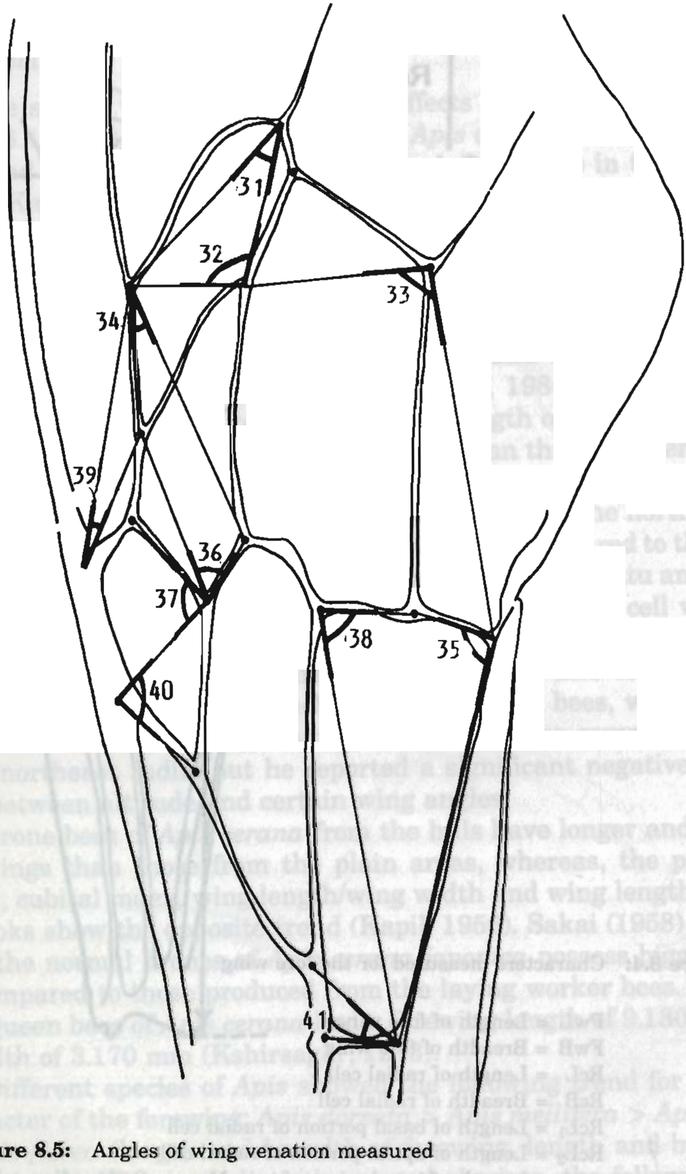


Figure 8.5: Angles of wing venation measured

31 to 41 = Different wing venation angles

sata (Akahira and Sakagami, 1959a; Kshirsagar, 1976; Mattu, 1982; Sharma, 1983; Singh, 1989; Kumari, 1987).

4) Hindwing

The hindwing, especially the number of hooks affect the flight ability of bees (Fig. 8.6). Biometrical studies on *Apis cerana* have revealed that bees in the hilly areas have larger hindwings as compared to the bees of the plains (Jain, 1967; Kshirsagar, 1976; 1981; Mattu and Verma, 1984c). A significant positive correlation has been established between the altitude and length and breadth of the hindwing, proportions of wing vein cells except vein VL, and number and extent of hamuli in worker bees of the Himachal region; but no such correlation was reported in the Kashmiri bees except with regards to the length of the vein VL and number of hamuli (Mattu and Verma, 1984c). They also reported that bees of the Kashmir region have significantly longer hindwings than those of the Himachal region. A similar study on *Apis cerana* samples from northeast India revealed that bees of this region have shorter and narrower hindwings (Singh, 1989).

Honeybees collected during the summer season have broader hindwings than those collected in other seasons (Mattu and Verma, 1984a). Worker bees of *Apis cerana* which were reared on combs with longer cells had larger hindwings than those in smaller cells (Jagannadham and Goyal, 1980).

Biometrical studies conducted so far reveal that there is no regular trend in the number of hooks in the bees from north to south India (Kapil, 1956; Jain, 1967; Kshirsagar, 1976; Mattu and Verma, 1984c; Singh, 1989). A positive correlation has been reported between the number of hooks and body size but not with hindwing length (Kshirsagar, 1976; Mattu, 1982; Singh, 1989). No significant correlation was found between the altitude and number and extent of hamuli for *Apis cerana japonica* of Japan (Sakagami, 1959), and *Apis cerana* of northeast India (Singh, 1989). Mattu and Verma (1984a) claimed that the number and extent of hamuli were not affected by seasonal variations.

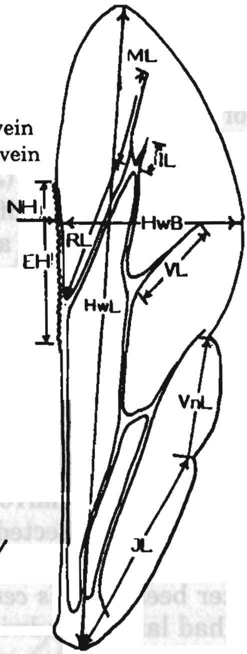
The following trend was revealed for length and breadth of the hindwing, vein RL, ML, VL and jugal lobe from a biometric comparison of species: *Apis dorsata* > *Apis Florea F.* > *Apis cerana F.* > *Apis mellifera* (Akahira and Sakagami, 1959a; Kshirsagar, 1976; Mattu 1982; Sharma, 1983; Bhandari, 1983; Singh, 1989; Kumari, 1987).

5) Hind leg

The size of the hind leg, especially metatarsus, affects the pollen-carrying capacity of honeybees (Fig. 8.7). Various investigators have revealed significantly longer hind legs of *Apis cerana* at higher alti-

Figure 8.6: Characters measured for the hind wing

HwL = Length of hind wing
HwB = Breadth of hind wing
RL = Length of basal portion of radial vein
ML = Length of apical portion of radial vein
VL = Length of discoidal vein
IL = Length of indica vein
NH = Number of hamuli
EH = Extent of hamuli
JL = Length of jugal lobe
VnL = Length of vannal lobe



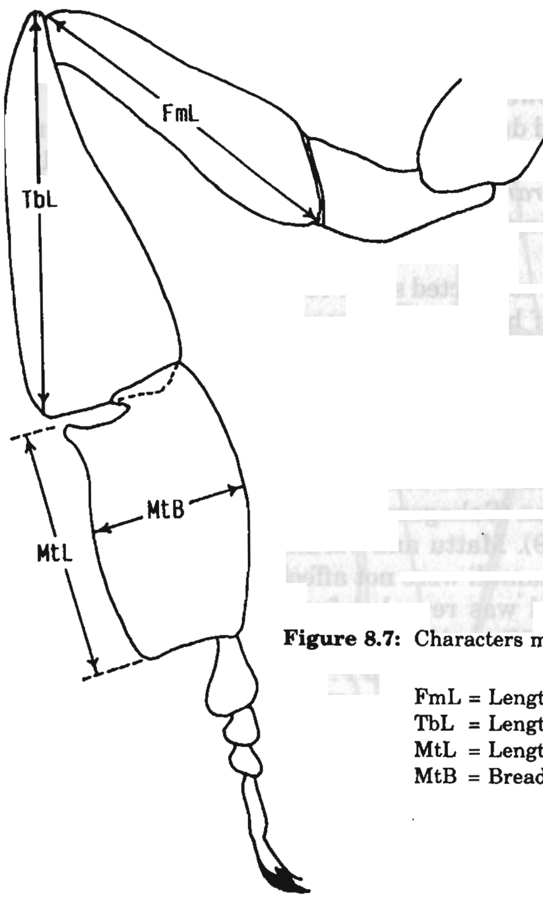


Figure 8.7: Characters measured for the hind leg

FmL = Length of femur
TbL = Length of tibia
MtL = Length of metatarsus
MtB = Breadth of metatarsus

tudes than in the plains (Kapil, 1956; Kshirsagar, 1976; Mattu and Verma, 1984b; Singh 1989). However, Akahira and Sakagami (1959) did not find any significant correlation between altitude and the length of the hind leg for *Apis cerana japonica*. Mattu and Verma (1984b) reported that in northern India worker bees of *Apis cerana* of the Kashmir region have significantly longer hind legs than those of the Himachal region. They also reported longer hind legs in bees collected in the summer season, than those collected in other seasons (Mattu and Verma, 1984a).

Comparative biometric studies on European and Oriental hive bees showed that European bees have longer hind legs than the Oriental bees (Okada et al., 1956; Sakai, 1956; Akahira and Sakagami, 1959b; Kshirsagar, 1976; Mattu and Verma, 1980; Mattu 1982). Further, Singh (1989) and Kumari (1987) observed short and narrow hind legs in the Manipuri (northwest India) and Andaman Island bees as compared to the north Indian bees. Jagannadham and Goyal (1980) observed *Apis cerana* reared in combs with larger cells had longer hind legs than those reared in smaller cells.

The following trend was noticed for various species of *Apis* with regard to different characters of hind leg: *Apis dorsata* > *Apis mellifera* > *Apis cerana* > *Apis florea* > (Mattu, 1982; Sharma, 1983; Bhandari, 1983; Singh, 1989; Kumari, 1987).

6) and 7) Tergites and sternites

These morphological characters act as indices of abdominal size where crop is located in which honey is stored (Figs. 8.8 to 8.11).

Kshirsagar (1976) reported a definite trend in the size of tergites of *Apis cerana* from north to south India. Worker bees of *Apis cerana* collected from the Kashmir region had significantly bigger tergites and sternites than those from the Himachal region, of the northwest Himalaya. Further, a significant positive correlation was established between altitude and size of tergites and sternites (Mattu and Verma, 1984b). Similarly, Singh (1989) also found a significant positive correlation between altitude and size of tergites in bees of northeast India. Bees collected in the summer and autumn season showed significantly bigger abdominal size than those collected in the rainy and winter seasons (Mattu and Verma, 1984a). Further, bees reared in combs with larger cells showed larger tergites and bigger honey stomachs (Jagannadham and Goyal, 1980). Kumari (1987) reported that the bees of south Andaman had smaller abdominal size as compared to the Himachal, Kashmir and Manipur bees of the Himalayan region.

No significant differences were revealed in the size of wax mirrors in worker bees of *Apis cerana* collected from the Himachal and Kashmir regions (Mattu and Verma, 1984b). They also reported a significant

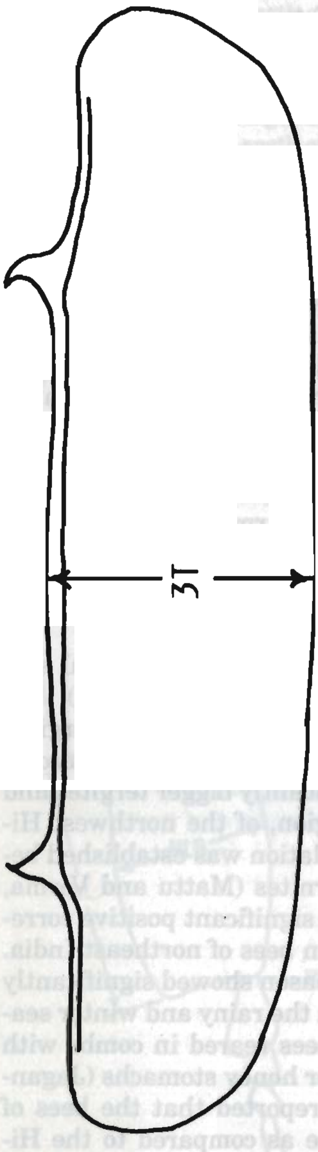


Figure 8.8: Characters measured for the third tergite

3T = Total length of tergite

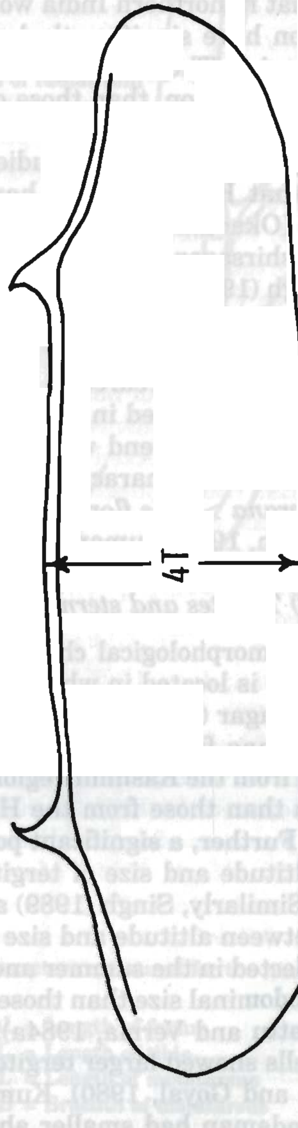


Figure 8.9: Characters measured for the fourth tergite

4T = Total length of tergite

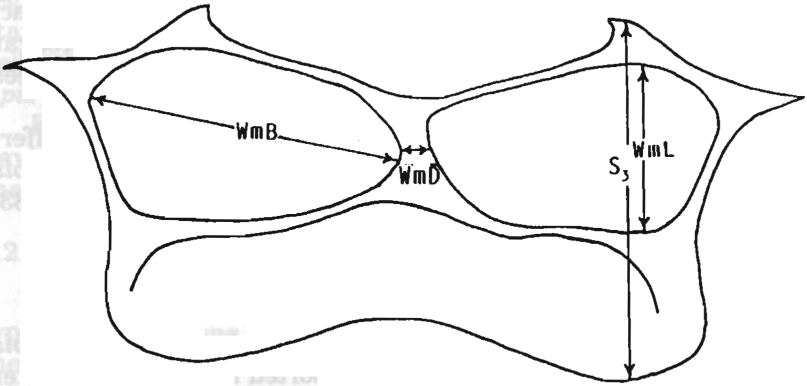


Figure 8.10: Characters measured for third sternite

WmL = Length of wax mirror
WmB = Breadth of wax mirror
WmD = Distance between wax mirrors
S_3 = Total length of sternite

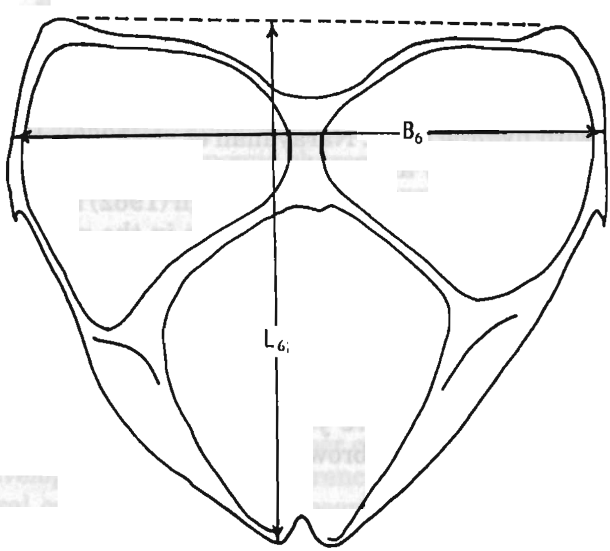


Figure 8.11: Characters measured for sixth sternite

L_6 = Length of sternite
B_6 = Breadth of sternite

positive correlation between altitude and length of third tergites, third sternites and sixth sternites. Similarly, Singh (1989) also reported a significant positive correlation between altitude and different characters of sternites in *Apis cerana* samples of northeast India. Kshirsagar and Ranade (1981) also found bigger tergites and sternites in bees collected from higher elevations.

With regard to various characters of tergites and sternites different species of Apis showed the following trend: *Apis dorsata* > *Apis mellifera* > *Apis florea* (Kshirsagar, 1976; Mattu, 1982; Sharma, 1983; Bhandari, 1983; Singh, 1989).

8) Colour patterns

A number of investigators have studied the colour pattern of *Apis cerana* from different parts of India and reported honeybees of darker colour at higher altitudes as compared to those found in the plains (Bingham, 1897; Maa, 1953; Kapil 1956; Singh, 1962; Kshirsagar, 1976; Mattu, 1982; Singh, 1989).

Kapil (1956) described the colour patterns in the hill variety of *Apis cerana* as follows: black to yellowish-black with brown hair on the thorax; abdominal tergites of anterior segments nearly half yellow and half black; sixth and seventh tergites less than half yellow and abdomen with brownish hairs. But in the plain variety of this species, he reported: Scutellum yellow to blackish or brownish-yellow with light-brown hairs on the thorax; abdominal tergites of the first three segments brownish-yellow with thin black on brown hind regions and abdomen with hyaline hairs. Narayanan et al. (1960 a,b; 1961 a,b) reported bees of leaden grey and leather golden colour from the Indian hills and plains, respectively. According to Singh (1962) bees were dark grey or black at higher altitudes and yellowish in the plains.

Mattu (1982) reported that bees from the mountainous zone were darker in colour as compared to those from the sub-mountainous zone of the Himachal and Kashmir regions. He described the general body colour of Himachali bees as dirty yellowish-brown, whereas, it was dirty yellow-blackish-brown in Kashmiri bees. Similarly, the proboscis, thorax and tip of mandibles were yellowish-brown in the Himachali bees, whereas, these parts were brown with a slight yellowish tinge in the Kashmiri bees.

Singh (1989) revealed differences in the colour patterns of *Apis cerana* collected from different parts of northeast India. According to him, bees collected from higher altitudes were darker in colour as compared to those from lower altitudes. He described the colour patterns of this species as: General body colour dirty yellowish-brown; proboscis, scutellum, thorax and tip of mandibles yellowish-brown; hind leg reddish-brown; tergites and sternites yellowish-brown.

Maa (1953) recorded the colour shades in *Apis cerana* queen bees as follows: integument pale black; clypeus, mouth parts molar area, tegulae and posterior margins of legs reddish-brown; wing weakly stained; vertex and supraantennal areas brown; face with black and yellowish hairs. Kshirsagar (1973) also found that the queen bees of *Apis cerana* were pale reddish-brown and dark-brown in colour.

Kapil (1956) described the colour of drone bees *Apis cerana* as black having a black scutellum with longer, denser, dark brown hairs on it, than on the thorax in general for both the hill and plain varieties.

8.2.2 Sub-species and Geographic Ecotypes

Before discussing the different sub-species and geographic ecotypes of *Apis cerana*, it is important to make a distinction between these two concepts based on the earlier studies on *Apis mellifera*. As a result of the continuous process of natural selection through the centuries, different sub-species of a particular species of honeybee have evolved. Such natural sub-species are different from other domestic animals because the latter were evolved through planned breeding by man. In the case of honeybees, such sub-species have been evolved under the influence of natural physical and biotic factors existing in the environment. Such sub-species of *Apis mellifera* existing in tropical Africa, north Africa and the near east and west Mediterranean region have been identified (see Table 8.3) through computer-based biometric analyses (Ruttner, 1985, 1986, 1987). These results reveal that each sub-species of honeybee species has further locally adapted populations called geographic ecotypes which differ from each other in several biological and economic characters. Such ecotypes adapted to specific environment have also evolved through the process of natural selection.

The biological and economic differences existing in different sub-species and geographic ecotypes of honeybees provide excellent opportunity for their genetic improvement by selection and breeding. These differences have been extensively exploited by man in *Apis mellifera* with remarkable success. For example, by the crossbreeding of *Apis mellifera* sub-species and geographic ecotypes, it is possible to increase honey production by 200 per cent (Fresnaye and Lavie, 1976) and to develop low and high preference lines for better pollination of agricultural crops (Nye and Mackesen, 1970). However, very little is known about *Apis cerana* except of the the arbitrary hilly and plain variety of this species (Kapil, 1956; Narayanan et al., 1960, 1961 a,b and Kshirsagar, 1976). These earlier biometric investigations were based on a few morphological characters and geographical samples, and also lacked proper statistical analysis of data. However, in the recent past, attempts have been made to identify different sub-

Table 8.3: Races of *Apis mellifera* L.

S.N.	Race	Common Name	Origin
1.	*A.m. intermissa*	The Tellian bee	From Maroo to Libya
2.	*A.m. capensis*	The Cape bee	South-west coast of South Africa
3.	*A.m. adansonii*	The African bee	Whole continent between Sahara and Kalahari
4.	*A.m. lamarckii*	The Egyptian bee	Nile valley north of Assuan
5.	*A.m. mellifera*	The Dark bee	All of Europe (north and west of Alps)
6.	*A.m. ligustica*	The Italian bee	From Venice to Germany
7.	*A.m. carnica*	The Carniolan bee	Southern parts of Austrian Alps and North Belkan (Yogoslavia)
8.	*A.m. caucasia*	The Caucasian bee	The high valleys of the Central Caucasus

Source: Ruttner, 1987.

species of *Apis cerana* by using computer assisted standard statistical methods. These results are reviewed as follows:

Ruttner (1985, 1986, 1987) has distinguished four different subspecies of *Apis cerana: Apis cerana cerana, Apis cerana himalaya, Apis cerana indica* and *Apis cerana japonica* (Fig. 8.12). His study was based on 34 morphological characters studied in 68 samples of *Apis cerana* collected from different parts of Asia. Statistical methods included principal component analysis, discriminant analysis or cluster analysis.

Bee scientists in Himachal Pradesh University, Shimla, India also carried out biometric studies on *Apis cerana* worker bees found in northeast, northwest and south India representing different physiographic conditions (Table 8.4). From each locality, 60 field bees (workers) were collected in summer from four to five wild colonies located in forests. In all, 55 morphological characters related to tongue, antenna, forewing, hindwing, hind leg, tergites and sternites were studied (Table 8.1). These characters were selected on the basis of previous work of Alpatov (1929) and Ruttner et al. (1978). Statistical analyses were carried out by using computer-based univariate and multivariate discriminant analyses. The results of these analyses as well as those of Ruttner (1985, 1986, 1987) are as follows:

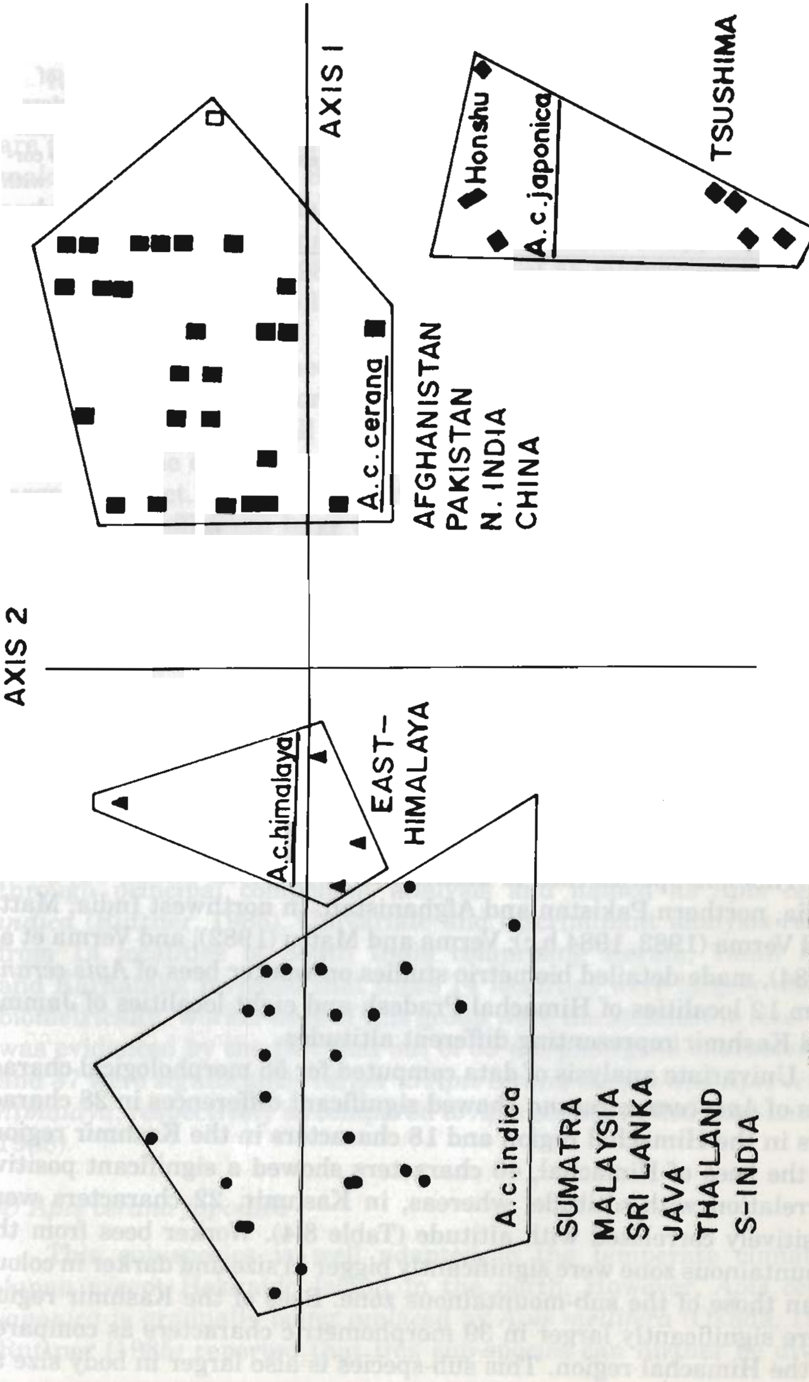


Figure 8.12: Principal component analysis (34 characters) with 68 A.cerena samples of 20 worker bees each (after Ruttner 1986)

Table 8.4: Correlations between morphometric characters and altitude for *Apis cerana* F. collected from different parts of India

S. No.	Region	Altitude range (metres)	No. of localities studies	No. of bees measured from each locality	No. of characters* significant positive correlation with altitude
1.	Northwest India (Himachal Pradesh)	587 to 3017	12	60	38
2.	Northwest India (Jammu & Kashmir)	938 to 2977	8	60	20
3.	Northeast India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram and Nagaland)	56 to 2012	16	60	23
4.	South India (Kerala, Karnataka, Tamil Nadu)	30 to 2286	14	60	34
5.	East India (Andaman Islands)	45 to 150	5	—	—

* 55 morphological characters relating to tongue, antenna, wings, tergites, sternites were studied.

Source: Singh, 1989.

1) Apis cerana cerana

This sub-species/race is distributed over north-China, northwest India, northern Pakistan and Afghanistan. In northwest India, Mattu and Verma (1983, 1984 b,c); Verma and Mattu (1982), and Verma et al. (1984), made detailed biometric studies on worker bees of *Apis cerana* from 12 localities of Himachal Pradesh and eight localities of Jammu and Kashmir representing different altitudes.

Univariate analysis of data computed for 55 morphological characters of *Apis cerana cerana* showed significant differences in 28 characters in the Himachal region and 18 characters in the Kashmir region. In the bees of Himachal, 40 characters showed a significant positive correlation with altitude, whereas, in Kashmir, 22 characters were positively correlated with altitude (Table 8.4). Worker bees from the mountainous zone were significantly bigger in size and darker in colour than those of the sub-mountainous zone. Bees of the Kashmir region were significantly larger in 39 morphometric characters as compared to the Himachal region. This sub-species is also larger in body size as compared to bees of northeast India and south India.

2) Apis cerana himalaya

Ruttner (1985) reported that bees from the eastern Himalaya form a separate cluster from the bees of the western Himalaya. These bees are possibly a separate sub-species which he named as *Apis cerana himalaya* (Ruttner, 1987). Biometric results of Singh (1989) on *Apis cerana* from northeast India (comprising Nagaland, Manipur, Mizoram, Assam, Meghalaya, Arunachal Pradesh and Sikkim) support these observations of Ruttner (1985) because, out of 55 morphological characters, more than 45 were larger in *Apis cerana cerana* as compared to *Apis cerana himalaya*.

The F values obtained by Singh, 1989 and Singh et al. 1989 for a univariate analysis for each of 55 characters for 16 localities of northeast India were all highly significant (significance probability < 0.0000). The discriminant analysis indicated that 16 localities were largely distinct. The reclassification of the individual bees by the discriminant coefficients have 80 to 100 per cent correct classification with an overall average of 91.6 per cent. The biometric relationships of the bees from 16 localities of northeast India are shown in a three-dimensional graph (Fig. 8.13). This graph shows that from northeast India, the following three geographic ecotypes of *Apis cerana himalaya* were recognized: (1) Naga and Mizo Hills, (2) Brahmaputra Valley, and (3) Main axis of the Himalaya (Fig. 8.13).

3) Apis cerana indica

The worker bees of *Apis cerana* from South India, Sumatra, Malaysia, Sri Lanka, Java and Thailand have been separately grouped through principal component analysis and named as *Apis cerana indica* (Ruttner, 1985). Univariate and discriminant analysis results from 14 localities of South India comprising Kerala, Tamil Nadu and Karnataka revealed that these 14 localities were largely distinct biometrically. Worker bees of this group were the smallest in size. This was evidenced by the fact that out of 55 morphological characters, 44 and 37 were significantly larger in *Apis cerana cerana* and *Apis cerana himalaya*, respectively as compared to *Apis cerana indica* (Lee Lamma, 1988).

4) Apis cerana japonica

This sub-species is well adapted to the temperate climate of Japan except Hokkaido Island in the north. However, *Apis cerana japonica* is gradually being replaced by *Apis mellifera* (Okada, 1985). Ruttner (1985) reported that this sub-species can further be divided

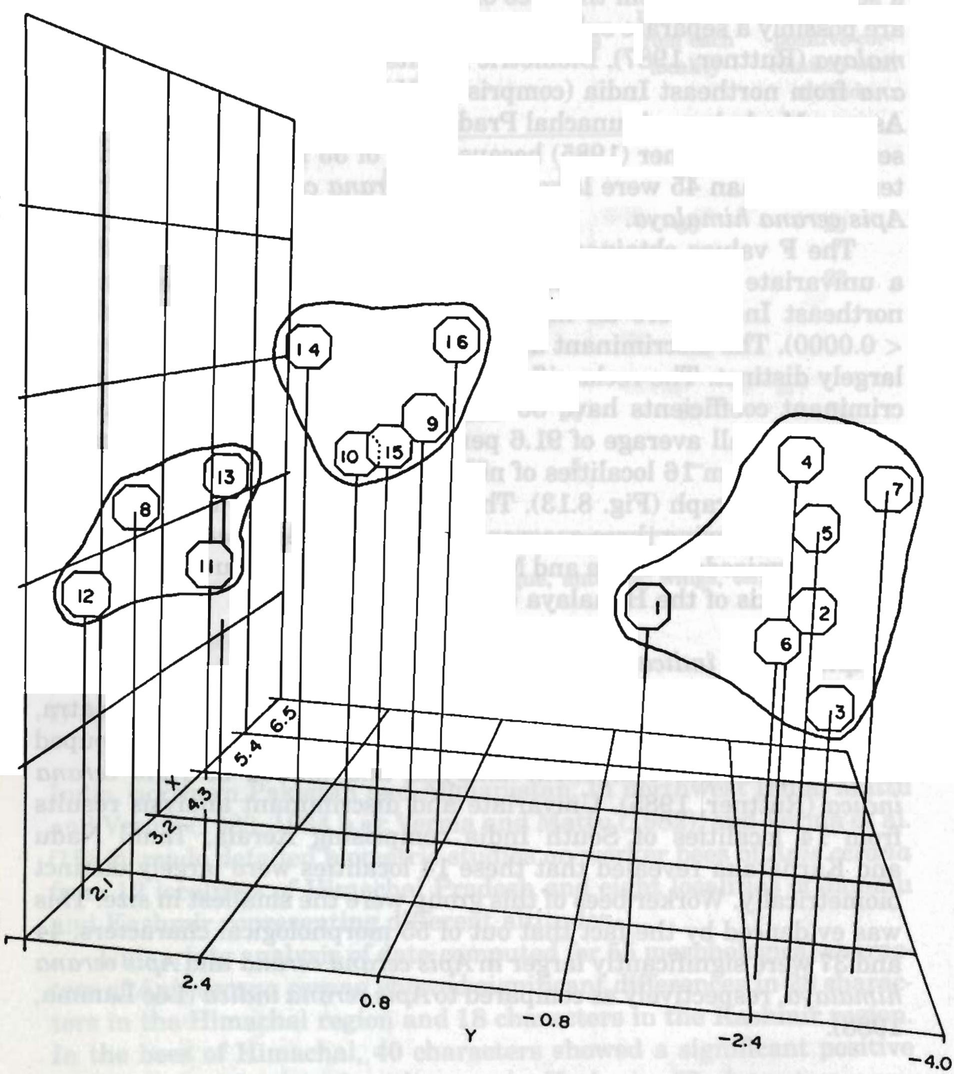


Figure 8.13: Three-dimensional view of the biometric relationships of *Apis cerana* from 16 localities of northeast Himalaya.

into two separate ecotypes or sub-groups, i.e. Honshu (Tokyo region) and Tsushima bees. These two ecotypes differ from each other in tongue length, forewing length, hair length and colour patterns. This sub-species also has a higher cubital index and slender abdomen as compared to other sub-species of *Apis cerana*.

A survey conducted by the Chinese Bee Resource Coordination Team, from 1976 to 1983, reveals that *Apis cerana* are found in all the provinces of China, except the Xinjiang Autonomous Region. The major distribution areas of the genus is to the south of the Yangtze river. *Apis cerana* in China, can be classified into five sub-species, namely, *Apis cerana skorivoki, Apis cerana indica, Apis cerana cerana, Apis cerana hainanensis* and *cerana abaensis*. Out of these, *Apis cerana hainanensis* and *Apis cerana abaensis* are reported for the first time. These findings also suggest that *Apis cerana* sub-species can further be divided into five different biometric groups and *Apis cerana hainanensis* consists of two different biometric groups or geographic ecotypes (Yang, 1990).

From the above results, the following conclusions can be drawn:

1. Morphometric comparison of three *Apis cerana* sub-species found in India revealed significant differences in size (*Apis cerana cerana* > *Apis cerana himalaya* > *Apis cerana indica*).
2. Although at present we only know four sub-species of *Apis cerana* in the Asian region, there may be more additions to this list if detailed investigations are made in other regions of Asia where *Apis cerana* is found. The above-mentioned works of Ruttner (1985, 1986 and 1987) on biometry of *Apis cerana* provide an excellent base for such studies.
3. Each sub-species of *Apis cerana* can further be divided into different geographic ecotypes. These ecotypes are biologically meaningful because they occupy the adjacent geographic areas. So far seven such ecotypes have been identified in different sub-species of *Apis cerana* in India but there may be a much greater number of ecotypes representing the different geographical regions.
4. Present results also suggest that any taxonomic division or construction of evolutionary relationships among the sub-species of *Apis cerana* should be based on the total distribution of the species in the geographic region, wherever, it is found. For such an investigation, a regional project aided by some international agency is needed.

8.2.3 SELECTION STUDIES ON *APIS CERANA*

Deodikar et al. (1961) and Deodikar and Thakar (1966) scrutinized *Apis cerana* colonies on the basis of various quantitative and qualitative characters in Pune, India. The most important quantitative characters were: egg-laying capacity, brood-rearing efficiency, colour strength, tongue length, body size, body weight and wing hook numbers, etc. The qualitative characters were: colour distribution in queen, drone and worker bees, compact or scattered brood, swarming, absconding, defense, robbing, foraging habits, aggressiveness, sense of orientation, regular or irregular combs, use of propolis, monsoon survival and hive sanitation. Further, at the end of each annual cycle, colonies with a maximum combination of desired quantitative and qualitative characters were graded into selection groups and those showing minus values below general average were eliminated. Then the queens were reared from the selection colonies and mating was done with the adequate population of drones of superior selected genotypes in isolated mating yards. The pedigree colonies thus obtained were subjected to rigorous progeny testing, and the procedure was repeated in each generation so as to effect the mass selection of superior genotypes of proven merits. Deodikar et al. (1961) and Deodikar and Thakar (1966) further reported that the results achieved in respect of more important quantitative characters such as tongue length, body size and honey yield were as follows:

1) The increase in tongue length in selection over general average ranged from 2.07 to 6.83 per cent during 1955 to 1964.
2) The increase in body size ranged from 0.703 to 2.55 per cent in different years from 1955 to 1964.
3) Honey yield increased from 21.10 to 94.43 per cent in selection over general average.

Besides this success in improving honey yield and other quantitative characters, selective breeding procedures also resulted in significant improvement in qualitative characters of economic value, such as absence of an excessive swarming impulse, reduced absconding, mild non-stinging temper, hive sanitation and incidental freedom from common diseases.

Different investigators observed that colony strength affects the honey production of *Apis cerana* (Ramachandran and Mahadevan, 1950; Sharma and Sharma, 1950; Woyke, 1976, 1977). Similarly, other research workers showed the direct influence of foraging efficiency on the brood-rearing capacity of *Apis cerana* colonies (Kapil, 1957; Hameed and Adlakha, 1973). Reddy (1980) observed the direct effect of foraging efficiency and pollen stores on the brood-rearing capacity of the colony. Woyke (1976) reported a significant positive correlation between honey yield and brood-rearing capacity of *Apis cerana* colonies.

Studies on egg-laying rates of different sub-species of *Apis cerana* queens revealed that the Mountain Grey race is superior to other races with regard to this character. For example, the daily egg-lying rate was 1,000 eggs for the Mountain Grey race, 600 eggs for the Golden race (Sharma, 1958b) and 700 eggs for the Kashmiri race (Saraf and Wali, 1972) of *Apis cerana*. Similarly, other researchers have reported different honey yields for *Apis cerana* colonies at different places of India: 4.53 kg in Pune (Deodikar) et al., 1961; Deodikar and Thakar, 1966); 3.75 to 4.65 kg in Himachal Pradesh (Atwal and Sharma, 1970) and 8.92 to 12.84 kg in Delhi (Naim and Phadke, 1972).

Verma (1986 a,b) initiated selection studies on *Apis cerana* colonies in Himachal Pradesh, and the results of his investigations are summarized as follows:

In Himachal Pradesh, the State Horticulture Department is maintaining bee colonies at 43 different beekeeping stations. Out of these apiaries, the best colonies were selected on the basis of such biological and economic characters as honey yield, pollen stores, area under brood, prolificness, foraging efficiency, temperament, cleanliness, strength of colony, etc.

There were significant differences in different colonies of *Apis cerana* with regard to honey yield, pollen stores, area under eggs, larvae, sealed brood, total brood, prolificness and foraging efficiency. For example, honey yield per colony ranged from 1.205 to 8.480 kg; pollen stores from 56.80 to 588.71 sq cm; total brood area from 606.16 to 1,862.66 sq cm; prolificness from 115.46 to 354.79 eggs per day and foraging efficiency 2.13 to 12.60 pollen loads per minute in different colonies of *Apis cerana* (Table 8.5).

Significant positive correlations ($P>0.01$) were observed among different biological and economic characters. For examples, honey yield was positively correlated with prolificness, pollen stores with foraging efficiency and prolificness, total brood area with pollen stores, prolificness and honey yield (Table 8.6).

Pollen storage area, total brood area, prolificness, and sealed brood area were maximum during May-June and September-October, suggesting these two as major honey-flow seasons in northern India.

8.2.4 Breeding Studies

In the breeding experiments conducted by Verma (1986 a,b); Rana et al. (1983) and Rana, (1987), inbred lines of *Apis cerana* of the Himachal region were developed by a brother × sister system of mating in an isolated mating yard, and its effect was studied in terms of

Table 8.5: Range of variations of different biological and economic characters in different colonies of *Apis cerana*

Character	Range of variation
Honey yield (kg)	1.205– 8.480
Pollen stores (sq/cm)	56.80 – 588.71
Area under eggs (sq/cm)	146.60 – 439.81
Area under larvae (sq/cm)	57.31 – 351.93
Sealed brood area (sq/cm)	349.00 –1227.33
Total brood area (sq/cm)	606.16 –1862.66
Egg laying per day	115.46 – 354.79
Foraging efficiency (pollen loads/minute)	2.13 – 12.60

Above data represent the range of variation from April to November for the year 1982 and 1983 for 30 colonies of *Apis cerana*. Due to drought during these years in northern India, above-stated values are lower than observed during normal period.

Source: Verma et al., 1988b.

Table 8.6: Correlations among different economic characters of *Apis cerana*

	TBA	PS	FE	SBA	AE	AL	PF	HY
TBA	—	0.619**	0.583*	0.591*	0.613*	0.249	0.719**	0.698**
PS	—	—	0.613**	0.419	0.521*	0.139	0.619**	0.397
FE	—	—	—	0.501	–0.486	0.395	0.621**	0.418
SBA	—	—	—	—	0.391	0.418	0.701**	0.578*
AE	—	—	—	—	—	0.482	0.701**	0.738**
AL	—	—	—	—	—	—	0.189	0.386
PF	—	—	—	—	—	—	—	0.638**

* P<0.05 TBA = Total brood area AE = Area under eggs

** P<0.01 PS = Pollen stores AL = Area under larvae

FE = Foraging efficiency PF = Prolificness

SBA = Sealed brood area HY = Honey yield

Source: Verma et al., 1988a.

change in morphological characters of worker bees and prolificness of queen bees. Inbreeding data collected from workers bees of *Apis cerana* found in Himachal Pradesh revealed significant lower values (P<0.01, P<0.05) for length of apical portion of radial cell, veins RL and IL, femur, tibia, third and fourth tergite, tongue, hind wing and sixth sternite, breadth of fore and hind wing and sixth sternite, breadth of fore and hind wing and distance between wax mirrors in F_1 inbred generations than the parent stock. Besides the above characters, length of fore wing, radial cell, 2nd abscissa, vein ML, vannal lobe and breadth of metatarsus and sixth sternite also showed significant decrease in F_2 inbred generations as compared to the parent stock.

Inbreeding also affected the prolificness and F_1 and F_2 queens as compared to the parent stock. For example, egg-laying rates were 343, 256, 163 eggs per day for parent, F_1 and F_2 inbred queens, respectively. These results also suggest that the inbreeding depression was more pronounced in F_2 (Parent>F_2, P>0.01) as compared to F_1 inbred (Parent>F_1 F_2, P<0.05) queens.

Verma (1986 a,b) also conducted cross-breeding experiments by crossing Himachal and Kashmir ecotypes of *Apis cerana* in an isolated mating yard, and its effect was studied in terms of change in morphological characters of the worker bees and prolificness of the queen bees. Cross-breeding experiments between the Himachali queens and Kashmiri drones showed significantly higher values (P>0.01, P>0.05) for the breadth of fore wing, length of vein VL, 2nd abscissa, hind wing, jugal lobe and third sternite, and distance between the wax mirrors of hybrid than parent worker bees of the Himachal region. On the contrary, the length and breadth of wax mirrors were significantly smaller in such hybrid worker bees than the Himachali parent stock. Thus, these studies revealed that hybrid worker bees showed intermediate values of certain morphological characters between their parent stock.

Hybrid queens obtained by crossing Kashmiri queens with Himachali drones showed an increase of 102.55 per cent (397 eggs/day) in prolificness as compared to the Kashmiri parent stock (196 eggs/day). However, in hybrid queens obtained by mating Himachali queens with Kashmiri drones, the prolificness decreased by 13.53 per cent (147 eggs/day) than the Himachali parent stock (170 eggs/day). Because of the incidence of Sacbrood virus disease of *Apis cerana* colonies during the course of investigation (April, 1984), the breeding experiments could not be carried further.

The above work on the selection and breeding of *Apis cerana* can be extended further by using analytical and hybrid breeding techniques. Such research work may help in improving the economic, biological and morphometric characters in this species to increase the honey production and better pollination of agricultural crops in Asia. This is a potential area for future research.

Breeding for resistance to Thai Sacbrood virus disease

Thai Sacbrood virus disease has been reported from Burma, Nepal and Thailand. In India, it was noticed for the first time in 1978 in

Meghalaya in the Indian hive bee, *Apis cerana* F. (Kshirsagar et al., 1981; Kshirsagar, 1983). The incidence and severity of this disease increased at an alarming rate, and more than 95 per cent of colonies infected in various parts of the country were killed due to the attack of this disease (Rana et al., 1986, 1987). It resulted in a great economic loss to the Hindu Kush-Himalayan Beekeeping Industry, not only in terms of honey and beeswax production, but it adversely affected pollination services rendered by this native species particularly in the temperate regions where this disease is more widespread as compared to the tropical and sub-tropical regions.

The presence of Thai sacbrood virus in the diseased colonies of *Apis cerana* in northern India was confirmed by conducting electron microscopic and serological (immunodiffusion tests) studies (Rana et al., 1986, 1987).

Different preventive control measures recommended earlier to control the spread of sacbrood disease in *Apis mellifera* were unsuccessful in *Apis cerana* (Rana et al., 1986). However, about 5 per cent of the colonies in the affected areas were resistant/escaped the attack of this disease. In such resistant colonies, this disease was studied in detail. Out of 52 colonies: only 30 developed severe symptoms of the disease, and were destroyed. The remaining 22 colonies were reared up to to F_5 generations to test resistance against the disease, and each generation was fed with the purified virus suspension in sugar syrup.

These results reveal that the symptoms of the disease appeared in disease-free colonies with in four to 10 days after feeding the purified virus suspensions in sugar syrup and such symptoms appeared earlier in mother/parent colonies than in subsequent generations. For example, disease symptoms appeared in 4, 5, 4, 7, 10 and 8 days in parent (mother), F_1, F_2, F_3, F_4 and F_5 generations, respectively. Also the percentage of affected brood was more in the mother than in the daughter colonies and hence, a continuous decrease in infection was observed in subsequent generations. The degree of infection was 50, 20, 10, 5, 5 and 4 per cent in mother, F_1, F_2, F_3, F_4 and F_5 generation colonies, respectively (Table 8.7).

Recovery from infection was observed within 30 days after the appearance of disease in the colonies. Mother colonies took a longer time to recover from the attack of the disease than the daughter colonies (25, 23, 20, 16 and 15 days for F_1, F_2, F_3, F_4 and F_5 generations, respectively). In mother colonies abnormal behaviours such as no coverage of brood by nurse bees, frequent tendency to abscond, increased aggressiveness, reduced prolificness and less efficiency to throw out the dead brood were observed, but in subsequent generations (F_1 to F_5) there was gradual improvement and colonies showed normal behaviour (Fig. 8.14).

Table 8.7: Test for resistance* against the Thai sacbrood virus isolate in honeybee

Species	Colony generation	Time required (days) for appearance of symptoms after inoculation	Brood infection (%)	Recovery period (days)	Colony behaviour
	Parent colony	3	40–50	30	Abnormal**
	First generation (F_1)	7	18–20	24	Near normal
	2nd generation (F_2)	4	8–10	22	Near normal
Apis cerana	3rd generation (F_3)	8	3– 5	20	Normal
	4th generation (F_4)	10	4– 5	15	Normal
	5th generation (F_5)	8	2– 4	16	Normal
	Parent colony	No symptoms	Nil	Nil	Normal
Apis mellifera	F_1 generation	No symptoms	Nil	Nil	Normal

* For testing resistance in each generation, five healthy colonies from diseased apiaries were fed with freshly purified virus suspension in 50% sugar syrup in the ratio of 1:200.

** Abnormal behaviour: no coverage of diseased brood by worker bees, tendency to abscond, increased aggressiveness and reduced efficiency in throwing out the dead brood.

Source: Rana et al., 1986.

The above experiments of feeding purified virus suspension were repeated with healthy *Apis mellifera* colonies, but no symptoms of the disease appeared in such colonies.

The above results indicate that some mechanism of resistance to Thai sacbrood virus disease exists in *Apis cerana*. In nature, this disease has a four-year cycle, and after this period about 5 per cent of the surviving colonies start multiplying in a normal way. For example, in Himachal Pradesh this disease was observed from 1982 to 1986/87. After this period all the surviving colonies were multiplying and about

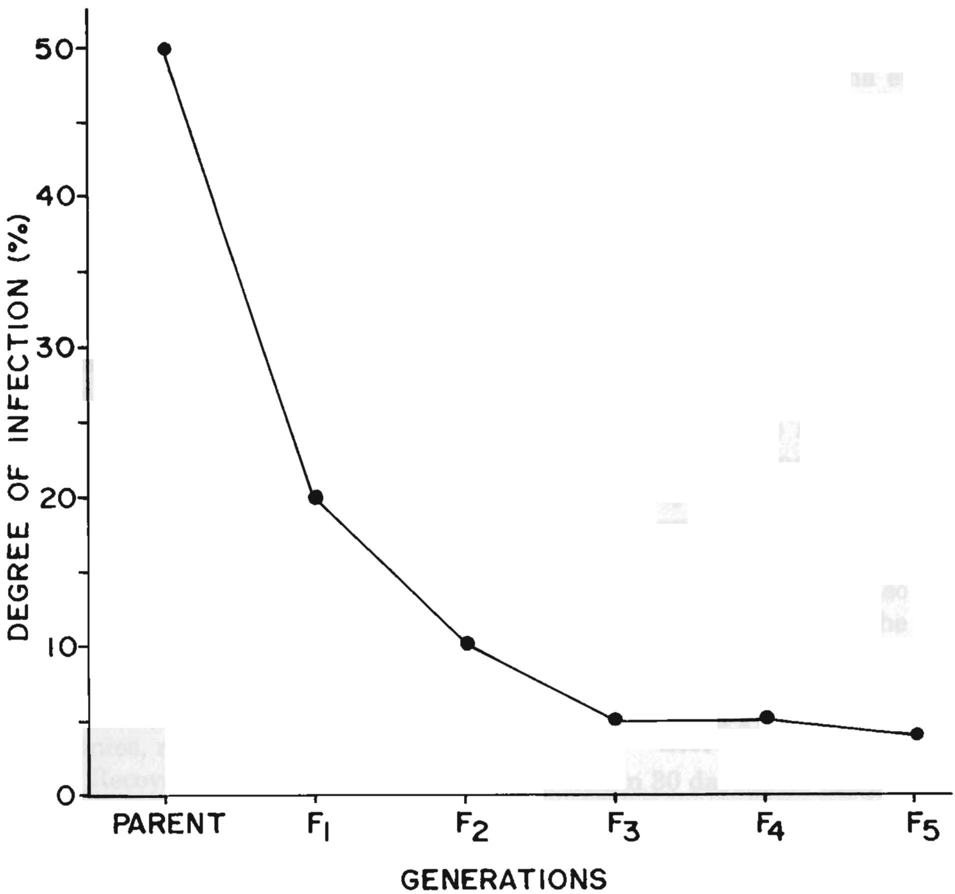


Figure 8.14: Degree of Thai Sacbrood virus infection in brood (%) from parent to F_5 generations of *Apis cerana*.

25 per cent of the normal population had been restored during the last two years or so. This has been the case in Nepal also (Verma, 1989b).

8.2.5 BEHAVIOUR STUDIES

1) *Mating Behaviour*: In nature, the queen bee mates in the air (about 30 feet above the ground) with a number (5 to 10) of drones. She apparently exercises no preference for race or strain of drones because the sexual pheromones of the queen bees of different subspecies have similar chemical composition. Hence, her mate or mates may come from her own colony, or from several miles away, or from an entirely different race. All efforts to restrict the mating flight to enclosures, where the queen and drones may be confined together, have failed. Such uncontrolled mating in nature makes genetic studies difficult. This problem has been overcome in *Apis mellifera* by the use of instrumental techniques (Ruttner, 1975). The mating behaviour of *Apis cerana* is reviewed as follows:

The number of premating flights was one to five with an average of 2.3 in northern India (Sharma, 1960) and one to seven with an average of 3.3 in West Germany (Ruttner et al., 1972) for *Apis cerana* queens. The age when the premating flights occurred was different at various places for the native queens. For example, it was one to six days with an average value of 3.6 days at Katrain, in Himachal Pradesh (Sharma, 1960), four days in the Kashmir valley (Shah and Shah, 1980) and 10 to 11 days in West Germany (Ruttner et al., 1972). Various research workers have reported different durations of premating flights for native queens. These were of two to three minutes duration in the Kashmir valley (Shah and Shah 1980), 1 to 25 minutes in Himachal Pradesh (Sharma, 1960) and 4 to 60 minutes (average 13.7 minutes) in West Germany (Ruttner et al., 1972).

Similarly, the time when the premating flight occurred also varied. For example, it was between 1230 and 1600 hours in Himachal Pradesh, (Sharma, 1960), 1300 and 1600 hours in West Germany (Ruttner et al., 1972) and 1330 and 1530 hours in Pune in India (Woyke, 1975).

Various investigations have reported the difference in ages of *Apis cerana* queens when mating flights occurred. For example, the age of the queen at the time of mating flight was two to six days (Adlakha, 1971), five to nine days with an average value of 6.4 days depending upon the weather (Sharma, 1960), six days (Shah and Shah, 1980) and 21 and 22 days (Ruttner et al., 1972). Similarly, the duration of mating flights also varied for the queen of this species. According to the reports of different research workers, this duration was 15 to 38 minutes with an average value of 22.3 minutes in Himachal Pradesh (Sharma, 1960), 27 minutes in Pune (Woyke, 1975) and 17 to 46 minutes with an average value of 30.8 minutes in West Germany (Ruttner et al., 1972). Mating flights of queen honeybees were observed between 1230 and 1600 hours in Himachal Pradesh (Sharma, 1960), 1300 and 1600 hours in West Germany (Ruttner et al., 1972) and 1400 and 1500 hours in Pune, India (Woyke, 1975). Ruttner et al., (1972) observed the mating flights between 17 and 18°C temperature in West Germany.

Ruttner et al., (1972) observed only three queens with double mating sign out of a total of eight studies in West Germany, whereas, Sharma (1960) reported two queens out of a total of twenty studied in Himachal Pradesh, India. Similarly, other researchers also reported the double mating sign for this species (Ruttner et al., 1972; Shah and Shah, 1980). The double mating sign showed the multiple mating habit of the queen bee of *Apis cerana* also. A well-mated queen of *Apis cerana* contains spermatozoa from more than five drones, because a single drone ejects about 1.0×10^6 spermatozoa only, representing the multiple mating habit (Ruttner et al., 1973). Similarly, Woyke (1973) observed that a single drone can eject only 0.16 µl semen during mating with an *Apis cerana* queen. However, Woyke (1975) later reported 1.5 to 3.0 µl (average µl) semen from the oviducts of the queen returning after the mating flight, again representing the multiple mating habit.

Sharma (1960) observed the start of egg-laying of *Apis cerana* queens at an interval of two to three (average 2.3 days) after her last mating flight. Adlakha (1971) also reported egg-laying at an interval of two to four days.

According to Lavrekhin (1960), drones of *Apis cerana* flew between 1600 and 1900 hours, and their maximum flight activity was between 1600 and 1700 hours in Russia. However, Ruttner et al., (1972) observed drone flights between 1030 and 1,600 hours even at very low (12 to 15°C) atmospheric temperatures. They reported the maximum drone flight activity between 1200 and 1400 hours in West Germany. Hence, according to Ruttner et al., (1972), drones start flying earlier than the queen and stop after her flights. Ruttner et al., (1973) reported that both the quantity of semen and number of spermatozoa were lower in drone of *Apis cerana* as compared to the *Apis mellifera* drones. According to Woyke (1973), it is very difficult to collect the semen from the mucus of *Apis cerana* drones and only a third of the semen is separable.

The above data suggest that various research workers in different regions have reported variations in the number and duration of premating and mating flights in *Apis cerana* queens. These authors have also reported different ages of the queen bees when premating and mating flights occurred and when egg-laying started. Variations in the number of premating flights may be due to different weather conditions, whereas, the occurrence of more than one successful mating flight may probably be due to atmospheric disturbances such as clouds and wind, etc. or lack of opening of the queen sting chamber at the proper time during the mating flight. The duration of premating and mating flights may also be affected by different climatic and topographic conditions. The age of the queen when premating and mating flights occurred and when egg-laying started may also depend upon the weather conditions and flora.

2) *Brood Rearing Behaviour*: Very little information is available on different aspects of brood rearing activity of the Asian hivebee, *Apis cerana*. Earlier studies on brood rearing were done by Ramachandran (1939) who reported 300 to 500 eggs per day as the rate of egg-laying for *Apis cerana* queens. Rahman and Sharma (1945) reported a high rate of brood rearing during the winter months at Lyallpur in Pakistan. Sharma (1948), again at Lyallpur, studied variations in brood area during different seasons. Brood rearing was observed in winter also and it recorded a slight decline in the latter half of March, after which brood rearing was carried at almost the same rate. Practically none of the colonies reared brood continuously throughout the summer. He recorded up to 1,880 sq cm of brood (24, 816 cells) amounting to 1,240 eggs per day during February. Ramachandran and Mahadevan (1950) observed a steady decline in brood rearing from June up to September at Coimbatore (South India). There was an initial expansion of brood in November and December, and the peak of brood rearing was observed during January to March. Later, Ramachandran and Cherian (1952) again studied the brood rearing cycles of *Apis cerana* at Coimbatore. They reported 692 sq cm or 10,799 cells of brood in a thriving colony at the peak of the brood-rearing period. This gave an output of 514 eggs per day. Studies on the brood-rearing activity of *Apis cerana* at Allahabad in Uttar Pradesh in India revealed 6,178 and 8,178 sealed cells for a period of 12 days during February and April, respectively, suggesting an oviposition rate of 515 and 681 eggs per day, respectively (Kapil, 1957).

Bisht (1966) found maximum brood-rearing activity of *Apis cerana* in February and March under the climatic conditions of Delhi. December was quite unfavourable. Saraf and Wali (1972) calculated the egg-laying rate of *Apis cerana* (hill strain) in Kashmir by measuring the brood area every three weeks. Brood rearing was maximum in May and early June and declined in October. Reddy (1980) made observations on the annual cycle of brood rearing at Bangalore (South India). Brood rearing occurred throughout the year, and this activity was maximum from March to November and minimum in December and January. The greatest amount of sealed brood was present in April. Shah and Shah (1981) studied the egg-laying capacity of *Apis cerana* in Kashmir.

They concluded that the egg-laying rate of Kashmiri bees was higher in the *Apis cerana* group in India and also higher than exotic *Apis mellifera* L. under conditions in the Punjab. Maximum brood rearing was reported in May and it was minimum in January.

Sharma (1958b) compared the brood-rearing activity of the mountain grey race of *Apis cerana* in the plains and at higher altitudes in India. He concluded that the brood-rearing activity was suspended at higher altitudes, with the approach of winter, but that this did not happen in the plains. The maximum laying rate of the mountain grey race of queen bees was about 1,000 eggs per day, whereas, the golden race of the plains laid about 600 eggs per day.

3) *Absconding Behaviour*: One of the major constraints in beekeeping with the Indian honeybee, *Apis cerana* is its absconding behaviour. Frequent swarming and absconding may be beneficial for the survival, dispersal and propagation of the species but it poses a serious threat to beekeeping, especially when it occurs during the honey-flow seasons. Absconding may be due to disturbances created by predators and pests, frequent manipulation by beekeepers, smoke, fire, inferior nesting site etc., or seasonal, due to dearth of resources or environmental fluctuations (Smith 1960, Fletcher 1975). Colonies under stress are also more prone to absconding, caused by poor colony strength, presence of old combs in the hive, extra foundation sheets in the brood nest and improper location of the colonies.

Dulta et al. (1988) conducted studies to understand the absconding behaviour of *Apis cerana* in temperate climates, and to elicit the possible causes, in so far as it relates to the conditions within the colony. These authors found that the absconding rate of *Apis cerana* may vary from 30 to 100 per cent and this species resembles African races of *Apis mellifera* in its absconding behaviour. It was also observed that the *Apis cerana* of northwest Himalaya is less prone to absconding than the one from the plains. It was found that absconding took place when the areas under honey and pollen stores, eggs, larvae, sealed brood and total brood in the colony were less than 710, 20, 50, 1, 10 and 60 sq cm, respectively. They left behind very little amount of honey, pollen and brood. A similar pattern was observed by Woyke (1976) for *Apis cerana* in Asia and by Winston et al. (1979) for *Apis mellifera adansonii* in South America. This reduction may be a means to conserve energy so as to enable the colony to reach a new site (Fletcher 1975). The absconding tendency can be delayed or checked by giving honey pollen and brood combs to the absconding colonies at proper times because these biological and economic characters are inter-related (Woyke 1976, Verma et al., 1988a,b).

Management practices such as feeding sugar syrup, changing brood combs, restricting entrances, provision of hive stands, limiting inspection of colonies, uniting small and healthy colonies and swarms with weaker colonies and regulating supering may help to reduce the frequency of absconding. Such management, practices must be applied at exactly the correct time to ensure success. Close monitoring of the availability of pollen and nectar throughout the year is also required (Olsson, 1988). The author tried these management methods to check absconding in the Coorg hills of South India for six years and succeeded in reducing absconding below 5 per cent. These practices helped in increasing the honey yield per colony from 3–5 kg to around 20 kg and the number of colonies participating in the main honey-flow doubled.

4) *Swarming Behaviour*: In social insects like honeybee, swarming is a natural instinct, whereby, a colony divides so that part of it, searches and settles in a new site usually with the old queen, whereas, the remaining members continue at the original site with the newly emerged queen which later mates with the drones in the air to become fertile. In this manner, bee colonies, perpetuate and do not become extinct. However, for a beekeeper, swarming means loss of both bees and honey and all possible attempts should be made to check it.

Swarming may occur due to congestion in the colony, poor ventilation of the hive, defective combs, continuous bad weather, hereditary factors, increasing number of idle bees, diseases like sacbrood, low fertility of the queen and decline in the production of queen substance (pheromone). Environment stress caused by starvation, excessive manipulation of colonies, attack of pests and predators and spread of epidemics are also responsible for frequent swarming (Verma, 1984).

Ruttner (1987) has reviewed the literature on the productive and migratory swarming of *Apis cerana*. Swarming behaviour of *Apis cerana* colonies in the mountainous region of northern India was studied by Sharma (1960). According to him it is usually a two-to-three-day-old queen which will swarm. Prior to swarming, an *Apis cerana* colony may raise as many as two to 29 queen cells with an average of nine cells per colony in the mountain region of northern India. Swarming generally take place between 0900 and 1300 hours in the mountain areas. The weight of the primary and secondary swarms may vary from 0.875 to 4 and 0.5 to 2.5 lbs, respectively. The number of bees in the primary swarm may vary from 16,000 to 35,000 and in the secondary swarm from 2000 to 10,000. The time taken by colony to return to normal working after swarming may vary from five to 21 days (Table 8.8).

Before a colony swarms, it shows several obvious signs or symptoms through which an experienced beekeeper can foresee the ultimately swarming. These signs or symptoms are production of large number of drones, increase in worker population, presence of queen cells at the lower edge of the frame, gorging of honey by worker bees, and reduced foraging by worker bees.

Table 8.8: Swarming behaviour of *Apis cerana* in northern India during spring season

Number of queen cells built prior to swarming	2–29	
Time of swarming (hours)	0900–1300	
Weight of swarms (1b)	0.875–4.0	(Primary swarm)
	0.5–2.5	(Secondary swarm)
Number of bees in swarm	16000–35000	(Primary swarm)
	2000–10000	(Secondary swarm)
Age of queen at the time of swarming (days)	2–3	
Time taken by colony to return to normal working after issue of swarm (days)	5–21	

Source: Sharma, 1960.

Swarming to some extent can be avoided through the provision of shade, ventilation, proper arrangement of nest brood, removal of uncapped queen cells or capped drone brood, artificial division of colony, introduction of new queen, etc. (Verma, 1984).

8.2.6 Diseases and Enemies

There are frequent reports of *Apis cerana* colonies being affected by nosema, virus cluster and sacbrood diseases in the Hindu Kush-Himalayan region. As no control measures are available for virus diseases, this needs watching closely. Recently, the European foul brood disease has badly affected *Apis cerana* colonies in the Kathmandu valley of Nepal Kingdom.

Among the mites, *Acarapis woodi, varroa jacobsonii, Neocyphalaeps Tropilaelaps* sp. and *Pymotes neferi* have been reported on *Apis cerana*. Among these, Acarine disease poses a serious problem (Verma, 1987a).

Although *Acarapis woodi* was first discovered in England in 1921, it was reported in the hilly state of Himachal Pradesh in India only in 1957 (Singh, 1957). Since then, this species of mite has spread to the entire northwest region of India where beekeeping with *Apis cerana* is widespread. The incidence, symptoms, biology and control of Acarine disease have been studied under Indian environmental conditions by several authors (Singh, 1957; Milne, 1957; Singh and Adlakha, 1958, 1960; Atwal, 1971; Shah and Shah, 1978a,b; Dinabandhoo and Dogra, 1979, 1980; Kshirsagar et al., 1980; Singh and Verma, 1981). According to these authors, the period of maximum infestation of *Apis cerana* colonies by *Acarapis woodi* varies from place to place depending upon the honey flow, brood rearing and other environmental conditions. In general, maximum infestation was observed during the spring (March-April) and autumn (October-November) seasons in the hilly regions of northern India. The percentage of the infested colonies varied from 20 to 85 per cent in different apiaries. Migratory beekeeping and transfer of colonies from wall to modern movable hives is the main cause for the rapid spread of this disease.

In India, this disease is being controlled either through chemotherapy or by adopting better management techniques. The conventional chemicals in use are fumigation with methyl salicylate, chlorobenzilate (Folbex), mixture of safrol + nitrobenzene + petrol, formic acid, fine powdered sulphur, menthol, etc. Treatment of colonies with these chemicals often results in loss of queens and can have other adverse effects on the bees without effectively curing the disease. Dinabandhoo and Dogra (1979, 1980) recommended the use of Dichlorovos (dimethyl 2-dichlorovinyl phosphate), an organophosphatic fumigant, for the control of Acarine disease in *Apis cerana* colonies. According to Anderson and Atkins (1968) and Singh et al. (1974), this compound is highly toxic to the bees. In developing countries, constraints are required to be exercised in the use of such hazardous biocides.

Poor management and negligence on the part of beekeepers are the main causes for the spread of this disease in *Apis cerana* colonies. By keeping the colonies strong and healthy, losses due to this disease can be reduced substantially. Occasional treatment of colonies with methyl salicylate in the initial stages of infestation coupled with strong selection of healthy colonies, help in the satisfactory control of this disease (Verma, 1987a).

Among the predators, five different species of wasps pose a serious threat to the beekeeping industry in this region. Because of its shimmering and evasive behaviour, *Apis cerana* can resist the attack of wasps better than *Apis mellifera*. Recently, Ono et al. (1987) observed that worker bees of *Apis cerana japonica* showed a distinct balling behaviour, usually involving 180–300 bees, against the attack of predacious hornets as an effective counterattack strategy. This produced heat for as long as 20 minutes, inside the ball higher than 46°C which was lethal to the hornet and not to the bees.

Two species of the wax moths, *Galleria mellonella* and *Archoria grisella* are serious pests in *Apis cerana* colonies as this native species of honeybees do not collect propolis to guard against the attack of moths. Control measures for wax moths are the maintenance of strong colonies, removal of wax and debris from the bottom board, fumigation of drawn combs with ethylene oxide, continuous release of parasitic wasps, *Apanteles galleriae* by mass multiplication in the apiary, and storage of drawn combs below −7°C for four hours or fumigation of the drawn combs with EDCT, Detia or Phostoxin (Ahmad, 1986).

Another important disease of *Apis cerana* is caused by a protozoan *Nosema apis* and is known as the Nosema disease. The disease occurs in the Hindu Kush-Himalayan region in spring and winter and depletes colony populations quickly. The disease can now be controlled by medication of the colonies with Fumidil-B (Fumagillin) fed with sugar syrup (Verma, 1989b).

8.2.7 WINTER MANAGEMENT OF COLONIES

In the mountainous Hindu Kush-Himalaya, bee colonies require special care particularly in the winter and monsoon seasons. In these seasons, bee activities are reduced to a minimum due to the low outside environmental temperatures particularly in January and February, and the prolonged wet spell during July and August. Consequently, there are problems of inadequate food reserves, queenlessness, reduced fecundity and diseases. As a result of this, *Apis cerana* colonies often abscond/desert the hive. Efficient colony management is therefore, required to obtain high honey yields. A beekeeper has to follow a package of the following management practises in these seasons in order to obtain surplus honey yields (Verma, 1989b).

1) Introduction of a new productive queen of superior genetic stock in each colony during the fall or spring season so that there is enough brood, young bees and good colony strength to withstand adverse environmental conditions.
2) Protection against strong winds, storms and snow should be provided. This can be done by sealing all the holes and crevices of the hive with a plaster made from a mixture of clay and cowdung. Colonies should be kept in protected places and insulated during the winter with fine chopped dry grass, wood shavings, saw dust, etc. Wintering *Apis cerana* colonies successfully under the environmental conditions of the Shimla hills without providing any external insulation is no problem, provided such colonies have at least five to six frames covered with bees and enough honey and pollen stores.
3) Provision of adequate food resources in term of honey and pollen stores during the monsoon and winter seasons is essential. In case of scarcity, feeding the colonies with sugar syrup mixture (prepared by mixing equal parts of sugar and water) becomes necessary. As explained earlier in several countries, during the good honey-flow season, beekeepers generally collect pollen at the entrance of the hive through a special device called a pollen trap. Such pollen is freeze-dried and fed to the colonies during dearth periods. Although this practice of feeding freeze-dried pollen is not in use in this region, several pollen substitutes/supplements are available and can be fed to the bee colonies during dearth period.

4) To maintain colonies in a disease-free condition, drug feeding or adopting some special management practices is essential. This aspect is discussed in a separate section in this chapter.
5) In Himachal Pradesh (northern India), the state horticulture department and a few progressive beekeepers migrate their *Apis cerana* colonies from the temperate hilly regions to the sub-tropical plain areas at the onset of the winter. This migratory practice protects the bees from severe winter and also provides them with alternate floral resources in the lowland areas during this slack period. When such colonies are transported back to the hilly region in spring, they are of good strength to produce surplus honey and can be used effectively for cross-pollination of the apple bloom.

8.3 EXOTIC *APIS MELLIFERA*

Large-scale importations and multiplication of exotic *Apis mellifera* into the developing countries of south and southeast Asia for better economic returns in terms of higher honey production and efficient pollination services has become a controversial subject among bee scientists. At present, different views are being expressed on this issue which are summarized as follows:

> As a result of continuous research efforts being made in developed countries in Europe, the Americas and the Pacific region for the last 100 years or more, many new and improved races of *Apis mellifera* have been evolved. At the same time, effective methods of management have also been developed for the successful domestication of this species of honeybee. Consequently, honey yield per colony has been increased by 200 per cent. Similarly, low and high preference lines for better pollination have been developed (Verma, 1985).

Keeping in view these results, some leading bee scientists and international donor agencies such as FAO of the United Nations, are recommending importation of this exotic species of honeybees into this region for the development of beekeeping as an income-generating activity particularly for the poor rural people living at, or below the subsistence level.

Such apiculture experts and donor agencies are of the opinion that only exotic *Apis mellifera* can bring about the "sweet revolution" in this region in the same way as the high yielding exotic varieties of wheat were instrumental for the "Green Revolution".

In parts of northern India and the North West Frontier Province of Pakistan, *Apis mellifera* has been the basis of a flourishing beekeeping industry and so much surplus honey is being produced that efficient marketing of this hive product is becoming a major problem.

Studies on the economics of beekeeping with native and exotic species of honeybees indicate such vast differences in the profit level that a farmer practicing beekeeping with exotic *Apis mellifera* in North West Frontier of Pakistan can easily afford an imported car, whereas, the one continuing with native *Apis cerana* is still using a bicycle (Ahmad, 1990).

Yet, projects involving large-scale introduction and multiplication of exotic *Apis mellifera* into this region is being discouraged.

Doubts are being expressed that this species may not adapt well to the new environment due to different climatic conditions, flora, mating competition with *Apis cerana* and hazards of predators and disease. Koeniger (1976b), a bee scientist from West Germany, made the following observations regarding the introduction of *Apis mellifera* into Asia during on International Conference on Apiculture in Tropical Climates:

"In the past, many attempts have been made to import *Apis mellifera* to Asia, but most of these experiments were failures. The northern *mellifera* bees are not adapted to the various enemies of honeybees. In Pakistan and Kashmir, for example, the hornet *(Vespa orientalis)* destroys the colonies, in Sri Lanka it was observed that all *mellifera* bees were caught by bee eaters (Merops). In other parts of Asia, it has been reported that *Apis cerana* robbed *mellifera* colonies. At other places, where the *mellifera* colonies were protected against predators, it was observed that all virgin queens failed to mate against their mating flights and we guess that the *mellifera* drones were prevented from copulation with the queens by the competition from drones of the other honeybee species. Nevertheless, at some places in northern India, *Apis mellifera* seems to survive. In consequence of this situation, some might consider it useful to import a tropical race of *Apis mellifera* but I want to stress that this would be a very hazardous and risky project. In the light of the sequence of events in South America, it seems possible that a tropical *Apis mellifera* could irreversibly damage the fauna of Asia, and indeed the consequence of such a step cannot be calculated."

Thus, the introduction of this exotic species into the Hindu Kush-Himalayan region may have unfortunate ramifications because of this species allopatric nature, susceptibility to diseases, parasites and predators, different bee flora and high cost technology for operations. Native *Apis cerana* possesses many valuable characters of great economic and biological significance, which have yet not been explored.

Another group of apiculture experts suggests that these two species of honeybees are complementary to each other as far as beekeeping in the temperate and sub-tropical regions of south and southeast Asia are concerned. In a sub-tropical climate, native *Apis cerana* cannot survive the excessive heat and consequently this species frequently swarms and absconds. This makes management of the species difficult and annual honey yield per colony is extremely poor (1 to 3 kg). However, exotic *Apis mellifera ligustica* (Italian bees) can withstand high temperatures better because of effective ventilation of the hive by fanning and also by forming a cluster at the hive entrance during the hot summer season (Verma, 1970). But this sub-species of *Apis mellifera* has not yet acclimatized well to the ecological conditions of the temperate mountainous regions and the colonies start dwindling in strength at the onset of winter (Verma, 1989b).

Keeping in view the better performance of native *Apis cerana* in the cold temperate region and that of *Apis mellifera* in the sub-tropical climate of this region, zonation of beekeeping areas suitable for each of these two species should be done. Beekeeping with *Apis cerana* should be encouraged in its principal temperate habit and in such areas beekeeping with exotic *Apis mellifera* should not be introduced. In the sub-tropical and tropical regions, beekeeping with exotic *Apis mellifera* should be tried with due care.

The present status of beekeeping with *Apis mellifera* in the Hindu Kush-Himalayan countries is reviewed as follows:

8.3.1 CHINA

In China, the first importation of European honeybees *Apis mellifera* was in 1913 (Svensson, 1977). Beekeeping with European bees is now practised mainly along the coast and in vast lowland areas of northeast and central China. At present, the Italian bees, *Apis mellifera ligustica* are mainly used for commercial honey production. Also there are Caucasian bees *(Apis mellifera caucasia)* and Carniolan bees (*Apis mellifera carnica*) but their number is small in comparison to Italian bees. Based on several years of beekeeping practise, China has resorted to zonation of potential beekeeping areas according to the suitability of different races of European honeybees to different environmental conditions. For example, the Caucasian and Carniolan races have been introduced into Manchuria, Inner Mongolia and Singkiang for more than 30 years, as these races are cold-resistant and produce surplus honey even in severe temperate climatic conditions. In central China, for the last 70 years, the Italian bee *Apis mellifera ligustica* is chiefly distributed for commercial honey production. This bee species is well acclimatized to a sub-tropical climate. In the south and southwest regions, beekeeping with *Apis cerana* is common. It includes Szchwan, Yungnan, Hunan, Kweichow, Kwangturg, Kwangsi and Fukien (Liu, 1985).

In China, there are no commercial apiaries which specialize in mass-scale queen rearing for sale to beekeepers. The usual practice is that each apiary has its own queen-rearing facilities.

Before 1950, when migratory beekeeping was practised on a small scale, it was much easier to maintain the purity of these exotic races of *Apis mellifera*. However, large-scale migratory beekeeping for obtaining additional crops of honey now has resulted in a mixing of the exotic races of *Apis mellifera*, with the result that availability of good pedigree queen bees became a problem. In order to solve this problem, Institute of Apicultural Research, under the Chinese Academy of Agricultural Sciences, launched a selective breeding programme for the genetic improvement of *Apis mellifera*. As a result of this, honey production per colony increased by 25 per cent per annum. The selective breeding programme includes collection of germplasm from different parts of China and from abroad, the establishment of special apiaries for inbreeding and cross-breeding by controlled mating, instrumental insemination and, replacement of the less productive stock by hybrid species (Zhenming, 1990).

The introduction of *Apis mellifera* has revolutionized the beekeeping industry in China, and today it is the second largest producer and the biggest exporter of honey in the world. There are more than five millions colonies of *Apis mellifera* in China producing 160,000 metric tons of honey. Nevertheless, beekeeping with this exotic species is faced with problems. These problems include constraints of epidemics such as parasitic mites (*Varroa jacobsonii, Tropilaelaps clareae*), proneness of this exotic species to the attack of wasps, bacterial diseases, etc. (Zhenming, 1990).

8.3.2 India

Several attempts have been made, since the beginning of this century to introduce exotic *Apis mellifera* into the Indian subcontinent. Up to 1920, only a small number of colonies on a trial basis were imported, but they could not survive in their new environment. Larger bee stocks of the Italian bee, *Apis mellifera ligustica*, and the Carniolan bee, *Apis mellifera carnica* were imported to Pune in Maharashtra in 1920 and in Travancore and Mysore in the thirties from England and Australia (Singh, 1957, 1964). These attempts were followed from time to time by imports to other provinces of India, such as United Province, Punjab and Kashmir, by different missionary and official organizations (Rahman and Singh, 1940a, Muttoo, 1952). A consignment of exotic bees imported to Kulu in Himachal Pradesh in April 1938 made a good initial start but these colonies also could not survive due to severe cold in the winter. Such importation efforts received a serious setback due to the appearance of the Acarine disease and European foulbrood disease in the native hive bee, *Apis cerana*, for the first time in 1956-57 and 1961. The appearance of these two serious epidemics in

India was attributed to the importation of *Apis mellifera* from Europe and America. Chahal and Gatoria (1983) tried to provide conclusive evidence that the spread of these diseases to native *Apis cerana* was not from imported *Apis mellifera*. They considered that the *Acarapis* mite causing Acarine disease either evolved in the steamy hot Indo-Malayan region or it might have come from the temperate Alps to India through natural spread. Similarly, these authors suggested that the geographical continuity of Asia with Europe may have served as a natural route for the spread of European foulbrood in India. These views seem contradictory, possibly because epidemics such as the Acarine disease cannot spread from ecologically different regions such as the temperate Alps or the hot Indo-Malayan region.

It was during the early sixties (1962-1963), that the Italian bee *Apis mellifera ligustica* were successfully introduced and established at the apicultural research station at Nagrota Bagwan in Himachal Pradesh by a group of bees scientists headed by Dr. A. S. Atwal from Punjab Agricultural University, Ludhiana. Initial attempts were made to introduce individual mated exotic queens of *Apis mellifera* imported from Davis (California), Rothamstead (England) and Bologna (Italy) into colonies of native *Apis cerana* by the technique of inter-specific queen introduction (Atwal and Sharma, 1968). However, these experiments took a long time for the multiplication of bee colonies and, therefore, this approach was not very successful. An alternate approach adopted was to import disease-free nucleus colonies of hybrid strains, Midnite and Starline, from Florida in 1966. These colonies were kept under strict experimental observation. The performance of these strains by themselves and with native *Apis cerana* was compared (Atwal and Sharma, 1970). These results suggested that among all the exotic strains, the yellow strain gave a better performance in terms of building the brood area at a faster rate, and they were also milder in temperament. Subsequent experiments revealed that the honey yield from exotic *Apis mellifera* as 19.4 kg at Nagrota and 14.5 kg at Ludhiana was three to four times greater than native *Apis cerana* (Atwal and Goyal, 1973). Through extensive research for the past 25 years, it has been possible to successfully acclimatize these exotic bees in the Indian Himalayan region as well as in the Indo-Gangetic plains.

The performance and prospects of beekeeping with *Apis mellifera* in northern India has recently been summed up by Atwal (1987) as follows:

"The introduction of *Apis mellifera*, the so-called Italian honeybee or the European honeybee species, into Punjab and Himachal Pradesh during the mid-sixties and its successful establishment during the following decade, has not only revolutionized honey production and improved farmers income, but also contributed substantially to the stability of agro-ecosystems in this region. The new species has replaced the Indian honeybee since 1985 when the colonies of the latter were practically wiped out by Thai-Sacbrood disease in Himachal Pradesh, and for the first time made beekeeping possible in the Punjab Plains."

The present stocks of *Apis mellifera* in northern India are the descendants of mixed stocks of California yellow, two hybrids obtained from Florida, and Causcasian bees imported from Australia. A regular stock of exotic *Apis mellifera* is being maintained both at Nagrota beekeeping farm and at the apiary of Punjab Agricultural University, Ludhiana. From these centres, the bee colonies are being distributed to the farmers of Himachal Pradesh and Punjab and to the adjoining states of India. The yearwise number of colonies in Punjab and Himachal Pradesh is given in Table 8.9, which indicates that their number is almost being doubled every year. Now beekeeping with exotic *Apis mellifera*, because of its higher honey yields, is spreading to other areas in the plains and mountains. Moreover, the sacbrood virus disease, which killed more than 95 per cent of the colonies in this region, has necessitated the importation of *Apis mellifera* into these areas (Verma, 1989b).

8.3.3 Pakistan

All past attempts to introduce beekeeping with *Apis mellifera* in Pakistan failed. Rahman and Singh (1940) tried to establish beekeeping with this exotic species at Lyallpur but without success due to serious attacks of wasps. It is only after 1977-1979 that the bee research group at National Agricultural Research Centre, Islamabad, headed by Dr. Rafiq Ahmad, succeeded in the successful introduction and acclimatization of this exotic species in Pakistan. During these years, package colonies of Caucasian bees *(Apis mellifera caucasia)* and package colonies of Italian bees *(Apis mellifera ligustica)* were imported from Russia and Australia, respectively. Earlier, Makhdoomi et al. (1977) studied the acclimatization, reproduction and foraging behaviour of these races of *Apis mellifera* under the ecological conditions of Islamabad and surrounding areas. All these races flourished well and yielded swarms. These colonies produced surplus honey from local honey plants such as *Carrisa opaca*, *Trifolium* sp. Frequent robbing of these bees by native *Apis cerana* and then becoming easy prey to wasps were major constraints. Ahmad and Ahmad (1986) listed several factors affecting the establishment of *Apis mellifera* in Pakistan in the initial stages. These included the presence of toxic flora, difficult management due to clustering of exotic bees at the entrance, attack of mites and hornets, high summer temperatures, and unsuccessful mating flights by the queen bees. However, these problems were overcome by adopting suitable management practises, with the result, beekeep-

Table 8.9: The number of exotic *Apis mellifera* L. colonies at the research stations and with the private beekeepers in northern India

	Himachal Pradesh			Punjab		
Year	Experimental colonies at Nagrota	No. of private beekeepers	No. of colonies with private beekeepers	Experimental colonies at Ludhiana	No. of private beekeepers	No. of colonies with private beekeeper
1965–66	13	Colonies not given	—	6	Colonies not given	—
1966–67	45	-do-	—	10	-do-	—
1967–68	54	-do-	—	15	-do-	—
1968–69	85	-do-	—	20	-do-	—
1969–70	115	-do-	—	27	-do-	—
1970–71	163	-do-	—	45	-do-	—
1971–72	164	-do-	—	132	-do-	—
1972–73	150	-do-	—	140	-do-	—
1973–74	151	-do-	—	142	-do-	—
1974–75	156	6	25	136	-do-	—
1975–76	173	15	86	140	-do-	—
1976–77	190	24	220	120	5	28
1977–78	200	32	475	112	34	116
1978–79	202	40	1000	125	80	750
1979–80	217	60	2000	135	157	1500
1980–81	202	120	3000	150	250	3000
1981–82	216	200	3500	177	500	5000
1982–83	235	250	4500	200	950	10000
1983–84	225	350	5000	250	1941	20000
1984–85	184	450	5500	205	3000	30000
1985–86	186	650	7000	195	5200	55000
1986–87	185	750	7800	164	6500	68000

Source: Atwal, 1987.

ing with *Apis mellifera* has revolutionized honey production in the country. Today there are 14,000 colonies of *Apis mellifera* in Pakistan and other parts of the region. This exotic species is gradually replacing beekeeping with native hive bees (Ahmad, 1990).

8.3.4 Afghanistan

Modern beekeeping in Afghanistan started in 1954, when an Afghan national, Mr. Abul Rauf, after 13 months of beekeeping training in Turkey, started keeping the native hive bee, *Apis cerana*. But he faced serious problems of absconding and low yield. After a series of unsuccessful attempts, three colonies of *Apis mellifera caucasia* were imported. These exotic bee colonies produced 10 to 20 times more honey (70 kg per annum) than *Apis cerana*. Encouraged by such high honey-yielding species of honeybees, in 1962, 10 more colonies of Italian bees, *Apis mellifera ligustica* were imported, which also did very well. Attempts were also made to improve the local hive bee *Apis cerana* by introducing exotic *Apis mellifera* queen into their colonies, but without success. Neither the Carniolan *(Apis mellifera carnica)* nor Italian *(Apis mellifera ligustica)* queen bees were accepted by the native *Apis cerana*. Later more Italian bee colonies were imported (Woyke, 1984).

In 1968, an American Peace Corps Volunteer, Mr. Carter Hoffman, originally a commercial beekeeper, launched a national beekeeping programme in Afghanistan and encouraged beekeeping with *Apis mellifera*. He also wrote a book entitled *Practical Ideas for Afghan Beekeepers*. Since then, the beekeeping industry with exotic *Apis mellifera* has flourished well (Swanston, 1969). In recent years, large numbers of Afghan beekeeper refugees carried with them *Apis mellifera* to Pakistan also, and these refugee beekeepers have played an important role in popularizing beekeeping with this exotic bee species in Pakistan (Khan, 1990).

Major constraints in beekeeping with *Apis mellifera* in Afghanistan are epidemics of *varroa* and *Tropiolaelaps* mites. In 1984, these mites killed more then 80 per cent of the *Apis mellifera* colonies in Afghanistan, In 1983, the FAO deputed Professor Woyke from Poland to look into the problem of bee mites in Afghanistan. Now, due to the discovery of effective chemicals and management practices, the problem of bee mite control is partly solved (Woyke, 1984).

8.3.5 BURMA

Large-scale importation of exotic *Apis mellifera* into Burma was done under an FAO project stared in 1979. Under this project, about 500 packages of Italian honeybees *Apis mellifera ligustica* was imported from Australia and one of them was seriously affected by American foulbrood. In 1982, there were about 1,000 colonies of *Apis mellifera* in Burma. Because of rich and diverse bee flora available in this country, it has the potential to support about 100,000 colonies of *Apis mellifera* (Morse, 1982). Parasitic mites, ants, high summer temperatures and excessive rainfall are the major constraints for the development of beekeeping in Burma.

8.4 COMPARATIVE BIOLOGY OF *APIS CERANA* AND *APIS MELLIFERA*

Before mass-scale introduction of exotic *Apis mellifera* into the Hindu Kush-Himalayan countries, it is important to study the adaptation of this exotic species in its new environment and compare its biological and economic characters with the native bee species, *Apis cerana*. Information on interspecific behaviour can be of great practical value for both beekeepers and bee scientists. The behaviour of honeybees may vary according to species and sub-species and also depend upon environmental factors such as bee flora, temperature, altitude and humidity. For the past 15 years, some studies on the comparative biological and economic characters of *Apis mellifera* and *Apis cerana* under the ecological conditions of this region have been conducted and are reviewed as follows:

8.4.1 Honey Yield

The annual honey yield of exotic *Apis mellifera* and native *Apis cerana* is compared in Table 8.10. Beside interspecific differences, great variations in honey yield also occur in different ecological zones for the same species. For example, the exotic *Apis mellifera* gave an annual average yield of 19.4 kg and 14.5 kg per colony in the sub-mountainous and plain region of India, respectively (Atwal and Goyal, 1973). According to Wongsiri et al. (1986), native *Apis cerana* colonies, produce 70 per cent less honey per colony annually than the exotic *Apis mellifera* in the Guandong Province of China where beekeeping with this native bee species is very popular and it represents 90 per cent of all bees. These authors suggest that since the colony size of *Apis cerana* is 30 per cent smaller than the exotic *Apis mellifera*, the individual *Apis cerana* worker bee is in no way inferior to *Apis mellifera* in honey production. Liu (1984) reported that *Apis cerana* collect 30 per cent less nectar during a foraging trip than *Apis mellifera* and this may be due to its smaller size of body and honey sacs. This difference in size ultimately affects the honey production potentials.

8.4.2 Brood Rearing

Sharma (1958b) compared brood-rearing activity of mountain grey race of *Apis cerana* in the plains and at higher altitudes. He concluded that the brood-rearing activity get suspended at higher altitudes as winter approached, but this did not happen in the plains. Maximum egg-laying rate of the mountain grey race queen bee was about 1,000 eggs per day, whereas, the golden race of plains laid about 600 eggs per day.

Table 8.10: Comparative honey yield of *Apis cerana* and *Apis mellifera* in the Hindu Kush-Himalayan countries

Country	Annual yield/colony in kg *Apis mellifera*	*Apis cerana*	Reference
India	14.5 to 19.4	4.3	Atwal and Goyal, 1973
Pakistan	21 (mean)	6 (modern hive) 2 (traditional hive)	Ahmad, 1984
China	60	40	Wongsiri et al., 1986
Bhutan	30	3	Verma, 1990b
Afghanistan	70 (maximum)	7 (maximum)	Woyke, 1984

Atwal and Sharma (1970) compared *Apis cerana* with different sub-species and ecotypes of *Apis mellifera* (Californian yellow, Starline, Italian yellow, English and Midnite) in terms of colony strength, brood-rearing activity and capacity for food storage. The Californian yellow ecotype was superior to others in all these activities and was followed by the Starline strain. *Apis mellifera* curtailed brood rearing at the time of honey flow (late April) but this was not the case with *Apis cerana*. The brood-rearing activity of *Apis mellifera* and *Apis cerana* was also compared by Hameed and Adlakha (1973) in the Kulu valley in Himachal Pradesh. During spring, *Apis mellifera* reared 38 per cent more brood than *Apis cerana*. Brood-rearing commenced in February, decreased after April, but increased again during August and showed a fall in next March. Woyke (1976) indicated that the brood of *Apis cerana* was very scattered on the combs. The main cause of this was that there were more larvae in the colony that the bees could rear (See also Table 8.11).

8.4.3 Flight Ability

Flight plays an important role in the foraging and migratory behaviour of honeybees. Pollinating efficiency is also affected by flight range. Different species of honeybees have different flight ranges, with a maximum of 8,500 m for *Apis dorsata* and minimum of 1,200 m for *Apis florea* (Singh, 1962). Flight ranges of *Apis mellifera* and *Apis cerana* are 5,100 and 3,200 m, respectively (Dulta and Verma, unpublished results). Since these interspecific differences in flight range of honeybees correspond to the order of their body size, it is possible that there may also be a relationship between the flight range and size of

Table 8.11: Comparative brood rearing by *Apis cerana* and *Apis mellifera* in the Shimla hills of northwest Himalaya

Month	Species	
	Apis cerana Brood area (sq cm)	*Apis mellifera* Brood area (sq cm)
March	1932.40	4200.88
April	2263.80	6867.31
May	2520.00	6155.88
June	1375.00	5342.53
July	1192.37	3237.90
August	1172.30	5669.55
September	1885.00	4697.53
October	1950.30	2483.25

Conclusion: *Apis mellifera* > *Apis cerana*

Source: Verma, 1986a.

the flight muscles. Flight ability in insects depends upon the length of the wings, in relations to their body size. The larger the wings, the faster are the bees able to fly. The wing length of *Apis cerana* is about 78 per cent of its body length, while that of *Apis mellifera* is only 70 per cent (Liu, 1984). This suggest that *Apis cerana* because of its faster flying ability is a more efficient forager than *Apis mellifera*. Further, flight behaviour data also support this contention. For example, Goyal and Atwal (1971) reported that that average flight speed of *Apis mellifera* is 50 m/2.95 sec and that of *Apis cerana* is 50 m/1.92 sec. These investigators also reported that wing vibration frequency of *Apis cerana* is 306 t/sec in comparison to 235 t/sec in *Apis mellifera*.

Flight range is affected by the thoracic indirect and direct muscles (Wigglesworth, 1965). Flight in honeybees is produced mainly by indirect fibrillar muscles (Pringle, 1957, 1974; Dade, 1962; Daly, 1963). Much work has been done on the morphology of flight muscles of *Apis mellifera* (Morison, 1927; Dade, 1962; Daly, 1964), but none on *Apis florea, Apis cerana* or *Apis dorsata*. Accordingly Dulta and Verma (1987b) undertook a morphometric study of the flight muscles of the four species of hoaneybee in relation to flight range and pollination efficiency and are summarized in Tables 8.12 and 8.13.

With a few minor exceptions the length and breadth of indirect and accessory indirect flight muscles followed the order: *Apis mellifera* > *Apis cerana*, with statistically significant differences between species (P<0.01). The order of size for direct flight muscles differed

Table 8.12: Mean length and breadth (mm ± SE) of various flight muscles in *Apis florea, Apis cerana cerana, Apis mellifera* and *Apis dorsata*

DL = dorsolongitudinal muscles; DV = dorsoventral; AP = anterior pleural; PP = posterior pleural; PS = pleurosternal; IS = intersegmental; (An) = measurement taken in anterior part of muscle; (Po) = measurement taken in posterior part.

For measurement 1–6 and 14–17, *dorsata* > *mellifera* > *cerana* > *florea* ($P<0.01$); for 7, *cerana* > *dorsata* > *florea* > *mellifera* ($P<0.01$); for 10, *cerana* > *dorsata* > *florea* > *mellifera* ($P<0.01$); for 13, *dorsata* > *mellifera* > *cerana* and *dorsata*, *mellifera* > *florea* ($P<0.01$); for 8, 11, 12, *cerana* > *dorsata* > *florea* > *mellifera* ($P<0.01$); for 9, *cerana* > *dorsata* > *florea* > *mellifera* ($P<0.01$). n = 14 for all samples.

Measurement No.	Measurement	Species			
		A. florea	*A. cerana*	*A. mellifera*	*A. dorsata*
1.	Length DL	3.00±0.03	3.70±0.02	4.10±0.02	5.20±0.02
2.	Breadth DL (An)	1.05±0.00	1.75±0.02	2.20±0.02	2.60±0.02
3.	Breadth DL (Po)	2.15±0.01	2.48±0.01	2.73±0.02	3.36±0.02
4.	Length DV	1.77±0.02	2.11±0.03	2.43±0.02	3.43±0.02
5.	Breadth DV (An)	1.84±0.02	2.94±0.02	3.46±0.02	3.84±0.02
6.	Breadth DV (Po)	1.24±0.02	1.74±0.02	1.87±0.02	2.41±0.01
7.	Length AP	1.67±0.02	2.58±0.02	1.63±0.02	1.96±0.02
8.	Breadth AP (An)	0.61±0.01	0.90±0.03	0.43±0.02	0.77±0.02
9.	Breadth AP (Po)	0.31±0.01	0.33±0.02	0.23±0.02	0.33±0.02
10.	Length PP	1.04±0.01	1.37±0.07	1.02±0.01	1.07±0.14
11.	Breadth PP (An)	0.41±0.01	0.74±0.02	0.40±0.02	0.59±0.01
12.	Breadth PP (Po)	0.20±0.00	0.53±0.02	0.13±0.02	0.33±0.02
13.	Length PS	0.26±0.02	0.31±0.03	0.43±0.02	0.53±0.02
14.	Breadth PS	0.43±0.02	0.69±0.01	0.83±0.02	0.93±0.02
15.	Length IS	0.87±0.02	1.16±0.01	1.43±0.02	1.84±0.02
16.	Breadth IS (An)	0.71±0.01	1.23±0.02	1.47±0.02	1.63±0.02
17.	Breadth PS (Po)	1.04±0.02	1.51±0.01	1.69±0.01	1.97±0.02

Source: Dulta and Verma, 1987b.

from the indirect, with *Apis cerana* > *Apis mellifera*. Again a few of the differences were non-significant statistically. Among the ecotypes of *Apis cerana* both direct and indirect flight muscles followed the general pattern Kashmiri > Himachali > Manipuri bees, again with a few exceptions. Within each species and each ecotype of *Apis cerana* the number and diameter of muscle fibres were usually proportional to muscle size (length and breadth). Comparisons between species suggest that *Apis dorsata* has the longest flight range of any of the four species because of its large indirect and accessory indirect flight muscles, followed in turn by *Apis mellifera*, *Apis cerana* and *Apis florea*. The data for indirect muscles suggest that *Apis cerana*

Table 8.13: Mean numbers (± SE) of muscle fibres and mean fibre diameter (μm ± SE) of flight muscles of *Apis florea, Apis cerana, Apis mellifera* and *Apis dorsata*

FD = mean fibre diameter; other abbreviations as for Table 8.12
For measurements 1, 2, 5 and 6, *dorsata* > *mellifera* > *cerana* > *florea* (P<0.01); for 3 and 4, *cerana* > *dorsata* > *florea* > *mellifera* (P<0.01); for fibre diameter, *dorsata* > *mellifera* > *cerana* > *florea* (P<0.01). n = 30 for all samples.

Measurement No.	Measurement	Species			
		A. florea	*A. cerana*	*A. mellifera*	*A. dorsata*
1.	DL	26.76±0.08	32.80±0.07	51.13±0.09	65.10±0.11
2.	DV	28.27±0.08	37.87±0.14	52.93±0.12	66.97±0.16
3.	AP	7.90±0.01	10.87±0.08	7.20±0.07	8.83±0.07
4.	PP	5.30±0.09	7.13±0.06	5.20±0.09	6.00±0.08
5.	PS	6.10±0.09	7.93±0.08	8.87±0.06	10.03±0.09
6.	IS	10.10±0.09	12.03±0.08	16.20±0.10	17.17±0.10
	FD_m	140.6 ±0.1	174.9 ±0.1	202.0 ±0.1	237.0 ±0.1

Source: Dulta and Verma, 1987b.

is the most adept of the four species in changing direction and body balance during flight, and *Apis mellifera*, the least. The direct flight muscles aid in turning and manouvring around flowers (Daly, 1963). It has generally been observed that *Apis mellifera* is more susceptible than *Apis cerana* to attack by wasps owing to the ability of the latter to rapidly change its angle of flight at the hive entrance so as to avoid attack. Such behaviour is completely absent in *Apis mellifera* and this could possibly be attributed to the smaller size of the direct muscles.

The extraction and quantitative estimation of fuel source and enzyme activities in the thoracic muscles of different species of honeybees was done by Dulta (1986). The amounts of glycogen, the major fuel source, lipids and enzymes like glycogen phosphorylase, succinic dehydrogenase and glycerophosphate deydrogenase followed the pattern: *Apis dorsata* > *Apis mellifera* > *Apis cerana* > *Apis florea* (P<0.01, P<0.05). Fuel source and enzymatic activity were significantly higher (P<0.01) in summer, the active season, than in winter, the lean season. The amounts of glycogen, total lipids and activities of the associated enzymes in honeybees were found to be directly proportional to the body size and flight muscles size, flight ranges and foraging efficiencies of the honeybees.

8.4.4 Olfactory Sense

Apis cerana has a better searching ability of scattered or sparse floral resources and is thus more suited to the local conditions of this region where, due to mass deforestation, density of honey plants is decreasing. The better ability to utilize scattered bee flora may be because the native bee species has a better sense of smell, particularly for the local floral resources. Such sensitivity might have evolved due to co-evolution of bees and flowers in the same region through centuries. This better ability to search sparse or scattered flora by *Apis cerana* is evident by the fact that after moving both the domesticated species of honeybees to a new location, *Apis cerana*, returned to the hive about half an hour earlier than *Apis mellifera* in the same area (Wongsiri, et al. 1986).

8.4.5 Foraging Hours

According to Verma and Dulta (1986), worker bees of *Apis cerana* start their foraging activity significantly earlier in the morning and cease it later in the evening in the Shimla hills of northern India. Thus, the average duration of foraging activity in *Apis cerana* (13.10 hours) is significantly more than that of *Apis mellifera*. Wongsiri et al. (1986) also reported that *Apis cerana* start collecting nectar 10 to 15 minutes before dawn and continue foraging shortly before dark. These researchers also concluded that the foraging period of *Apis cerana* is two to three hours longer than that *Apis mellifera* in China.

8.4.6 Fanning Behaviour

Worker bees of *Apis mellifera*, while fanning their wings face their heads towards the entrance and *Apis cerana* in the opposite direction in order to draw in air for the purpose of cooling their nests. (Ruttner, 1987). Such fanning behaviour also affects ventilation and the honey ripening process inside the hive. During a nectar flow, considerable amount of water needs to be removed from the hive so as to reduce the moisture content of the honey to 17–20 per cent. However, if the outside environmental temperature exceeds 38°C, *Apis cerana* cannot withstand this and tend to abscond (Verma, 1970).

8.4.7 Hoarding Behaviour

Rana (1989) measured the comparative hoarding behaviour of *Apis mellifera* and *Apis cerana* in terms of the amount of sugar syrup hoarded per bee per day under controlled laboratory conditions. These results reveal that *Apis mellifera* hoards significantly more sugar syrup than *Apis cerana* (Table 8.14).

Table 8.14: Effect of temperature on the hoarding behaviour and longevity of honeybees

Temperature °C	No. of replicates	Hoarding behaviour (Sugar syrup removed, mg/bee/day)		Longevity (LT_{50}) value	
		A. mellifera	*A. cerana*	*A. mellifera*	*A. cerana*
15	6	19.99±0.49	21.03±0.70	7.36±0.08	7.26±0.13
20	6	36.52±0.91	36.68±1.25	19.40±1.85	20.28±1.00
27	6	80.68±1.55	60.80±1.29	25.99±1.24	25.26±1.09
35	6	131.94±1.98	106.57±3.24	28.45±0.74	28.57±2.17

Hoarding behaviour: (a) At higher temperature > lower temperature for both species ($P<0.01$)

(b) *Apis mellifera* > *Apis cerana* at 35 and 27°C ($P<0.01$)

(c) *Apis cerana* > *Apis mellifera* at 20 and 15°C ($P>0.05$)

Longevity: (a) At higher temperature > lower temperature for both species ($P<0.05$).

Source: Rana, 1989.

The above results on hoarding behaviour support the view that *Apis mellifera* is genetically superior in honey production compared to *Apis cerana* because in the hoarding behaviour experiments, outside environmental factors can be controlled. However, during slack seasons, *Apis mellifera* must be provided with supplemental sugar feeding. In China, *Apis mellifera* colonies require continuous feeding from July to February and average requirement per colony is 32 kg per year. *Apis cerana* require much less sugar feeding with an average of 5 kg per colony per year (Lai, 1960; Liu, 1984).

8.4.8 Aggressive Behaviour

Apis cerana, when disturbed, exhibit a characteristic behavioural pattern of pulling their body forward with their antennae raised, without the movement of legs, and produce a peculiar hissing sound. This behaviour is called shimmering and has been reported by various authors, in *Apis cerana* (Butler, 1974; Sakagami, 1960), and *Apis dorsata* (Roepke, 1930; Lindaeur, 1956). Such behaviour is not found in *Apis mellifera* but the native bee of Cyprus, *Apis mellifera cyprica*, has a trace of it. Fuchs and Koeniger (1974) reported that *Apis cerana* made a hissing sound, with frequencies mainly between 500 and 5000 hz, for the defence of the colony. These airborne sounds, induced in the hive, make the bees more aggressive and later the flight activity and aggressiveness were reported to be reduced significantly after such hissing sound (See also Table 8.15).

Table 8.15: Comparative stinging response of *Apis cerana* and *Apis mellifera*

	Apis cerana	*Apis mellifera*
1. Shimmering behaviour	Present	Absent
2. Stinging response	Less painful	More painful and irritating causes oedema
3. Quantity of bee venom excreted	Low	High
4. Proneness to sting	Easily disturbed	Less excitable

Reference: Atwal and Dhaliwal, 1969.

Studies on the comparative aggressive behaviour of *Apis mellifera* and *Apis cerana* were carried out under field conditions by giving physical stimulus such as hanging black balls at the hive entrance (Rana, 1989). The following five characters were studied:

1. the latency of the first sting made in the ball,
2. the latency of the colony to become aggressive,
3. the number of stings in the ball,
4. the number of stings on the gloves of the observer, and
5. the total distance that the bees followed an observer after the disturbance.

Apis mellifera took 18.6 seconds for initiation of the first sting as compared to 27 seconds by *Apis cerana*. The latency of the colony to become aggressive was more for *Apis cerana* (41.5 seconds) as compared to *Apis mellifera* (28.4 seconds). The number of stings left in the test ball were significantly higher in *Apis mellifera* than in *Apis cerana*. Infuriated bees of *Apis mellifera* followed an observer for a distance of 27.81 metres as compared to *Apis cerana* which went up to 18.68 metres. These results were significant, and considering them as a measure of aggressiveness, it was observed that *Apis mellifera* were more aggressive than *Apis cerana* (Table 8.16). Different colonies of the same species also differed from each other in their aggressiveness on all the measures. The Mean length of sting was significantly higher in *Apis mellifera* (2.286 mm) than *Apis cerana* (1.814 mm). However, there may not be any relationship between sting length and aggressiveness of honeybees (Table 8.15). *Apis mellifera* bees were shown to be very prone to stinging and were easily disturbed as compared to *Apis cerana* which were less excitable and could be safely handled (Atwal and Dhaliwal, (1969).

Table 8.16: Comparative aggressive behaviour of *Apis mellifera* and *Apis cerana* (Stort's method, 1974)

Species	Latency of first sting (sec)	Latency of a colony to become aggressive (sec)	No. of stings in the gloves	No. of stings in the ball	Pursuit distance (m)	Size of sting (mm)
Apis mellifera	18.6±0.5	28.4±0.6	0.8±0.1	8.3±0.4	27.81±0.57	2.28±0.006
Apis cerana	27.0±1.4	41.5±0.6	0.5±0.1	6.1±0.2	18.68±0.45	1.81±0.008
Mean difference	8.4**	13.1**	0.3 NS	2.2*	9.13**	0.47**

Each value is a mean ± standard error of five colonies, each colony with 50 observations.

NS = not significant

* = Significant ($P<0.05$)

** = Highly significant ($P<0.01$)

Aggressiveness: *Apis mellifera* > *Apis cerana* ($P<0.01$)

Source: Rana, 1989.

Responses of honeybees to four alarm pheromones, namely, isobutyl acetate, isoamyl acetate, 2-heptanone and n-amyl alcohol were studied under laboratory conditions (Rana, 1989). The latency for the initiation of the reaction in response to pheromone was significantly greater at low temperatures than at high temperatures in both *Apis mellifera* and *Apis cerana* (Table 8.17). The intensity of the reaction was judged as weak, medium, strong or very strong based on the degree of change in activity and number of bees involved when an alarm pheromone was given to bee. At higher temperatures, strong or very strong responses were observed, whereas, at low temperatures weak or medium responses were observed in both species. However, at a given temperature, intensity of the response was not significantly different between *Apis mellifera* and *Apis cerana*. The measure of aggressive behaviour in the present studies indicated that *Apis mellifera* responded to colony disturbance or to alarm pheromones more quickly, for a longer period, in greater number, with greater intensity, and with more stinging than *Apis cerana* (Table 8.17). Thus, the former species is more aggressive than the latter species. This more gentle temperament of *Apis cerana* may prove very useful in bee selection and breeding programme.

Table 8.17: Response of alarm pheromones to *Apis mellifera* and *Apis cerana* at 30°C

Pheromone	Time to reach (sec.)		Duration of reaction (sec.)		Percentage of bee's fanning	
	Apis mellifera	*Apis cerana*	*Apis mellifera*	*Apis cerana*	*Apis mellifera*	*Apis cerana*
Isobutyl acetate	8.31±0.17	9.63±0.13	57.78±1.07	51.44±0.81	20.88±0.89	18.93±0.91
Isoamyl acetate	4.54±0.10	5.87±0.11	77.55±1.39	66.12±0.85	21.74±1.04	19.82±1.46
2-heptanone	5.88±0.11	6.88±0.11	67.82±0.89	62.06±0.54	24.41±1.20	21.92±1.43
n-amyl alcohol	6.99±0.13	8.29±0.18	62.40±0.81	55.98±0.84	23.01±0.99	20.87±1.28

Each value is an average of 50 observations

Time to react and duration of reaction are different for *Apis mellifera* and *Apis cerana* ($P<0.01$)

Response of different pheromones to *Apis mellifera* and *Apis cerana* is significantly different ($P<0.01$)

Source: Rana, 1989.

8.4.9 Robbing Behaviour

Sakagami (1959) made observations on the interspecific relations between *Apis mellifera* (introduced) and *Apis cerana japonica* (endemic) and found that *Apis cerana* was more tolerant and less aggressive than *Apis mellifera*. He also suggested that robbery by *Apis mellifera* played an important role in the decrease of *Apis cerana* populations.

The robbing behaviour of *Apis mellifera* towards *Apis cerana* has also shown that the former species is aggressive inside the hive and also when small groups of both species are kept in confinement. *Apis mellifera* has also been found to be dominant at a common feeding place, however, *Apis cerana* has been found to be more aggressive than *Apis mellifera* only at the immature stages or when sealed broods of the latter were inserted in a hive of the former. The greater aggressiveness of *Apis mellifera* over *Apis cerana* was due to the former, being stronger, are therefore likely to be in a good position to resist the presence of the latter (weaker) under natural conditions. *Apis cerana* colonies are robbed by *Apis mellifera* causing the former to abscond. Robbing of diseased and weak colonies of *Apis cerana* by the strong colonies of *Apis mellifera* led to the spread of Acarine disease in the latter (Verma 1984; Dhaliwal and Atwal, 1969). These results were supported by earlier observations of Sakagami (1959) who reported that decrease of *Apis cerana japonica* colonies in Japan, concomitant with the increase of *Apis mellifera*, was partly due to the competition between the two species. Keeping in view the overall dominance of *Apis mellifera* over *Apis cerana* it appears that in order to keep both species in the same ecological habitat some special management techniques should be evolved, otherwise large-scale introduction of *Apis mellifera* may threaten the extinction of *Apis cerana*. This is an important aspect which deserves serious consideration.

8.4.10 Temperature Regulation

All the species of the genus *Apis* in their ability to regulate the hive temperature against outside air temperature change and these data are reviewed in Table 8.18. This information should help in assessing the adaptability of the two species to different climates.

In summer, when the outside air temperature was maximum (39°C), both the species significantly lowered their hive temperatures. When the outside air temperature exceeded 40°C, *Apis cerana* colonies absconded frequently, whereas, no such tendency was observed in *Apis mellifera*. At temperatures above 40°C, the fanning was more regular and frequent in *Apis mellifera* than in *Apis cerana* (Table 8.19). This is evident by the fact that evaporation rates of *Apis mellifera* hives were significantly higher than those of *Apis cerana* (Verma, 1970). Both in fall and spring, *Apis cerana* started foraging activities at 0700 hours but *Apis mellifera* began at 0900 hours when the outside temperature was much higher.

In winter, the mean cluster temperature at *Apis cerana* and *Apis mellifera* fluctuated between 36.7° to 37.1°C and 33.0 to 33.9°C against outside air temperature at 3.6°C to 17.3°C. The cluster temperature of *Apis cerana* hive was significantly higher than that of *Apis mellifera* possibly due to difference in compactness of cluster and the colony strength (Verma, 1970).

Results on high and low lethal temperatures suggest that *Apis mellifera* survived high lethal temperature (50°C) longer than *Apis cerana* (Table 8.20). This is remarkable considering that *Apis mellifera* bees originated in a much cooler climate and suggests the existence of inter-specific difference between bees of the same species from different climatic regions. The survival time at 5°C showed no difference between the species (Verma and Edwards, 1972).

Table 8.18: Mean temperature (°C) in bee hives* and outside air in different seasons and under different weather conditions

	Summer		Early fall	Late fall	Winter	Spring	
	Clear weather (Jun 12–18)	Cloudy of rainy weather (July 1–7)	(Nov. 5–11)	Sun	Shade (Nov. 27–Dec. 3)	(Jan.16–22)	(Mar 1–7)
Apis mellifera	32.5–37.0	32.2–34.6	26.7–34.3	(38.2)	(38.2)	26 –28 (33 –33.8)	32.8–33.4
Apis cerana	32.3–37.3	31.7–34.1	26.5–34.4	(37.1)	(37.2)	(22 –25.2) (37.1–39.0)	35.3–36.1
Empty hive	—	—	11.7–29.9	20.7	21.7	4.6–18.3	—
Outside air	29.4–39.0	27.4–32.8	12.3–32.2	—	21.6	3.5–17.3	13.2–29.2

*Results in parentheses indicate cluster temperature and without parentheses hive air temperature.

Source: Verma, 1970.

Table 8.19: Mean evaporation rate (mm^3 water/minute/100 mm^2 evapor-surface) and temperature of the hive and outside air in different season

	Summer		Fall		Spring	
	Temp (°C)	Evapor. rate	Temp (°C)	Evapor. rate	Temp (°C)	Evapor. rate
Apis mellifera	35.8	0.80	33.7	0.90	33.6	0.8
Apis cerana	35.7	0.40	34.1	0.80	36.0	0.5
Outside air	31.0	1.1	29.4	3.4	29.6	2.2

Source: Verma, 1970.

Table 8.20: Mean survival time (± standard error) for bees at high and low lethal temperatures in October and January

	Time at 50° (min)		Time at 5° (hr)	
	October	January	October	January
Apis mellifera	16.00±0.40	8.30±0.38	60.0±0.9	84±0.7
Apis cerana	8.60±0.32	3.80±0.10	60.0±0.1	84±0.9

Source: Verma and Edwards, 1972.

At present, Hindu Kush-Himalayan region has mainly the Italian race of European honeybee *Apis mellifera ligustica* especially in northern India. The above data on temperature regulation and tolerance suggest that the *ligustica* sub-species of *Apis mellifera* is better suited to the hot climate, whereas, *Apis cerana* is well adapted to the cold climate. This fact should be kept in mind while introducing exotic bees to other new parts of Asia.

8.4.11 Mating Behaviour and Fertility

One of the major difficulties in the bee-breeding programme of *Apis cerana* is the peculiar mating habit of the queen honeybee. The difficulty has been overcome in exotic *Apis mellifera* by the use of instrumental insemination techniques. However, similar use of the technique in native *Apis cerana* has unexpectedly turned out to be a difficult task because of the difficulty in obtaining the requisite quantities of semen ejaculated by drones of this species. An individual *Apis cerana* drone ejaculates about 0.35 µl of semen containing about 1.20 million of spermatozoa and these values are five to six times lower than of *Apis mellifera* drones. So the breeding programme for *Apis cerana* is generally carried out by allowing natural mating in isolated mating yards in order to avoid mixing of drones of different genetic origins (Verma, 1989a).

Comparative mating behaviour of *Apis cerana* and *Apis mellifera* queen and drone bees was studied in the Shimla hills of northern India by Verma (1986a). Out of the twenty-five experimental queen bees of each bees species studied, only one of *Apis mellifera* did not return from its mating flight.

Such data revealed significantly greater number of premating flights of *Apis mellifera* as compared to *Apis cerana* queen. The duration of such flights, however, was longer in the native than in the exotic queen bee. The queen bees at the time of mating and oviposition were older in *Apis mellifera* as compared to *Apis cerana*. Further, *Apis mellifera* queens started mating flights earlier than the *Apis cerana* queens. Drone bees started their flights activity earlier in *Apis mellifera* than *Apis cerana*. The peak period of mating flights of queen bees and drones coincided in both species (Table 8.21). The queen bees of both species secrete the pheromone of the same chemical composition during their mating flight which attracts drones of both species (Ruttner, 1969; Ruttner and Maul, 1983). These results suggest that drones of one species may make an abortive attempt to mate unsuccessfully with the queen bee of other species.

The queen bee of *Apis mellifera* possesses twice the number of ovarioles in the ovary, its spermatheca can store three times more number of spermatozoa, and it daily egg-laying rate is also three times as compared to the queen bee of *Apis cerana* (Table 8.22). Therefore, the natural mating and low fertility rate of *Apis cerana* offers a lot of constraints for its genetic improvement by selection and breeding. Further research is needed to develop a technique for the instrumental insemination of the queen bee of *Apis cerana* as has already been done for *Apis mellifera* (Verma, 1989a).

8.4.12 Diseases and Enemies

Varroa jacobsonii and *Tropilaelaps clareae* are the best known mites affecting honeybee colonies. Both these mite species are posing a serious threat to modern beekeeping with exotic *Apis mellifera* in Asia. In the Hindu Kush-Himalayan region, *Tropiolaelaps clarae* is a more serious threat to *Apis mellifera*. This infestation was first reported in the plains of the Punjab in 1963 (Atwal, 1969; Atwal and Goyal, 1971). *Apis dorsata* was the original native host of this parasitic mite (Bhardwaj, 1968; Laigo and Morse, 1968) and it is possible that the tendency of robbing by the *Apis mellifera* colonies was instrumen-

Table 8.21: Comparative mating behaviour data on *Apis cerana* and *Apis mellifera* queens

S. No.	Parameters	*Apis cerana* RV	*Apis cerana* MEAN	*Apis mellifera* RV	*Apis mellifera* MEAN
1.	Queen which did not return from mating flight	—	—	—	1
2.	Absconding or swarming during mating flight	—	—	—	—
3.	Number of premating flights	1 to 5	1.7	5 to 12	7.4
4.	Number of mating flights	0 to 1	1	1 to 2	1.2
5.	Age of queen at first mating flight (days)	2 to 7	5.4	4 to 6	5.3
6.	Age of queen at last mating flight (days)	5 to 8	6.7	7 to 11	8.8
7.	Duration between last mating flight and egg laying (days)	2 to 6	4.5	3 to 5	4.0
8.	Time of mating flights of queen (hrs)	1230 to 1530		1214 to 1450	
9.	Peak period of mating flights of queen (hrs)	1300 to 1400		1230 to 1330	
10.	Flight span of premating flights (minutes)	1 to 17	7.8	1 to 15	3.7
11.	Duration of mating flights (minutes)	19 to 35	22.5	17 to 38	28
12.	Minimum temperature for mating flights (°C)	18 to 28	—	18 to 23	—
13.	Number of queens with double mating signs	—	—	0 to 1	1
14.	Initiation and cessation of drone flight (hrs)	1100 and 1600		1045 and 1530	
15.	Peak activity of drone flight (hrs)	1345 to 1515		1200 to 1415	
16.	Number of queen cells formed in each colony	4 to 15	7.8	2 to 14	6.7

RV = Range of variation.
Source: Verma, 1986a.

tal in the transfer of *Tropiolaelaps clarae* to itself. A survey conducted by our research group (Verma, unpublished results), has revealed that about 30% per cent of *Apis mellifera* colonies are affected with this mite species in the plains and in the hilly regions of northern India where beekeeping with the exotic species has become very popular.

The maximum infestation of *Apis mellifera* colonies coincides with the peak period of the brood-rearing activity, both in the plains and

Table 8.22: Reproductive systems *Apis mellifera* and *Apis cerana*

S.N.	Characters	*Apis mellifera*	*Apis cerana*
1.	Number of follicles in testis of newly emerged drone	222.57±3.36*	108.21±2.62
2.	Volume of semen in individual ejaculate (µls)	1.20±0.05	0.32±2.44
3.	Number of spermatozoa per ejaculate (millions)	7.97±2.22	1.19±3.26
4.	Number of spermatozoa per µl semen (millions)	7.55±0.61	3.54±2.26
5.	Number of spermatozoa seminal vesicle (millions)	4.61±2.43	0.62±0.44
6.	Number of ovarioles in ovary	173.80±4.86	116.00±2.78
7.	Number of spermatozoa in spermatheca after 48 hours of mating (millions)	4.15±0.24	1.63±2.12
8.	Number of eggs laid per day	1500	397 ± 94.86

*Standard error about mean

Conclusion: Fertility of *Apis mellifera* > *Apis cerana* ($P>0.01$)

Source: Kumari, 1988.

in the hilly regions of northern India. The nature and extent of the infestation is similar to that reported earlier in other parts of Asia and Europe (Burgett et al., 1983).

In India, fumigation with chlorobenzilate (Folbex) and dusting the brood nest with a fine powder of sulphur dust are the common chemical measures being used to control this mite species on *Apis mellifera* colonies.

Apis mellifera is also very susceptible to American and European foulbrood. Different species of wasps cause serious damage to *Apis mellifera* and yet no effective control measures are available. On the other hand, *Apis cerana* suffer more loss due to the incidence of sacbrood virus disease, attack of wax moths, and acarine disease (Verma, 1987a). *Varroa jacobsoni* had also been reported on this native bee species but without causing any harm (Gupta, 1967; Pandey, 1967).

8.4.13 Inbreeding Problem

The introduction of *Apis mellifera* in several parts of Asia may face the problem of inbreeding because of its multiplication from a limited stock and the hapiodiploidy system of sex determination. Yet, importing of more exotic queen bees may prove risky because of the hazards of disease and parasites. The safest way, therefore, is the artificial insemination of virgin queen bees with a homogenous mixture of semen collected from a large number of drones so that the effective population size *(Ne)* in honeybee breeding is increased. Such a programme, therefore, provides new opportunities to keep inbreeding depression and brood losses at a low level (Verma, 1989a).

Verma (1978 a,b) developed a technique of the homogenous mixing of pooled samples of honeybee semen. These results show that honey spermatozoa can be washed and mixed homogeneously by centrifugation without causing any significant decrease in oxygen uptake. Experiments on instrumental insemination with suspension of freshly washed and centrifuged spermatozoa showed that the same number of spermatozoa reached the spermatheca after 48 hours of insemination as was the case with insemination with fresh semen. No necrosis of reproductive organs of the queen bee was observed (Verma, 1972 a,b; 1973, 1974, 1983 1989a).

Kaftanoglu and Peng (1980) modified the above method for washing honeybee semen in large quantities. Queens inseminated with such washed semen produced a brood similar to that of conventional methods except that oviposition was delayed. Moritz (1983) used genetic markers to determine the effectiveness of the above methods and reported that the random mixing of semen occurred through such techniques. Practical and theoretical basis of breeding closed populations of honeybee, and its genetic consequences have been discussed by Page and Laidlaw (1982 a,b) and Moran and Oldroyd (1983).

8.5 *APIS DORSATA*

8.5.1 Biology and Management

This species of honeybee is found all over the Hindu-Kush Himalayan region, in the plains as well as in the hills up to a height of 2,000 metres above mean seas level. It builds a single comb nest in an open cave under a roof or rock cliff. The size of a single open-air comb of *Apis dorsata*, depending upon the season and stage of development of a colony measures 1.5 to 2 m from side to side and 0.6 to 1.2 m from top to bottom. The upper portions of the comb store honey and pollen and are generally 10 to 25 cm thick. Below this storage area is the brood nest (Singh, 1962). In the Andamans islands on an average, the bee colonies were found attached at a height of 3-6 m from the ground level (Ahmad and Abbas, 1985).

The comb is suspended from rocks, ceilings of neglected and uninhabited houses, high hedges like vitex or branches of tall trees such as *Ficus bengalansis* (banyan), *Ficus religosa* (pipal), *Mangifera indica* (mango) and *Syzygium cumini* (jamun). Dozens of colonies may be found on one tree. *Apis dorsata* build their nests in such localities where flowers with abundant nectar supply are available. As soon as the nectar supply in a particular locality depletes, they migrate to other places (Dhano, 1947).

Apis dorsata prefers construction of nests on buildings as compared to open trees due to the availability of more protection against rain or wind. Accordingly to a survey carried out by Nandi and Mahabel (1974), 144 hives were found on buildings and only 31 on trees. These authors also suggested that apart from wind directions, the earth's magnetic field also had some effect on the construction of the hive in this species. However, Deodikar et al. (1977) reported 45 per cent of colonies on terrestrial supports while about 55 per cent were arboreal.

According to an estimate made in 1950, 75 per cent of all harvested honey and 81 per cent of the beeswax is harvested from colonies of this species in India. However, now with large-scale introduction of *Apis mellifera* and expansion of modern beekeeping with *Apis cerana*, this percentage has changed considerably and it is difficult to make an exact estimate now. According to different authors, honey yield per colony may vary from 5 to 50 kg. However, the average honey yield per colony is about 5 to 10 kg. Singh (1962) reported that a single colony may yield up to 37.3 kg of honey during a year. Dutta et al. (1984) reported a native plant *(Ammomum aculeatum)* from the Andamans Island of India which is frequently used by traditional honey hunters to tranquilize *Apis dorsata* bees during honey extraction. The sap extracted from stems and leaf stalks when smeared on the body of the honey collectors tranquilizes the bees and they do not sting. Active component in the sap of this plant has yet not been identified. This sap has no such visible effect on *Apis cerana* and its effect of *Apis mellifera* and *Apis florea* has not been investigated.

According to Qayyum and Ahmad, (1967), eggs of *Apis dorsata* hatched after two to three days. The larval stage lasted for four to five days in worker and drone bees and 4.5 days in queen bees. the duration of the pupal stage varied from 9.5 to 12 days in worker bees, 13.5 to 15.5 days in drones and 6.5 to 7 days in the queen bees. The relative lengths of oviducts and ovarioles in this bee species were very similar to *Apis mellifera* L., but *Apis dorsata* F. had 130 ovarioles per ovary in the queen bees and more than 20 in the worker bees. *Apis dorsata* also produced laying workers in the absence of a queen bee from the colony. Vishwanathan (1950a) observed that *Apis dorsata* constructed separate queen cells with similar shape as the other bees did for rearing the queen. However, the size of the queen cells was much longer and such queen cells were found to be protruding completely out of the lower edge of the comb. Vishwanathan (1950b) also studied the temperature regulation in *Apis dorsata* F. colonies, and it varied slightly in different parts of the same comb. The maximum temperature was observed in the central area with brood (27.3–28.3°C) and the average colony temperature ranged from 26.5 to 28.3°C against the outside temperatures of 20.7°C. Diwan and Satvi (1965) worked out the mechanism of venom ejection by *Apis dorsata* worker bees. If a worker bee is held by its wings over a watch glass, the abdomen is pointed downwards. Bees then eject a transparent poisonous liquid from the everted sting.

Thakar (1973) made preliminary attempts to hive *Apis dorsata* colonies. The process involved mounting the single comb that houses the colony inside a large wire screen cage fitted with flight holes. The comb was then put in a hive made of glass or any other transparent material, in which an "artificial tree" with horizontal side branches made of wooden bars and baited with beeswax was placed. Various other equipments were also designed, to attract swarms, to capture settled colonies and to transfer them to desired locations. In such a hive, *Apis dorsata* activity was normal. The worker bees appeared less aggressive in such a hive than in a natural best, perhaps because of better shelter or security in the hive. Further, during dearth periods the hive could be transferred to where suitable forage was available.

Mishra et al. (1977) made an attempt to domesticate wild, ferocious and migratory rock bees. They introduced *Apis dorsata* queens into nucleus hives with young worker bees of *Apis cerana* and *Apis mellifera*. However, *Apis dorsata* queens were not accepted by the colonies of other species. Roonwal (1956) observed that during partial solar eclipse, the number of bees leaving and returning to the hive increased considerably and this activity declined after the eclipse.

Newton (1969) studied the behavioural response of honeybees to colony disturbance by smoke. Smoke caused reduction in the number of guard bees that would otherwise have been recruited in great numbers at the entrance by the effect of the alarm pheromone, i.e. isopentyl acetate. The number of outgoing foragers were similarly affected. *Apis dorsata* are good honey gatherers and they start their foraging activity later than *Apis cerana*. They even forage at night on nocturnally blooming plant species (Diwan and Satvi, 1965). Kapil and Kumar (1975) studied the foraging activity of *Apis dorsata* on *Brassica juncea* and reported active foraging when temperature ranged between

15 and 23°C. They also suggested that besides temperature, other climatic factors also affected the foraging activity of *Apis dorsata*.

8.5.2 MORPHOMETRICS

Apis dorsata has attracted the attention of many scientists in the field of beekeeping due to its high honey-gathering capacity and ferocious nature. However, very little is known about its biology, behaviour and morphometrics (Millen, 1942; Sechrist, 1950; Viswanathan, 1950a; Thakar and Tonapi, 1961; Morse and Laigo, 1969a and Sakagami et al., 1980). The first description of the tongue length of *Apis dorsata* was given by Venkatasubbaya (1938). He reported that the average tongue length of this species from Karnataka (South India) was 6 mm as compared to *Apis cerana* which had a tongue measuring 4.75 mm.

Venkata Rau (1946) observed that the worker bee of *Apis dorsata* was 18.75 mm long and approximately 4.687 mm in width. He also noted differences between the fully grown mature bees, undertaking outdoor foraging activities, and the young nurse bees. The foraging bees showed larger darkening of the last four abdominal segments with a white band between each of these segments, while in nurse bees, these bands were much lighter and there was a dark streak between the fourth and fifth segments.

Rahman and Singh (1948) reported that the tongue length of *Apis dorsata* and *Apis florea* from Lyallpur was 6.683 and 3.441 mm, respectively. The mean tongue lengths of *Apis cerana* from Katrain *(Kulu valley)* and imported *Apis mellifera* were 5.525 and 6.438 mm, respectively. Thus, among the four species of this genus, *Apis dorsata* had the longest and *Apis florea* had the shortest tongue length. Trehan and Singh (1961) studied the biometry of the rock bee, *Apis dorsata* collected from different regions of the Punjab (northern India) as well as from colonies nesting on different plant species. The mean tongue lengths of *Apis dorsata* from the plains and submountainous regions were 6.47 and 6.45 mm, respectively. These differences were statistically non-significant, therefore, the population in the plains and submountainous region were alike. Further, the length and breadth of worker cells of *Apis dorsata* from the plains and submountainous regions were smaller as compared to the size of the drone cells. There was no significant difference in the size of worker and drone cells from the plains and submountainous regions of the Punjab, and these observations supported the earlier view that the populations of both the areas were the same. These authors also measured the size of worker and drone cells from the colonies nesting on different plant species such as Loquat, Pipal, Kikkar and Ber. The mean length and breadth of worker cells of *Apis dorsata* nesting on Loquat, Pipal, Kikkar and Ber were 16.97, 5.35 mm; 17.06, 5.41 mm; 16.78, 5.22 mm; and 17.03, 5.42 mm, respectively. The mean length and breadth of drone cells of *Apis dorsata* nesting on the same plants were 17.13, 5.55 mm, 5.56 mm; 17.36, 5.54 mm; and 17.19, 5.53 mm, respectively. They found that the difference in length and width of worker and drone cells from different colonies nesting on the same plant were not significant. Thus, the populations of *Apis dorsata* in the Punjab region were alike, and did not involve any separate variety or biological race. Further, the slight variations in these measurements were probably observational or individual, and regional or colonial position of the bees was not responsible for it. Venkata Rau (1946) also made observations on the size of the comb cells in *Apis dorsata* colonies. He observed a slight increase in the size of the hive after four months. The upper portion of the hive, which acted as a honey store, was 15 cm deep and 12.5 cm in thickness. The depth of the cells in the honey store portion ranged from 5 to 6.25 cm and the width was 0.62 cm.

Jain (1967) made comparative studies on the biometrics of *Apis dorsata*, *Apis cerana* and *Apis florea* at Udaipur in Rajasthan. Their studies were based on 50 specimens each, collected from three colonies of Apis spp. These results showed that the tongue of *Apis dorsata* was much longer as compared to that of *Apis cerana* and *Apis florea*. Similarly, measurements of other body parts of *Apis dorsata* showed higher mean values than other *Apis* spp. For example, the fore and hind wings were much longer and broader in *Apis dorsata* than in *Apis cerana* or *Apis florea* and the number of hooks on the hind wings of *Apis dorsata* was also greater in number.

Kshirsagar (1969) made preliminary observations on the biometry of the queen bee of *Apis dorsata* collected from Karnataka. Biometrical studies on the *Apis dorsata* queen included body length (27.90 mm), antennal length (6.03 mm), tongue length (3.36 mm), number of hooks (23), fore wing length (13.18 mm) and breadth (4.46 mm), hind wing length (9.48 mm) and breadth (2.96 mm), cubital index (93.37) and various other measurements of different tergites and sternites. Biometrical observations recorded by Roepke (1923) from Indonesia included total body length (17.5 mm), length of forewing (14.5 mm), breadth of thorax between the implantation of wings (5.2 mm), breadth of head (4.5 mm), length of scape (1.2 mm) and length of flagellum (3.1 mm). Roepke's results showed longer body length, and longer and broader forewings than those recorded by Kshirsagar (1969). Sakagami et al. (1980) made comparative studies on the biometry of *Apis laboriosa* and *Apis dorsata*. The distribution range of these two species covered the mountainous areas of Nepal, northern India and Yunnan. They examined more than 100 morphometric characters of these two species collected from India, Nepal, Thailand, Cambodia, Laos, Vietnam, North Borne and Palwan. Their results suggest that most of the morphological characters of *Apis dorsata* had lower mean values as compared to *Apis laboriosa*, thus two distinct species of the genus *Apis* were present in these regions.

Singh (1981) made collection of *Apis dorsata* from Ludhiana, Solan, Bilaspur and Shimla areas. She showed higher mean values for the tongue length, and breadth of the fore and hind wings; number and extent of hamuli; size of hind legs; tergites and sternites as compared to other species of the genus *Apis*. The correlation between length of tergites and forewing length was positive. Variations in the mean values of morphological characters of *Apis dorsata* from different localities were observational and thus no sub-species or ecotypes were identified.

Kshirsagar (1969) reported the colour pattern of *Apis dorsata* queen bees. He described that the body was generally dark brown in colour and more or less densely pubescent except for the parts of the abdomen. The first abdominal segment was distinctly lighter than the rest. The wings had a yellowish-brown tinge with darker veins. The legs were brown and antennae dark brown in the queen bees of this species.

8.6 *APIS FLOREA*

8.6.1 BIOLOGY AND MANAGEMENT

The little bee, *Apis florea* F. is found in the plains and rarely live in places higher than 1500 m above sea level. Like *Apis dorsata*, this small bee also builds a single comb which is often suspended from branches of bushes, hedges, trees, caves of buildings, house chimneys, empty caves, and piles of dried sticks.

The comb measures about 35 cm in length, 18 cm in height and about 2 cm in thickness. Honey is stored in the upper part of the comb which is about 5–7 cm thick (Singh, 1962). Nests of *Apis florea* are protected by a three-to-six layer curtain of bees over the comb. Ghatge (1949) reported that removal of their comb resulted in temporary loss of their protecting and flight behaviour, and bees would no longer sting. Sandhu and Singh (1960) made observations on the brood-rearing activity and biology of *Apis florea*. Larvae hatch out after three to four days from the egg stage. Some eggs during June to July and November months did not hatch at all and were discarded by bees after six to seven days of oviposition. Duration of the larval period was 5.8, 6.4, and 6.7 days and the total development period was 16.5, 20.7 and 22.5 days for queen, worker and drone bees, respectively. The brood-rearing activity was almost suspended during extreme winter and summer but was at its peak in May and November. During the active season, the brood area ranged from 10 sq cm to

627.74 sq cm and the number of eggs laid by the queen in a day varied from 58 in February to 365 in May. A swarm of *Apis florea* colony consists of 600 worker bees, in a queen and some drones. In *Apis florea*, absconding was very common and dancing behaviour occurred in horizontal position (Akratanakul, 1976). Pandey (1974) observed long distance movement of *Apis florea* colonies due to the shortage of bee florea.

Attempts to hive *Apis florea* in an open mesh has not been very successful because colonies tend to abscond. Seelay et al., 1982 reported that the defence system in *Apis florea* colonies involves a series of adaptations such as nest site, nest architecture, colony population, division of labour, age polyethism and colony mobility. The small dispersed colonies of *Apis florea* are difficult to locate but once found, they can be easily overpowered because they inflict painless stings and the nests are easily accessible. *Apis florea* migrate frequently and the colony seldom remains at one place for more than five months at a stretch. The bees choose a shady nesting place during the hot summer, and in autumn they make a short migration to an unshaded place.

The annual honey yield from a colony varies from 1 to 3 kg. It is believed that honey produced by *Apis florea* has special medicinal value and mystical properties. *Apis florea* honey has higher dextrin content and has less tendency to granulate than the honey of other *Apis* spp.

Apis florea plays an important role in the pollination of different fruits, vegetables and oil seeds (Sidhu and Singh, 1961; Jain, 1967). Shifting of colonies along with branches to which combs are attached to an orchard at flowering time for pollination has been made with uneven results (Whitcomb, 1980). These bees migrate frequently in search of flora (Pandey, 1974). *Apis florea* worker bees did not forage at temperature below 18°C (Whitcomb, 1980, 1981). The peak foraging activity period of *Apis florea* was later in the day than *Apis mellifera* in northern India, thus reducing possible competition for floral resources.

8.6.2 Morphometrics

Rahman and Singh (1948) studied the tongue length of *Apis florea* collected from Lyallpur (Pakistan) and recorded it as 3.441 mm. They have also reported mean tongue length of *Apis cerana* from Katrain (Kulu valley) as 5.52 mm and that of the exotic bee, *Apis mellifera* as 6.43 mm. Thus, *Apis dorsata* had the longest and *Apis florea* had the shortest tongue length. Ghatge (1949) observed a white strip on *Apis florea* with a blackish abdomen.

Maa (1953) studied the twelve biometrical characters of *Apis florea* queen which included the body length (13 mm); tongue length (2.08 mm), ratio of length and breadth of prementum (2.23); forewing length (10 mm); radial index (94.87); pre-mentopalpal index (90.62); Kruger's index (150) and Jugovannal index (114.3). The weak point of his study was that only one old museum specimen from an unknown place was studied. Narayanan et al. (1960b) measured tongue length and number of hamuli on the hindwing of 250 worker bees (fifty each from five colonies). The mean tongue length was found to be 3.27. The average tongue length in five colonies ranged from 3.25–3.29 mm. The frequency distribution showed that 112 bees possessed tongue length of 3.28 mm and the next majority group of 74 had 3.21 mm. They found significant differences in the average number of hooks on the left and the right hind wing of 250 bee samples. The mean number of hooks was 10.96 per hind wing. The single majority group of 128 had 10 hooks on each wing. Inter-colony variation was 0.37 hooks and maximum variation in 500 wings was six hooks per wing. No correlation was found between the tongue length and the number of hooks. The tongue length of the Pusa area (Bihar, India) *Apis florea* was 3.27 mm as compared to 3.44 mm of that of the Punjab area. It was concluded that the size of *Apis florea* under hot and dry conditions was slightly larger than under comparative mild and damp conditions.

Jain (1967) in his studies on the biometry of *Apis florea* F. from Udaipur (Rajasthan, India) reported the following results; body length (9.10 mm); breadth of thorax (2.26 mm), forewing length and breadth (6.21 and 2.22 mm, respectively), hind wing length and breadth (3.85 and 1.36 mm, respectively); number of hamuli on hind wing (10.92) and size of pollen basket (2.16 and 0.77 mm, respectively).

Kshirsagar (1971) made a morphometric study of the queen bee of *Apis florea* by collecting 10 specimens from Indore (Madhya Pradesh, India) and Pune (Maharastra, India) and considered 64 biometrical characters. The results included body length (150 mm); postmentum length (0.37); tongue length (3.10 mm); total antennal length (3.47 mm); forewing length (8.47); forewing breadth (2.99 mm); radial index (72.21 mm); hind wing length (6.01 mm); hindwing breadth (2.00 mm), number of hamuli (9) and jugovannal index (117.99). His results did not tally with those of Maa (1953). Kshirsagar has suggested that the difference might be due to changes in the museum specimens and natural variations among particular ecotypes.

According to Kshirsagar (1971) the body colour of the *Apis florea* queen bee was amber yellow. The head and thorax were dark brown and legs were dark in colour up to the tibia but the tarsus of each leg was amber yellow. Sternites were yellow except the tip of the abdomen.

8.7 ORIGIN, EVOLUTION AND CYTOLOGY OF ASIAN HONEYBEES

8.7.1 ORIGIN AND EVOLUTION

There is very little evidence available from the fossil records regarding the origin and evolution of the present species of honeybees. This is because present-day knowledge regarding the morphological features of fossil bees is too meagre. The common view held is that oriental bees evolved as a monophylectic offshoot from the borrowing wasps of the super-family Sphecoidea (Comstock, 1936; Malyshev, 1968; Michener, 1944, 1969). For such an evolutionary process to take place, morphological adaptations such as loss of carnivorous habit, development of long tongue, hairy-body and pollen basket seems essential (Wilson, 1971; Butler, 1974). So far no sphecoid wasps studied possess the traces of such morphological features for certain so that these could be identified with certainty as the ancestral groups of honeybees. Origin of the flowering plants or angiosperms and honeybees appear to be closely linked. Angiosperm originated in the xeric interior during the middle of the cretaceous period and some sphecoid wasps species were present at the time and possible divergence might have occurred during this period. The first records of fossil bees were from the Baltic amber of the upper Eocene epoch (Manning, 1952), Zeuner and Manning, 1976) perhaps forty million years old.

Certain aspects of honeybee biology and behaviour suggest the following evolutionary trend: *Apis florea* ⟶ *Apis dorsata* ⟶ *Apis cerana* ⟶ *Apis mellifera*. The origin of primitive species of honeybees like *Apis florea* and *Apis dorsata* might be coeval or subsequent to the origin of angiosperms, whereas, advanced species like *Apis cerana* and *Apis mellifera* might have originated sometime during Pleistocene and they have been synchronous with earlier glacial cycles which were responsible for extensive origin of polyploid forms particularly among plants (Deodikar, 1962). The above-stated evolutionary trend is evidenced by the fact that the little honeybee *Apis florea* and the giant honeybee, *Apis dorsata* show certain features as they live on a single comb under the open sky and their communication behaviour is not as perfect as that of *Apis mellifera*. The third species *Apis cerana* has a greater resemblance to *Apis mellifera*. Its morphological features are quite similar and it makes its nest in hollows on several combs; in addition its communication mechanisms in principle is the same as that of *Apis mellifera* (Lindauer, 1957). However, Koeniger (1976a) presented a new interpretation of the honeybee phylogny. He assumed hollow nest as the ancestral type from which the different life strategies such as building aerial single-combed nest adapted to tropical climate evolved. Recently discovered honeybee species, *Apis* *laboriosa* build single open comb nests in the temperate Himalayan region, and are more adapted to cooler climate (Sakagami et al., 1980). Thus, the distribution range of *Apis cerana* in southeast Asia overlaps completely with that of *Apis dorsata*. This negates the theory that *Apis dorsata* could be evolutionarily more advanced than *Apis cerana* or *Apis mellifera* in terms of the nest building strategies.

The Indo-Malayan region seems to be the centre of the origin of the honeybees because three or more different species of honeybees occur in this region whereas, southwest Asia, Africa, Europe and many other countries have just a single species of honeybee. Even this single European species of honeybee *(Apis mellifera)* might have evolved from its prototype which occur in this region (Deodikar, et al., 1959; Deodikar, 1964; Deodikar et al., 1961). During the northward migration of *Apis* by various land routes across the Himalayan barrier, *Apis cerana* seems to have evolved into *Apis mellifera* and a number of its African and Eurasian sub-species (Deodikar, 1960). Kapil (1962) made a comparative study on the male and female reproduction systems of *Apis cerana* and *Apis mellifera* and suggested the evolutionary trend among *Apis cerana* from the south towards the north and westwards. The gradual increase in ovarian size in this direction among *Apis cerana* suggested the evolution of *Apis mellifera* from the oriental *Apis cerana*. Earlier Wheeler (1928) also suggested that genus *Apis* as of the South Asiatic origin and European and African *Apis mellifera* evolved from this species. Further morphometric comparison of different races of *Apis cerana* found in the Himalayan region indicated differences in size (northwest Himalaya > Central Nepal Himalaya > Northeast Himalaya). Also *Apis cerana* of the northeast Himalayan region were larger in size than South Indian bees (Verma, 1989b). These results suggest that as the Himalaya rose in height, larger sized *Apis cerana* invaded the higher elevations from different populations in the lowland areas surrounding the mountains and in this process larger races of *Apis cerana* might have evolved into *Apis mellifera*.

8.7.2 Cytology

In general, a honeybee colony consist of a queen (sexually mature females), a few hundred drones (sexually mature males) and thousands of worker bees (female members with reduced and nonfunctional ovaries). The drones develop from unfertilized eggs while the queen and the worker bees develop from the fertilized eggs (first reported by Silesian bee breeder, Johannes Dzierzon in 1845). The males, therefore, possess only half the number of chromosomes as compared to the females (queen and workers) and are regarded as haploids (16N) while the females are diploids with 32 number of chromosomes. (Meves, 1907; Nachtsheim, 1913).

Earlier there were different view regarding to the basic chromosome number of the different species, *Apis mellifera, Apis cerana, Apis dorsata* and *Apis florea.*

Whiting (1945) first contradicted Nachtsheim's (1913) view and regarded 8 as haploid and 16 as diploid number of chromosomes in *Apis mellifera.* According to this author, oogenesis is regular in the honeybee and the reduction of chromosome number of eight occurs in primary oocytes. In order to explain the viability of males in Hymenoptera, Whiting (1945) suggested that the apparent or presumed haploid set of the males is fundamentally diploid. Since the females possess twice the male chromosome number in certain tissues (e.g. oogonia), it was suggested that females are tetraploid. Hoshiba and Kusangi (1978) described the karyotype of *Apis mellifera* and showed the haploid chromosome complement in males (n=16), with eight metacentric and eight submetracentric chromosomes. They reported that the largest chromosome in metaphase stage is 4.3 μm long and the shortest 1.8 μm, after pretreatment with colchicine. The secondary contraction is also seen in the longest metaphase chromosome.

Deodikar et al. (1959) supported Whiting's (1945) statement and regarded 8 as haploid chromosome number (in males) and 16 as diploid chromosome number, in two species of honeybees, *Apis dorsata* and *Apis florea*, which are natives of India. The karyotype of *Apis cerana* showed that the haploid chromosome complement of 16 in male consists of eight homomorphic pairs, which often show distinct somatic associations. It was, therefore, inferred by Deodikar and Thakar (1966) that males of *Apis cerana* are numerically haploid but genetically diploid, the females being tetraploid. *Apis cerana* was, therefore, named as primitive tetraploid, while *Apis mellifera* was regarded as tetraploid with 16 chromosomes in male and 32 in female. *Apis florea* and *Apis dorsata* were considered as primitive species of genus *Apis*, with eight as the basic number of chromosomes. These two species of honeybees also exhibit primitive behaviour in terms of communication dances, which are performed in a horizontal plane instead of vertical plane as in other species (Lindauer, 1957).

According to Deodikar et al., (1959), the somatic chromosome complement of female *Apis cerana*, showed 32 chromosome distinctly. Out of these 32 chromosomes, 8 had median, 8 submedian and 16 subterminal constrictions. However, they referred that due to the short length of chromosomes, the submedian and subterminal constrictions are not clear. The somatic chromosome complement of haploid male in *Apis cerana* consisted of two pairs with median, two with submedian and four with subterminal constrictions (2 mc + 4 stc). These authors also reported that 16 chromosomes in haploid set of somatic complement of male *Apis cerana*, occur in eight homomorphic pairs, with distinct somatic associations.

Sharma et al. (1961) gave detailed account of the cytology of spermatogenesis in *Apis cerana*. They show the presence of 16 chromosomes in the spermatocytes throughout spermatogenesis. They also reported the formation of a cytoplasmic bud during spermatogenesis. According to these authors, meiosis I of spermatogenesis in *Apis cerana* is abortive, resulting in the formation of a cytoplasmic bud. Since the number of chromosomes is already haploid in drones, due to their parthenogenetic mode of development, regular meiosis I is absent. However, a stimulation of the normal meiosis exists and results in the formation of a non-nucleated cytoplasmic bud. The chromosome becomes compact and condensed at metaphase stage. After this stage, the chromosomes show a slight tendency to move towards the poles, but this movement is just haphazard. Soon they start fusing with each other on the spindle and gradually the chromosomes lose their identity and individuality, and finally clump together, forming a uniformly staining irregular mass.

Deodikar and Thakar (1966) again reported a clear distinction between the diploid and tetraploid groups of the genus *Apis*. According to them, the diploid group included *Apis dorsata* and *Apis florea*, with somatic chromosome complement 16 in females (queen and workers) and 8 in males (drones) and they build a single comb suspended vertically, nest exposed to light. The tetraploid group, according to them included *Apis mellifera* and *Apis cerana* with 32 chromosomes in the female and 16 in the male. These species built multiple parallel combs vertically suspended and the nest exposed to dark. These authors, therefore, stated that the tetraploid group *(Apis mellifera* and *Apis cerana)* is evolutionarily an advanced group, derived from the primitive diploid group *(Apis dorsata* and *Apis florea)*, which originated from ancestoral protoapis group with a basic chromosome number of 4.

Kapralova (1977) reported the number of chromosomes ranging up to 8, 16, 32, 42, 48 or even more from various bee tissues. She studied cell karyotypes in somatic tissues of honeybees *(Apis mellifera)* at various ontogenic stages, including normal larvae, pupae and adults of queens, workers and drones. According to her the largest chromosomes of somatic cells in metaphase stage was 2 μ long and smallest 0.35 μ. In sexual tissues (ovaries and testes), the germ cells possessed 8, 16, 24, 32, or 64 chromosomes. The number of chromosomes in these cells was divisible by 8. She, therefore, suggested that 8 is the basic chromosome number for honeybees *(Apis mellifera)*.

Fahrenhorst (1977) studied the germ cells from the testes of drone larvae and of white-eyed pupae in four species of honeybee, namely, *Apis mellifera, Apis cerana, Apis dorsata* and *Apis florea*, and showed

16 as the haploid chromosome number for each species. He, thereby, contradicted the results of Deodikar and Thakar (1966b), who reported 8 as the haploid chromosome number in *Apis dorsata* and *Apis florea*.

Verma (1988) solved the above controversy by supporting the view of Fahrenhorst (1977) that the chromosome number in the germ cell (ovaries and testes) of all the four species of genus *Apis*, (*Apis mellifera, Apis cerana, Apis dorsata* and *Apis florea*), is the same i.e. 32 in the queen bee and 16 in the drone bee. She further suggested that in all the species of this genus, these is frequent pairing of somatic chromosomes and the number of such pairs may vary from 4 to 12. These pairs are possibly formed by the union of two or more similar or homomorphic chromosomes. As four pairs is the least number of pairs in male cells and eight pairs in female cells, it seems that four are the heteromorphic or similar chromosomes. Therefore, four number of chromosomes appears to be the basic number in all the different species of the genus, *Apis*. These four heteromorphic chromosomes have divided and redivided during the course of evolution to give 16 as the haploid and 32 as diploid number of chromosomes in male and female, respectively. In the germ cells of the queen ovary, normal meiosis occurs resulting in haploid cells with 16 as the chromosome number. In male germcells (testes) the meiotic divisions are not complete. The meiosis is an abortive one, though the formation of bivalents occurs but these bivalents do not separate in Anaphase I, thereby retaining the same number of chromosomes as that of the mother cell. Since the bivalents are formed in males, it indicates that reshuffling of the chromosomal parts do occur. Thus, the cells formed due to an abortive meiosis may possess the same number of chromosomes as that of the mother cell but are different so far as the nature of the chromosomes is concerned.

CHAPTER 9

Honey Plant Resources

9.1 INTRODUCTION

Honeybees visit a variety of plant species to collect pollen and nectar which are the raw materials of the beekeeping industry. In the act of foraging for pollen and nectar, honeybees incidentally reciprocate by performing valuable pollination services for the plants. Honeybees and certain flowering plants have, therefore, evolved a well-adjusted system of interdependence, and such relationship is one of the most significant events of organic evolution (Deodikar, 1962; Martin, 1979). Pollen is practically the sole source of proteins, lipids, minerals and vitamins which is mostly used to feed the brood. Nectar contains mainly sugars in water. The main sugars of nectars are maltose, raffinose, melibiose, trehalose, and melezitose. Besides sugar, nectar also contains proteins, amino acids, other organic acids and volatile oils. Nectar acts as a main fuel for flight, foraging, hive activity and developing brood.

The present chapter deals with the significance of melissopalynology, bee botany, floral calendar and nectar secretion studies in relation to beekeeping in Asia. Studies on the pollen collecting behaviour of *Apis cerana*, eco-physiology of *Plectranthus* sp., major honey plants of the Hindu Kush-Himalaya, and linkages between beekeeping and social forestry have also been included. A list of common honey plants as well as those which act as medium and minor resources of honey is given in Tables 9.1 and 9.2.

Table 9.1: Common honey plants of the Hindu-Kush Himalayan region

Family/plant species	Common name	Honey poten-tiality	Flowering period	Distribution	Type (nature)	Other economic uses
1	2	3	4	5	6	7
Acanthaceae						
Adhatoda zeylanica Nees	Basuti	N^2P^2	APR-NOV	S.Tropical, S.Temperate, Temperate	Shrub (W)	Medicinal & Soil reclamation
Justicia pubigera Nees	Bankas	N^2P^2	AUG-OCT	S.Temperate, Temperate	Herb (W)	Medicinal
Rungia parviflora Nees	Rungia	N^3P^3	JUL-AUG	S.Tropical, S.Temperate,	Herb (W)	Medicinal weed
Strobilanthes wallichi Nees	Strobi-lanthes	N^3P^3	AUG-OCT	S.Temperate, Temperate	Shrub (W)	
Aceraceae						
Acer spp.	Great maple	N^2P^2	MAR-APR	S.Temperate, Temperate	Tree (W/C)	Timber
Agavaceae						
Agave americana L.	Century plant	N^3P^3	SEP-NOV	S.Tropical	Shrub (W)	Ornamental & Fibre
Amaranthaceae						
Amaranthus paniculatus L.	Amaranth	N^2P^2	JUN-JUL	S.Tropical, S.Temperate, Temperate	Herb (W)	Crop

Amaryllidaceae						
Allium cepa L.	Onion	N^3P^3	MAY-JUN	S.Tropical, S.Temperate, Temperate	Herb (C)	Medicinal &
Allium sativum L.	Garlic	N^3P^3	MAY-JUN	S.Tropical, S.Temperate, Temperate	Herb (C)	Vegetable, Condiment & Medicinal
Anacardiaceae						
Mangifera indica L.	Mango	N^2P^3	MAR-APRIL	S.Tropical	Tree (C)	Fruit, Fuel & Timber
Odina woodier Roxb.	Karambal	N^2P^3	FEB-APR	S.Tropical, S.Temperate,	Tree (C)	Fodder, Confectionery &
Rhus spp.	Sumac	N^3P^3	MAY-JUN	S.Temperate, Temperate	Tree/Shrub (C)	Gum Tannin
Apiaceae						
Coriandrum sativum L.	Coriander	N^3P^3	MAR-JUN	S.Tropical, S.Temperate, Temperate	Herb (C)	Medicinal, Alcoholic, Beverage & Condiment
Daucus carota L.	Carrot	N^2P^3	MAR-MAY	S.Tropical, S.Temperate, Temperate	Herb (C)	Fodder & Vegetable
Foeniculum vulgare Mill	Fennel	N^3P^3	AUG-SEP	S.Tropical, S.Temperate, Temperate	Herb (C)	Medicinal, Fodder & Condiment
Heracleum spp.	Hogweed	N^3P^3	MAY-JUL	S.Tropical, S.Temperate, Temperate	Herb (W)	Medicinal
Apocynaceae						
Carissa carandas L.	Karandas	N^2P^2	APR-MAY	S.Tropical, S.Temperate, Temperate	Shrub (W/C)	Preservation
Arecaceae						
Phoenix spp.	Wild date palm	N^2P^3	MAY-JUL	S.Tropical, S.Temperate	Shrub (W)	Fruit
Asclepiadaceae						
Asclepias curasscavica L.	Milkweed	N^2P^2	APR-JUN	S.Tropical, S. Temperate	Shrub (W)	Medicinal & Fibre
Aasteraceae						
Ageratum conyzodies L.	Ageratum	N^3P^3	JUL-SEP	S.Tropical, S.Temperate, Temperate	Herb (W/C)	Ornamental
Artemisia maritima L.	Mugwort	N^3P^3	AUG-OCT	S.Temperate, Temperate	Herb (W/C)	Medicinal & Ornamental

Table 9.1 (Cont'd...)

1	2	3	4	5	6	7
Aster spp.	Star-wort	N^3P^3	OCT-NOV JUL-SEP	S.Tropical, S.Temperate, Temperate	Herb (C)	Ornamental
Bidens spp.	Spanish needle	N^3P^2	SEP-DEC	S.Tropical, S.Temperate, Temperate	Herb (W)	
Calendula arvensis L.	Marigold	N^3P^3	MAY-JUL	S.Tropical, S.Temperate,	Herb (C)	Medicinal & Ornamental
Cardus onopardiodes Fisch	Musk Thistles	N^2P^2	MAY-AUG	S.Tropical, S.Temperate, Temperate	Herb (W)	Fodder
Carthamus tinctorius L.	Safflower	N^2P^2	JAN-FEB	S.Tropical, S.Temperate	Herb (C)	Fodder, Oil & Dyeing
Centaurea cyanus L.	Corn-flower	N^2P^3	FEB-APR	S.Temperate, Temperate	Herb (C)	Medicinal & Ornamental
Chrysanthemum spp.	Chrysan-themum	N^3P^3	MAY-SEP	S.Tropical, S.Temperate, Temperate	Herb (W/C)	Insecticide & Ornamental
Cichorium intybus L.	Chicory	N^3P^3	MAY-AUG	S.Tropical, S.Temperate, Temperate	Herb (W)	
Cirsium spp.	Field Thistles	N^2P^3	MAY-AUG	S.Tropical, S.Temperate, Temperate	Herb (W)	
Cosmos sulphureus Cav.	Cosmos	N^3P^2	SEP-NOV	S.Tropical, S.Temperate, Temperate	Herb (W/C)	Dyeing & Ornamental
Echinops echinatus Roxb.	Globe Thistle	N^3P^3	MAY-JUN	Temperate	Herb (W)	Medicinal
Eupatorium spp.	Through-wort	N^3P^3	JUL-SEP	S.Tropical, S.Temperate, Temperate	Herb (W)	Medicinal
Helianthus annuus L.	Sunflower	N^2P^2	JUL-SEP	S.Tropical, S.Temperate, Temperate	Herb (W/C), (W)	Lubricant oilseed, Fodder Ornamental
Inula cappa	Inula	N^2P^2	SEP-NOV	Temperate	Herb (W)	
Mikania scandens Willd.	Mikania	N^2P^3	MAR-APR	S.Tropical	Climber (W)	Medicinal
Senecio spp.	Ragwort	N^3P^3	JUN-SEP	S.Tropical, S.Temperate, Temperate	Herb (W)	Medicinal

Solidago longifolia Schrad	Golden rod	N^2P^3	JUN-SEP	S.Tropical, S.Temperate, Temperate	Herb (W/C)	Medicinal & Ornamental
Sonchus spp.	Sow thistle	N^3P^3	JUN-OCT	S.Tropical, S.Temperate, Temperate	Herb (W)	
Tagetus spp.	Marigold	N^3P^3	JUL-OCT	S.Tropical, S.Temperate, Temperate	Herb (C)	Medicinal, Aromatic & Ornamental
Taraxacum officinale Weber	Dandelion	N^2P^2	MAR-AUG	S.Tropical, S.Temperate, Temperate	Herb (W)	Medicinal
Tussilago farfara L.	Coltsfoot	N^3P^3	APR-JUN	S.Tropical, S.Temperate	Herb (W)	Vegetable & Medicinal
Vernonia spp.	Ironweed	N^3P^3	JUN-SEP	S.Tropical, S.Temperate, Temperate	Herb (W)	Medicinal & Ornamental
Balsaminaceae						
Impatiens glandulifera Royle	Balsam	N^1P^2	JUL-SEP	S.Tropical, S.Temperate, Temperate	Herb (W)	Ornamental & Medicinal
Berberidaceae						
Berberis lycium L.	Barberry	N^2P^1	MAY-JUN	S.Tropical, S.Temperate, Temperate	Shrub (W)	Medicinal, Root & Fruit
Betulaceae						
Alnus nitida (Spach) Endl.	Alder	N^3P^2	SEP-NOV	S.Tropical, S.Temperate, Temperate	Tree (W)	Timber & Dyeing
Corylus colurna Dence.	Hazelnut	P^2	MAR-MAY	S.Tropical, Temperate	Shrub (W/C)	Seeds Edible & Fuel
Bombacaceae						
Bombax ceiba L.	Silk cotton tree	N^2P^2	FEB-MAR	S.Tropical, S.Temperate, Temperate	Tree (W)	Fibre, Timber & Fodder
Boraginaceae						
Cynoglossum glochidiatum Wall.	Hounds tongue	N^3P^3	JUN-SEP	S.Tropical	Herb (W)	Ornamental
Ehretia acuminata R.Br.	Ivory wood	N^1P^2	FEB-APR	S.Tropical, S.Temperate	Tree (W/C)	Timber, Fodder & Fruit Edible

Table 9.1 (Cont'd...)

1	2	3	4	5	6	7
Brassicaceae						
Brassica juncea (L) Czern.	Indian mustard	N^2P^2	DEC-MAR	S.Tropical, S.Temperate, Temperate	Herb (C)	Vegetable & Oilseed
Brassica napus L. var. *glauca* (Roxb) Schutz.	Mustard	N^1P^1	DEC-MAR	S.Tropical, S.Temperate, Temperate	Herb (C)	Oilseed, Vegetable & Lubricant
Brassica napus var *toria* L.	Toria	N^1P^1	DEC-MAR	S.Tropical, S.Temperate, Temperate	Herb (C)	Vegetable, Oilseed & Lubricant
Brassica oleracea var. *capitata* L.	Cabbage	N^2P^3	MAY-JUL	S.Tropical, S.Temperate, Temperate	Herb (C)	Vegetable
Brassica rapa L.	Turnip	N^2P^2	FEB-APR	S.Tropical, S.Temperate, Temperate	Herb (C)	Vegetable & Fodder
Cardamine spp.	Cuckoo flower	N^2P^2	JAN-FEB	S.Tropical, Temperate	Herb (W)	Medicinal
Eruca sativa Mill	Rocket salad	N^1P^1	DEC-MAR	S.Tropical, S.Temperate, Temperate	Herb (C)	Medicinal, Oilseed & Fodder
Raphanus sativus L.	Radish	N^3P^3	FEB-MAR	S.Tropical, S.Temperate, Temperate	Herb (C)	Vegetable & Medicinal
Cactaceae						
Opuntia spp.	Prickly pear	N^2P^2	APR-MAY	S.Tropical, S.Temperate, Temperate	Shrub (W)	Medicinal
Caesalpiniaceae						
Bauhinia variegata Wight	Geranium tree	N^2P^3	FEB-APR	S.Tropical, S.Temperate, Temperate	Tree (W)	Vegetable, Fodder & Ornamental

Bauhinia vahli Wight	Camel's foot climber	N^2P^3	MAR-MAY	S.Tropical, S.Temperate, Temperate	Tree (W)	Fibre, Vegetable, Fodder & Fuel
Cassia spp.	Indian Laburnum	N^2P^2	APR-JUL	S.Tropical, S.Temperate,	Tree (W)	Confection & Medicinal
Caesalpinia spp.	American Surmach	N^3P^3	NOV-APR		Small Tree (W)	Timber & Tanning
Delonix regia Raf.	Gulmohr	N^3P^2	MAY-JUN	S.Tropical, S.Temperate	Tree (W/C)	
Tamarindus indica L.	Tamarind	N^3P^3	MAR-MAY	S.Tropical, S.Temperate, Temperate	Tree (C)	Medicinal, Condiment, Fruit, Fodder & Oil
Cannabacaceae						
Cannabis sativa L.	Hemp	N^2P^2	JUN-SEP	Temperate	Weed (W/C)	Oil, Medicinal & Alkaloid fibre
Capparaceae						
Capparis himalayensis Jafri	Kanthar	N^3P^3	APR-MAY	S.Tropical, S.Temperate, Temperate	Climber (W/C)	Medicinal
Capparidaceae						
Crataeva religiosa Forst	Barna	N^2P^2	APR-MAY	S.Tropical, S.Temperate	Tree (W/C)	Ornamental
Caprifoliaceae						
Lonicera sempervirens L.	Honey suckle	N^3P^3	MAY-AUG	S.Tropical, S.Temperate	Shrub (W/C)	Ornamental
Viburnum spp.	Vikurum	N^3P^3	MAY-JUN	S.Tropical, S.Temperate	Shrub (C)	Ornamental
Chenopodiaceae						
Chenopodium album L.	White goose foot	N^3P^3	MAR-MAY AUG-OCT	S.Tropical, S.Temperate, Temperate	Herb (W/C)	Vegetable & Fodder

Table 9.1 (Cont'd. . .)

1	2	3	4	5	6	7
Combretaceae						
Terminalia arjuna Wight	Arjun	N^2P^2	MAY-JUL	S.Tropical, S.Temperate	Tree (C)	Timber, Fuel, Tanning & Dyeing
Terminalia chebula Retz	Yellow myrobalan	N^2P^2	MAY-JUN	S.Tropical, S.Temperate	Tree (W/C)	Fruit, Medicinal, Bark for Tanning & Dyeing
Con volvulaceae						
Convolvulus arvensis L.	Convol-vulus	N^3P^3	APR-SEP	S.Tropical, S.Temperate, Temperate	Weed (W)	
Ipomoea batatas Lam.	Sweet potato	N^2P^3	AUG-NOV	S.Tropical, S.Temperate, Temperate	Herb (C)	Tuber, Edible Vegetables & Medicinal
Ipomoea pulchella Roth	Railway creeper	N^3P^3	AUG-NOV	S.Tropical, S.Temperate, Temperate	Herb (W)	Seed, Purgative & Parantic
Cuscuta reflexa Roxb.	Amar-Vel	P^3	JUL-OCT	S.Tropical, S.Temperate, Temperate	Parasitic, Succulent, Herb (W)	Medicinal
Cucurbitaceae						
Citrullus vulgaris Schrad	Water-melon	N^2P^2	APR-MAY	S.Tropical	Climber (C)	Fruit & Medicinal
Cucumis spp.	Cucumber, Melon	N^2P^2	JUL-SEP	S.Tropical, S.Temperate	Climber (C)	Oil & Medicinal
Cucurbita maxima L.	Pumpkin	N^2P^2	APR-JUN	S.Tropical, S.Temperate	Climber (C)	Vegetable, Seed & Medicinal
Lagenaria siceraria L. Gourd	Bottle	N^3P^3	MAY-JUL	S.Tropical, S.Temperate	Climber (C)	Vegetables & Medicinal
Luffa echinata Roxb.	Ribbed Gourd	N^3P^3	MAY-JUL	S.Tropical, S.Temperate	Climber (C)	Vegetables, Medicinal & Purgative

Dipsacaceae Wall.						
Dispsacus inermis	Teasel	N^3P^3	JUL-OCT	S.Tropical, S.Temperate, Temperate	Herb (C)	
Scabiosa speciosa Royle	Scabious	N^2P^3	MAY-JUL	S.Tropical, S.Temperate, Temperate	Herb (W/C)	Ornamental & Medicinal
Ericaceae						
Gaultheria fragrantissima Wall.	Fragrant winter-green	N^2P^2	MAY-JUN	Temperate	Shrub (W)	Fruit & Medicinal
Rhododendron spp.	Alpine Rose	N^3P^3	MAR-MAY	Temperate	Tree (W)	Medicinal & Flowers for Cold Drinks, Jams
Euphorbiaceae						
Emblica officinalis Gaertn.	Indian goose-berry	N^2P^2	MAR-MAY	S.Tropical	Tree (W)	Fruit, Tanning & Medicinal
Euphorbia royleana Bros.	Euphorbia	N^3P^3	APR-MAY	Temperate	Shrub, Juicy, Hedge plant (W/C)	Medicinal
Phyllanthus acida (L) Skeels	Star goose-berry	N^2P^2	APR-JUN	S.Tropical	Tree (W/C)	Fruit & Tanning
Ricinus communis L.	Caster oil-plant	P^2	MAY-AUG	S.Tropical, S.Temperate	Shrub (W/C)	Lubricant, Oilseed, Purgative & Medicinal
Fagaceae						
Castanea sativa Mill.	Sweet Chestnut	N^3P^3	MAY-SEP	S.Tropical, S.Temperate, Temperate	Tree (W/C)	Timber, Seed & Nuts Edible
Quercus spp.	Oak	N^2P^3	APR-JUL	S.Tropical, S.Temperate	Tree (W/C)	Timber

Table 9.1 (Cont'd...)

1	2	3	4	5	6	7
Gentianaceae						
Gentiana pedicellata Wall.	Gentiana	N^3P^3	APR-JUL	S.Temperate, Temperate	Herb (W)	Medicinal
Swertia spp.	Swertia	N^3P^3	AUG-OCT	S.Temperate, Temperate	Herb (W)	Medicinal & Soil
Geraniaceae						
Erodium spp.	Erodium	N^2P^2	APR-JUN	S.Tropical, S.Temperate, Temperate	Herb (W/C)	
Geranium spp.	Crane's bill	N^3P^3	MAY-SEP	S.Tropical, S.Temperate, Temperate	Herb (W/C)	Medicinal & Ornamental
Iridaceae						
Iris nepalensis Don	Iris	N^2P^2	APR-MAY	Temperate	Herb (W/C)	Medicinal & Ornamental
Juglandaceae						
Juglans regia L.	Walnut	N^2P^2	FEB-APR	S.Temperate, Temperate	Tree (W)	Dyeing & Medicinal
Lamiaceae						
Calamintha spp.	Summer savory	P^3	SEP-OCT		Herb (W/C)	Medicinal
Lamium spp.	Dead nettle	N^2P^3	APR-OCT	S.Tropical, S.Temperate, Temperate	Herb (W)	Medicinal
Leonurus cardiaca L.	Mother-wort	N^3P^3	JUN-SEP	S.Tropical, S.Temperate, Temperate	Herb (W)	Medicinal
Mentha spp.	Mint	N^3	JUL-OCT	S.Tropical, S.Temperate, Temperate	Herb (W/C)	Carminative, Stimulant & Aromatic
Nepeta spp.	Catmint	N^3P^3	MAY-AUG	S.Tropical, S.Temperate, Temperate	Herb (W)	Medicinal

Ocimum spp.	Tulsi	N^3P^3	JUN-SEP	S.Tropical, S.Temperate	Herb (W/C)	Medicinal
Origanum vulgare L.	Marjoram	N^2P^2	JUL-SEP	S.Tropical, S.Temperate	Herb (W)	Medicinal, Oil & Aromatic
Plectranthus rugosus Nall.	Shain	N^1P^2	AUG-NOV	S.Temperate, Temperate	Shrub (W)	
Plectranthus coetsa Benth.	Shain	N^1P^2	SEP-OCT	S.Temperate, Temperate	Under Shrub (W)	
Plectranthus gerardianus Benth.	Shain	N^1P^2	AUG-OCT	S.Temperate, Temperate	Under Shrub (W)	
Rosmarinus officinalis L.	Rosemary	N^2P^21	APR-JUN		Herb (W/C)	Ornamental & Medicinal
Salvia spp.	Sage	N^2P^2	JUL-OCT	S.Tropical, S.Temperate, Temperate	Herb (W/C)	Ornamental & Medicinal
Stachys spp.	Wound-wort	N^2P^3	JUN-SEP	S.Tropical, S.Temperate, Temperate	Herb (W)	Medicinal
Teucrium spp.	Wood Sage	N^3P^3	AUG-SEP	S.Temperate, Temperate	Herb (W)	
Thymus spp.	Thyme	N^2P^3	MAY-OCT	S.Tropical, S.Temperate, Temperate	Shrub (W)	Medicinal & Aromatic
Lauraceae						
Litsea polyantha Juss.	Meda	N^3P^3	DEC-JAN	Temperate	Tree (W)	Medicinal
Liliaceae						
Allium cepa L.	Onion	N^2P^2	MAY-JUN	S.Tropical, S.Temperate	Herb (C)	Vegetable & Medicinal
Asphodelus tenuifolius Cav.	Piazi	N^3P^2	JUL-OCT	S.Tropical, S.Temperate, Temperate	Herb (W)	
Linaceae						
Linum spp.	Flax	N^3P^3	FEB-MAR	S.Tropical, S.Temperate, Temperate	Herb (W/C)	Medicinal, Oilseed & Fibre
Lytheraceae						
Lagerstremoia indica L.	Pride of India	N^2P^2	JUL-SEP	S.Tropical, S.Temperate, Temperate	Small tree (W)	Purgative, Timber & Ornamental

Table 9.1 (Cont'd. . .)

1	2	3	4	5	6	7
Malvaceae						
Abelmoschus esculentus L.	Lady's finger	N^3P^3	JUL-SEP	S.Tropical, S.Temperate, Temperate	Herb (W)	Vegetable & Fibre
Althaea rosea Cav.	Hollyhock	N^2P^2	JUN-OCT	S.Tropical, S.Temperate	Herb (C)	Dyeing & Ornamental
Gossypium arboreum L.	Cotton	N^3P^3	JUL-SEP	S.Tropical, S.Temperate	Shrub (C)	Fibre & Oil
Hibiscus cannabinus L.	Deccan-hemp	N^3P^3	JUL-AUG	S.Tropical, S.Temperate	Herb (C)	Fodder, Crop & Fibre
Malva sylvestris L.	Mallow	N^2P^3	JUN-OCT	S.Tropical, S.Temperate	Herb (C)	Medicinal & Ornamental
Meliaceae						
Azadirachta indica Brandis	Margosa	N^2P^3	MAY-SEP	S.Tropical, S.Temperate, Temperate	Avenue tree, Forest tree (W)	Medicinal & Insecticide (Repellant)
Toona ciliata M.	Cedrella	N^1P^2	MAR-JUN	S.Tropical, S.Temperate	Tree (W)	Dyeing & Woody Furniture
Mimosaceae						
Acacia spp.	Acacia	N^2P^2	MAY-JUL	S.Tropical, S.Temperate	Tree (W)	Medicinal Dyeing, Tanning Industry & Timber
Albizia lebbek Benth.	Siris	N^2P^2	APR-MAY	S.Tropical, S.Temperate	Tree (W/C)	Fodder, Fuel Paper Industry & Timber
Mimosa pudica L.	Sensitive plant	N^2P^2	JUL-NOV	S.Tropical, S.Temperate	Herb (W)	Ornamental
Parkia roxburghli G. Don	Supota	N^3P^2	OCT-DEC		Tree (W/C)	Fruit

Moringaceae						
Moringa oleifera Lam.	Drumstick tree	N^3P^3	JAN-MAR	S.Tropical	Tree (W)	Medicinal & Perfumery & Lubricant
Moraceae						
Morus spp.	Mulberry	P^2	MAR-APR	S.Tropical	Tree (W/C)	Source of food for silkworm
Musaceae						
Musa sapientum L.	Banana	N^3P^3	MAR-DEC	S.Tropical, S.Temperate	Shrub (C)	Fruit & Medicinal
Myrtaceae						
Callistemon citrinus (Curt.) Skeels	Bottle Brush	N^2P^2	APR-MAY		Avenue tree (W/C)	Ornamental
Eucalyptus spp.	Eucalyptus	N^1P^1	FEB-APR OCT-DEC	S.Tropical, S.Temperate, Temperate	Avenue tree (W/C)	Paper Industry & Timber
Psidium guajava L.	Guava	N^3P^3	MAY-JUN	S.Tropical, S.Temperate	Tree (C)	Fruit,Leaves for Tanning& Dyeing
Syzygium cumini (L.) Skeels	Jambolan	N^1P^2	APR-JUN	S.Tropical, S.Temperate	Avenue tree (W/C)	Fruit, Fodder, Medicinal, Dyeing & Tanning
Onagraceae						
Epilobium spp.	Willow herb	N^2P^2	JUN-SEP	S.Tropical, S.Temperate	Roadside tree (W)	
Oxalidaceae						
Oxalis corniculata L.	Indian sorrel	N^3P^1	FEB-JUN	S.Tropical, S.Temperate, Temperate	Shrub (W)	Medicinal

Table 9.1 (Cont'd...)

1	2	3	4	5	6	7
Papaveraceae						
Argemone mexicana L.	Pivla-Dhotra	P^3	MAY-JUL	S.Tropical, S.Temperate, Temperate	Herb (W)	Lubricant & Medicinal
Papaver spp.	Poppy	N^3P^3	MAR-MAY	S.Tropical, S.Temperate, Temperate	Herb (C)	Medicinal & Ornamental
Papilionaceae						
Butea monosperma (Lam.) Kuntze	Palas	N^2	MAY-SEP	S.Tropical, S.Temperate, Temperate	Tree (W)	Dyeing & Medicinal
Cajanus cajan L.	Pulse	N^3P^3	MAY-SEP	S.Tropical, S.Temperate, Temperate	Shrub (W)	Crop, Food for Lac Insect & Fodder
Cicer arietinum L.	Gram	N^3P^3	FEB	S.Tropical, S.Temperate, Temperate	Herb (C)	Pluse, Crop & Fodder
Crotoloaria juncea L.	Sannhemp	N^3P^3	JUL-SEP	S.Tropical, S.Temperate, Temperate	Herb, under Shrub (C)	Crop, Fibre & Leaves, Good Manure
Dalbergia sissoo Roxb.	Sissoo	N^1P^2	MAR-MAY	S.Tropical, S.Temperate	Tree (W)	Timber, Fuel, Fodder, Shade & Paper industry
Erythrina suberosa Roxb.	Coral tree	N^2P^2	MAY-JUN	S.Tropical, S.Temperate, Temperate	Tree (W/C)	Fibre
Glycine max Merr (L.)	soybean	N^3P^3	JUL-AUG	S.Tropical, S.Temperate, Temperate	Herb (C)	Oilseed Crop, Fodder, Banking industry & Paints
Indigofera spp.	Indigo-fera	N^2P^2	JUN-AUG	S.Tropical, S.Temperate, Temperate	Shrub (W)	Fodder
Lespedeza spp.	Lespedeza	N^2	JUN-JUL	S.Tropical, S.Temperate, Temperate	Shrub (W)	Soil reclamation & Fodder
Medicago sativa L.	Lucerne Alfalfa	N^1P^2	MAY-AUG	S.Tropical, S.Temperate, Temperate	Herb (W/C)	Fodder, Paints & Drying oil
Melilotus Mill. spp.	Mellilot	N^1P^2	MAR-JUL	S.Tropical, S.Temperate, Temperate	Herb (C)	Fodder

Phaseolus spp.	Pulses, Beans	N^3P^3	JUL-AUG	S.Tropical, S.Temperate, Temperate	**Herb (C)**	Crop, Food & Fodder
Pisum sativum L.	Garden pea	N^3P^3	MAR-JUL	S.Tropical, S.Temperate, Temperate	Herb (C)	Vegetable & Green Manure
Robinia pseudoacacia L.	Black locust	N^1P^2	APR-JUN	S.Tropical, S.Temperate, Temperate	Tree (W/C)	Medicinal, Ornamental, Fuel & Timber
Sophora mollis L.	Pagoda tree	N^2P^2	MAR-JUL	S.Temperate	Tree (W)	Ornamental
Trifolium alexandrinum L.	Egyptian clover	N^1P^1	APR-JUL	S.Tropical, S.Temperate, Temperate	Herb (W/C)	Green Manure & Soil/ Reclamation
Trifolium pratense L.	Red clover	N^2P^2	APR-JUL	S.Tropical, S.Temperate, Temperate	Herb (W/C)	Fodder
Trifolium repens L.	White clover	N^1P^2	APR-JUL	S.Tropical, S.Temperate, Temperate	Herb (W/C)	Green Manure, Fodder & Crop
Trigonella spp.	Methi	N^3	JUN-SEP	S.Tropical, S.Temperate, Temperate	Herb (W/C)	Medicinal, Fodder & Vegetable
Vicia spp.	Field beans	N^3P^3	APR-AUG	S.Temperate, Temperate	Food (W/C)	Fodder
Pedaliaceae						
Sesamum indicum L.	Sesamum	N^3P^3	JUL-SEP	S.Tropical, S.Temperate, Temperate	Herb (C)	Crop, Oilseed Confectionary & Insecticidal
Plantaginaceae						
Plantago spp.	Plantago	N^2P^1	MAR-SEP	S.Tropical, S.Temperate, Temperate	Herb (W)	Medicinal

Table 9.1 (Cont'd...)

1	2	3	4	5	6	7
Poaceae						
Bambusa bambos Druc.	Bamboo	N^3P^3	NOV-DEC	S.Tropical, S.Temperate	Treec (W)	Forest, Wood Furniture & Paper industry
Cynodon dactylon L.	Dub	P^3	MAY-SEP	S.Tropical, S.Temperate, Temperate	Fodder (W)	
Sorghum vulgare Pers.	Cholam	N^3P^2	MAY-JUN SEP	S.Tropical, S.Temperate, Temperate	Crop, Grain Fodder (C)	Malting & Fermentation Industry
Zea mays L.	Maize	P^2	JUL-AUG	S.Tropical, S.Temperate, Temperate	Grain, Fooder (C)	Industrial alcohol & Corn starch
Polygonaceae						
Fagopyrum sagittatum Moench	Buck-wheat	N^1P^2	JUN-SEP	S.Tropical, S.Temperate, Temperate	Herb, Grain (C)	Flour
Polygonum spp.	Polygo-num	N^2P^3	JUN-SEP	S.Tropical, S.Temperate, Temperate	Herb (W/C)	Medicinal & Tannin
Rumex spp.	Rumex	N^3P^3	JUN-OCT	S.Tropical, S.Temperate, Temperate	Herb (W)	Medicinal
Portulacaceae						
Portulaca glandiflora Hook	Portu-laca	N^2P^1	JUN-SEP	S.Tropical, S.Temperate, Temperate	Herb (C)	Ornamental
Primulaceae						
Primula spp.	Primula	N^3P^3	MAY-SEP	S.Tropical, S.Temperate, Temperate	Herb (W)	Ornamental
Proteaceae						
Grevillea robusta A. Cunn	Silver Oak	N^1P^1	MAR-JUN	S.Tropical	Tree (W)	Ornamental

Punicaceae						
Punica granatum L.	Pomegranate	N^2P^1	APR-MAY	S.Tropical, S.Temperate	Shrub/ Tree (C)	Fruit, Tanning & Medicinal
Punica nana L.	Wild Pomegranate	N^2P^1	APR-MAY	S.Tropical, S.Temperate	Shrub/ Tree (W/C)	Fruit, Tanning & Medicinal
Ranunculaceae						
Caltha spp.	Marsh Marigold	N^3P^2	APR-JUL	Temperate		
Clematis spp.	Clematis	N^2P^2	MAR-MAY		Shrub (W)	Ornamental
Ranunculus arvensis L.	Butter cup	N^3P^3	MAY-JUN	S.Tropical, S.Temperate, Temperate	Herb (W)	Medicinal
Rhamnaceae						
Ziziphus jujuba Lam.	Chinese date	N^2P^3	JUL-SEP	S.Tropical, S.Temperate	Tree (W/C)	Fruit, Fodder & Oilseed
Rosaceae						
Eribotrya japonica Lindl.	Loquat	N^3P^3	FEB-MAR	S.Tropical, S.Temperate	Tree (C)	Fruit
Fragaria vesca L.	Fragaria	N^2P^2	MAY-SEP	Temperate	Herb (C)	Ornamental
Malus domestica Mill.	Apple	N^1P^3	MAR-APR	S.Temperate, Temperate	Tree (C)	Fruit
Malus pumile Mill.	Apple	N^1P^1	MAR-APR	S.Temperate, Temperate	Tree (C)	Fruit
Potentilla spp.	Silver weed	N^2P^3	JUN-AUG	S.Tropical, S.Temperate, Temperate	Herb/ Shrub (W/C)	Medicinal

Table 9.1 (Cont'd...)

1	2	3	4	5	6	7
Prinsepia utilis Royle	Bekhal	N^1P^2	SEP-NOV	S.Tropical, S.Temperate, Temperate	Shrub (W)	Fatty Oil & Hydrogenation
Prunus armeniaca L.	Apricot	N^1P^1	MAR-APR	S.Temperate, Temperate	Tree (C)	Fruit & Oil
Prunus amygdalus Batsch.	Almond	N^1P^1	MAR-APR	S.Temperate, Temperate	Tree (C)	Fruit, Edible Seeds, Oils in in Perfumery
Prunus avium L.	Cherry	N^1P^1	MAR-APR	S.Temperate, Temperate	Tree (C)	Fruits
Prunus cerasoides D.	Wild Cherry	N^1P^2	OCT-NOV	S.Temperate, Temperate	Tree (W/C)	Fruit & Ornamental
Prunus domestica L.	Plum	N^1P^1	FEB-MAR	S.Tropical, S.Temperate, Temperate	Tree (C)	Fruit
Pyrus pashia Buch-Ham	Wild pear	N^1P^1	FEB-MAR	S.Tropical, S.Temperate, Temperate	Tree (W)	Fruit, Root-stock for Pear
Pyrus persica L. Batsch.	Peach	N^1P^1	FEB-MAR	S.Tropical, S.Temperate, Temperate	Tree (C)	Fruit
Pyrus communis L.	Pear	N^1P^1	FEB-APR	S.Tropical, S.Temperate, Temperate	Tree (C)	Fruit
Rosa macrophylla L.	Rose	N^3P^2	MAR-MAY	S.Tropical, S.Temperate, Temperate	Shrub (C)	Fruit, Hedge & Ornamental
Rosa moschata Mill	Wild Rose	N^2P^1	APR-JUN	S.Tropical, S.Temperate, Temperate	Shrub (W/C)	Ornamental
Rubus spp.	Berries	N^2P^2	APR-JUN	S.Tropical, S.Temperate, Temperate	Shrub Climber (W/C)	Hedges & Fruit
Rubiaceae						
Mussaenda frondosa L.	Bedina	N^2P^2	OCT-NOV	S.Tropical	Shrub (W)	Medicinal
Wendlandia exserta (Roxb.)	Chanlai	N^2P^1	NOV-FEB	S.Tropical	Tree (W)	Timber & Ornamental

Rutaceae						
Citrus aurantifolia Swing.	Lime	N^2P^2	MAR-APR	S.Tropical, S.Temperate, Temperate	Tree (C)	Oil for Cosmetics & Root-stock for Mandarins
Citrus limettoides L.	Mitha	N^2P^2	MAR-APR	S.Tropical, S.Temperate, Temperate	Tree (C)	Fruit & Oil
Citrus maxima L.	Changotra	N^2P^2	MAR-APR	S.Tropical, S.Temperate, Temperate	Tree (C)	Fruit
Citrus medica limonum L.	Lemon	N^2P^2	MAR-APR	S.Tropical, S.Temperate, Temperate	Tree (C)	Fruit, &Flavouring Confectionery
Citrus reticulata L.	Manderin	N^2P^2	MAR-APR	S.Tropical, S.Temperate, Temperate	Tree (C)	Fruit, Oil & Confectionery
Citrus sinensis L.	Sweet Orange	N^2P^2	MAR-APR	S.Tropical, S.Temperate, Temperate	Tree (C)	Fruit, Flavouring Food Products & Medicinal
Salicaceae						
Salix spp.	Willow	N^2P^2	FEB-MAR	S.Tropical, S.Temperate, Temperate	Tree/ Shrub (W/C)	Timber & Ornamental
Sapindaceae						
Aesculus indica Colebr.	Horse chestnut	N^2P^2	MAY-JUN	S.Temperate, S.Temperate	Tree (W)	Fodder, Nuts & Timber
Nephelium litchi Comb.	Litchi	N^1P^2	MAR-APR	S.Tropical, S.Temperate	Tree (C)	Fruit
Sapindus spp.	Soapnut	N^1	MAY-JUN	S.Tropical, S.Temperate	Avenue Tree (W/C) &Timber	Medicinal, Fruits as Soap

Table 9.1 (Cont'd...)

1	2	3	4	5	6	7
Scrophulariaceae						
Scrophularia spp.	Figwort	N^1P^2	JUL-SEP	S.Tropical, S.Temperate, Temperate	Herb, Weed (W/C)	
Solanaceae						
Capsicum spp.	Chillies	N^3P^3	JUL-AUG	S.Tropical, S.Temperate, Temperate	Herb (C)	Medicinal & Vegetable
Datura stramonium L.	Tharn Apple	P^3	JUN-SEP	S.Tropical, S.Temperate, Temperate	Herb (W)	Medicinal
Lycopersicum esculentum Mill	Tomato	N^3P^3	MAR-OCT	S.Tropical, S.Temperate, Temperate	Herb (C)	Vegetable
Nicotiana tabacum L.	Tobacco	N^3P^3	JUN-AUG	S.Tropical, S.Temperate, Temperate	Herb (W/C)	Insecticidal, Plant & Varnishes
Solanum spp.	Brinjal	N^3P^3	JUN-AUG	S.Tropical, S.Temperate, Temperate	Shrub (C)	Fruits & Ornamental
Theaceae						
Schima wallichii	Needle Wood	N^2P^2	MAY-JUN	S.Tropical	Tree (W)	Medicinal & Paper pulp
Thymelaeaceae						
Daphne oleoides Scherb.	Daphne	N^3P^3	JUL-SEP	S.Temperate, Temperate	Shrub (C)	Ornamental & Purgative

Tiliaceae						
Grewia oppositifolia Roxb.	Beol	N^3P^3	MAY-JUL	S.Tropical, S.Temperate, Temperate	Tree (W/C)	Fibre, Fruit, Timber & Fodder
Tilia spp.	Lime Basswood	N^1	JUN-AUG	S.Tropical, S.Temperate, Temperate	Avenue Tree (W/C)	Ornamental & Timber
Verbenaceae						
Vitex spp.	Bannah Voilet	N^2P^2	MAY-JUN	S.Tropical, S.Temperate, Temperate	Shrub (W)	Ornamental, Hedge & Medicinal
Violaceae						
Viola odorata L.	Sweet Violet	N^3P^3	JUN-AUG	S.Tropical, S.Temperate, Temperate	Herb (W)	Perfumery, Medicinal & Ornamental
Vitaceae						
Vitis vinifera L.	Grapes	N^3P^3	MAY-JUN	S.Tropical, S.Temperate, Temperate	Shrub (W)	Fruit & Fermented Fruit juice

N^1 = Major honey source
N^2 = Medium honey source
N^3 = Minor honey source

P^1 = Major pollen source
P^2 = Medium pollen source
P^2 = Minor pollen source

W = Wild
C = Cultivated

S.Tropical = Sub-Tropical
S.Temperate = Sub-Temperate

Source: Compiled from multiple sources.

Table 9.2: Medium and minor honey plant resources of Hindu Kush-Himalaya

Family	Plant species
Acanthaceae	*Dyschoriste* Nees
	Hemidelphis polysperma (Heyn ex Roth) Nees
	Hygrophila difformis (L.f.) Blume
	Hypestes spp.
	Phaulopsis imbricata (Forssk.) Sweet
	Pristrophe bicalyculata
	Ruellia spp.
Aizoaceae	*Glinus oppositifolius* (L.) A.D.C.
Alangiaceae	*Alangium salviifolium* (L.f.) Wangerin
Amaranthaceae	*Achyranthes indica* (L.) Mill
	Aerva lanata (L.) Juss. ex Schult
	Celosia arqentea L.
	Digera arvensis Forssk.
Anacardiaceae	*Anacardium occidentale* L.
	Holigarna grahamii (wt.) Hook. f.
	Lannea spp.
	Pistacia vera L.
	Schinus molle L.
	Spondias spp.
Annonaceae	*Annona* spp.
	Polyalthia longifolia (Sonn.) Thwaites
Apiaceae	*Anthriscus* spp.
	Bupleurum tenue Ham. ex Don
	Trachyspermum amni Sprague
Apocynaceae	*Allamanda cathartica* L.
	Alstonia scholaris (L.) R. Br.
	Cartharanthus roseus (L.) G. Don
	Holarrhena pubescens (L.) R. Br.
	Nerium indicum Nill.
	Rauvolfia serpentina (L.) Benth. ex Kurz
	Strophanthus gratus (Hook) Frach.
	Tabernaemontana divaricata (L.) R. Br.
	Thevetia peruviana (Pers.) K. Schum.
	Vinca rosea L.

Family	Plant species
Aquifoliaceae	*Ilex* spp.
Araliaceae	*Hedera nepalensis* K. Koch
	Schefflera spp.
Ascelepiadaceae	*Calotropis gigantea* Ait
	Cynanchum komayovii
Asteraceae	*Arctotis grandis*
	Blumea lacera DC
	Chicus arvensis
	Dahlia variabiles (Willd.) Desf
	Dentella repens (L.) J.R. & G. Frost
	Dimorphotheca aurantiaca
	Eclipta prostrata
	Enhydra fluctuans
	Gaillardia aristata
	Guizotia spp.
	Saussurea affinis
	Spilanthes acmella
	Synedrella nodiflora
	Tithonia tagetifolia
	Venidum fastuosum
	Vigulera helianthoides
	Xanthium strumarium
Begoniaceae	*Begonia* spp.
Berberidaceae	*Mohonia* spp.
Betulaceae	*Betula* spp.
Bignoniaceae	*Kigelia* spp.
	Markhamia stipulata
	Tecoma stans (L.) H. B. & K
Bombacaceae	*Durio zibethinus* Murr.
Boraginaceae	*Anchusa officinalis*
	Borago officinalis L.
	Brugmansia spp.
	Echium spp.
	Heliotropium indicum L.
	Paracarum spp.
	Tournefortia arqeutea
Brassicaceae	*Barbarea intermedia*
	Rorippa indica (L.) Hiern
	Sinapsis spp.
Caesalpiniaceae	*Cynometra alexandria*
	Delonix regia (Boj.) Ref.
	Saraca indica

Table 9.2 (Cont'd...)

Family	Plant species
Campanulaceae	*Campanula alsinodes*
	Lobelia spp.
Cannaceae	*Canna indica* L.
Capparidaceae	*Cleome viscosa* L.
Caprifoliaceae	*Caerulea* spp.
	Sambucus hookeri Rehder
Caricaceae	*Carica papaya*
Celastraceae	*Euonymus hamiltonianu*
Chenopodiaceae	*Spinacia oleracea* L.
Cochlospermaceae	*Cochlospermum insigne*
Combretaceae	*Quisqualis indica* L.
Commelinaceae	*Amischophacelus axillaris* (L.) Rao & Kammathy
Convolvulaceae	*Evolvulus nummularius* (L.) L.
	Jacquemontia nodiflora
	Merremia hederacea (Burm.f.) Hallier f.
	Mina lobata Cerv.
	Rivea corymbosa
Cucurbitaceae	*Benincasa hispida* (Thunb.) Cogn.
	Coccinia grandis (L.) Voigt
	Momordica spp.
	Sicyos deppei
Cyperaceae	*Caresa cruciata*
	Cyperus kyllingia
Datiscaeae	*Datisca* spp.
Dilleniaceae	*Dillenia* spp.
Dipterocarpaceae	*Shorea* spp.
Ebenaceae	*Diospyros* spp.
Ehretiaceae	*Cordia myxa*
	Ehretia spp.
Elaeocarpaceae	*Elaeocarpus tectonis*
Ericaceae	*Vaccinium* spp.
Euphorbiaceae	*Aleurites montana* (Lour) E.H. Wils.
	Antidesma ghesaembilla Gaertner
	Chrozophora rottleri (Geisel.) Juse & Sprengel
	Codiaeum variegatum (L.) Blume
	Croton bonplandianus Baill
	Gelonium multiflorum Juss.
	Hevea brasiliensis (Willd. ex. Adr. de Juss.) Mull-Arg
	Jatropha spp.

Family	Plant species
	Mallotus spp.
	Manihot glaziovii Muell-Arg
	Putranjiva spp.
	Sapium sebiferum (L.) Roxb.
	Securinega virosa (Roxb. ex Willd.) Baill
	Trewia nudiflora L.
Fagaceae	*Ilex* spp.
Flacourtiaceae	*Xylosoma* spp.
Fumariaceae	*Fumaria parviflora*
Geraniaceae	*Pelargonium zonale*
Grossulariaceae	*Ribes* spp.
Hippocastanaceae	*Aesculus* spp.
Hydrophyllaceae	*Hydrolea zeylanica* (L.) Vahl
Iridaceae	*Iris* spp.
Lamiaceae	*Clinopodium umbrosum*
	Dracocephalum moldavica
	Dysophylla spp.
	Eusteralis pumila (Graham) Rafin
	Hyptis suaveolens Poit.
	Leucas spp.
	Marrubium vulgare L.
	Perrila frutescens (L.) Britt.
Lauraceae	*Actinodaphne augustifolia*
	Machilus spp.
	Persea gratissima
Lecythidaceae	*Barringtonia acutangula* (L.) Gaertn.
	Careya arborea Roxb.
	Aspenaragus spp.
Liliaceae	*Lilium polyphyllum*
Loganiaceae	*Buddleia asiatica* Lour.
Lythraceae	*Lawsonia inermis* L.
	Lythrum spp.
	Punica granatum L.
Magnoliaceae	*Magnolia grandiflora* L.
Malpighiaceae	*Hiptage madablota*
Malvaceae	*Abutilon* spp.
	Sida acuta Burm. f.
	Urena lobata L.
Marantaceae	*Clinogyne dichotoma* Salisb
Meliaceae	*Aphanamixis polystachya* (Wall.) Parker
	Swietenia mahagoni Jacq.
Mimosaceae	*Enterolobium saman* prain ex King

Table 9.2 (Cont'd...)

Family	Plant species
	Leucaenia leucocephala
	Pithecellobium dulce (Roxb.) Benth
	Prosopis farcata
Moraceae	*Artocarpus* spp.
	Ficus spp.
	Streblus asper Lour
Myrsinaceae	*Embelia laeta*
Myrtaceae	*Cleistocalyx operculata* (Roxb.) Merr & Perry
	Melaleuca leucadendron L.
	Myrtus communis L.
Nyctaginaceae	*Boerhaavia diffusa* L.
	Bougainvillea spectabilis Willd.
	Mirabilis jalapa L.
Oleaceae	*Fraxinus excelsior* L.
	Jasminum sambac (L.) Aiton
	Liqustrum spp.
	Olea spp.
Onagraceae	*Ludwigia hyssopifolia* (G. Don) Excell
Oxalidaceae	*Averrhoa* spp.
Palmae	*Areca catechu* L.
	Borassus flabellifer L.
	Cocos nucifera L.
	Elaeis quineensis L.
	Phoenix sylvertris (L.) Roxb.
Papilionaceae	*Abrus precatorius* L.
	Arachis hypogaea L.
	Clitoria ternátea L.
	Desmodium gangeticum (L.) DC
	Lablab purpureus (1.) Sweet
	Lathyrus sativus L.
	Lenss culinaris Medik
	Lotus corniculatus L.
	Pongamia spp.
	Pterocarpus macrocarpus
	Sesbania grandiflora (L.) Poir
	Vigna mungo (L.) Hepper
Pinaceae	*Pinus roxburghii* Sar.
Polemoniaceae	*Phlox drummondii* Hook.
Polygonaceae	*Antigonon leptopus* Hook & Arn
	Coccoloba belizensis
Plumbaginaceae	*Limonium bicolor*
Ranunculaceae	*Anemone biflora*
	Nigella sativa L.

Family	Plant species
Resedaceae	*Reseda alba*
Rhamnaceae	*Berchemia edgeworthii*
	Gouania polyagama
	Paliurur spina cristi
Rhizophoraceae	*Bruguiera* spp.
	Rhizophora mangle
Rosaceae	*Crataegus oxyacantha* L.
	Sorbaria tomentosa
Rubiaceae	*Adina cordifolia* (Roxb.) Hook. f.
	Anthocephalus chinensis (Lam.) Rich. ex Walp
	Borreria verticilata
	Coffea arabica L.
	Dentella repens (L.) J.R. & G. Frost
	Galium asperifolium
	Ixora spp.
	Meyna laxiflora Robyns
	Morinda spp.
	Oldenlandia spp.
	Spermacoce hispida L.
Rutaceae	*Aeqle marmelos* (L.) Correa
	Feronia limonia Swingle
	Glycosmis arborea (Roxb.) DC
	Murraya spp.
Salicaceae	*Populus* spp.
Sapotaceas	*Aesandra butyracea*
	Madhura latifolia Roxb.
	Mimusops elengi L.
Sapindaceae	*Cardiospermum halicacabum* L.
	Dimocarpus longau
	Erioglossum spp.
	Lepisanthes rubiginosa (Roxb,) Leenh
	Litchi chinensis Sonn.
Scrophulariaceae	*Adendsma bilabiata* (Roxb.) Merr.
	Lindernia ciliata (Colsm.) Pennell
	Scoparia dulcis L.
Simaroubaceae	*Aignthus* spp.
	Ailanthus glandulosa
Solanaceae	*Cestrum nocturnum* L.
	Physalia minima L.
Sterculiaceae	*Dombeya mastersii* Hook.f.
Symplocaceae	*Symplocos spicata*

Table 9.2 (Cont'd...)

Family	Plant species
Tamaricaceae	*Tamarix aphylla* (L.) Karst
Theacea	*Eurya* spp.
	Thea sinensis L.
Tiliaceae	*Corchorus capsularis* L.
Tropaeolaceae	*Tropaeolum* spp.
Ulmaceae	*Celtis* spp.
Urticaceae	*Boehmeria requlosa*
Verbenaceae	*Caryopnteris wallichiana* Schau
	Clerodendrum spp.
	Duranta repens L.
	Lantana camara L.
	Lippia spp.
	Nyctanthes arbortristis L.
	Phyla nodiflora (L.) Greene
	Tectona grandis L.f.
	Verbena spp.
Vitidaceae	*Ampelocissus* spp.
Vitaceae	*Parthenocissus quinquefolia*
Zingiberaceae	*Hedychium* spp.
Zygophyllaceae	*Peqanum harmala* L.

Source: Compiled from multiple sources.

9.2 MELISSOPALYNOLOGY, BEE BOTANY AND FLORAL CALENDARS

Honeybees while foraging for nectar on flowers of different entomophilous plants also gather some pollen with it. This pollen is retained in the ripened honey even after extraction. The microscopical examination of these pollen grains in the honey is known as melissopalynology or "Pollen analysis of honey". Melissopalynological studies are helpful in both quantitative and qualitative pollen analysis of honey (Louveaux et al., 1978). Quantitative analysis is used for confirming the botanical origin of unifloral and multifloral honeys. For example, honey samples are considered as rich, poor and extremely poor in pollen if the number of pollen grains per 10 gm of honey samples are above 100,000, 20,000 to 100,000, and below 20,000 respectively. Similarly, for the presentation of frequencies of pollen grains in honey, Louveaux et al. (1978) adopted the following system: "Predominant pollen" (having more than 45 per cent of the pollen grains counted), "secondary pollen" (16–45 per cent), "Important minor pollen" (3–15 per cent) and "Minor pollen" (less than 3 per cent). Pollen analysis of honey also helps in the identification of the geographical origin of honey samples because local flora have characteristic plant associations that are reflected in the corresponding spectrum of pollen types represented in the local honeys (Maurizio, 1975; Nair, 1985). Such studies also help in the identification of plant sources of toxic honey, relative preferences by honeybees for individual plants flowering simultaneously and to find the season of honey extraction.

Besides melissopalynology, an other aspect of study which is of great importance to the beekeeping industry is "bee botany". This involves the mapping of the regional bee flora with emphasis on density, distribution, honey potentially, time and duration of bloom of honey plants.

Such floral calendars should be prepared for each ecological region where beekeeping is practised. These floral calendars are of special value for the development of beekeeping in the temperate Hindu Kush-Himalayan region where multiple bee flora exist. Moreover, in this region, due to very low temperatures and dearth of bee flora during winter, movement of bee colonies to lowland areas becomes essential. For such migratory beekeeping, floral calendars are of great help in selecting the most suitable places where bee should be moved during this period.

In India, melissopalynological studies were initiated by Deodikar and Thakar (1953) who conducted the pollen analytical study of major honey-yielding plants in Mahabaleswar hills of Maharashtra. They wanted to standardize those honeys which are marketed under the name of certain specific plants and identified pollen of 12 major nectar plants. Sen and Banerjee (1956) analysed the pollen content of a sample of honey obtained from a garden near Calcutta and observed an overabundance of one anemophilous sporomorph. Mittre (1958) examined the pollen contents of ten samples of Indian honeys known under the name Nepal honey, Almora honey, Kashmir honey, Lucknow honey, Lotus honey and Sunderbans honey. He observed that the commercial samples are made up of a mixture of several kinds of honeys. Phadke (1964), while studying the physico-chemical composition of major unifloral honeys of Mahabaleshwar, reported that *Carvia callosa* honey contained unusual amount of non-reducing sugars. *Carvia* sp., was considered a good source of honey in these hills. Chaubal and Deodikar (1965) studied pollen grains of poisonous plants in honey samples from the Western ghats and identified poisonous plants as: *Clematis* spp., *Datura arborea*, *Euphorbia geniculata*, *Lasiosiphon* sp. and *Lobelia nicotianaefolia*.

Nair (1964) made a comprehensive pollen analysis of 76 samples of Indian honeys collected from the peninsular region (Andhra

Pradesh, Karnataka, Tamil Nadu), Western region (Maharashtra and Rajasthan), Indo-Gangetic region (Uttar Pradesh and Punjab), Eastern region (Bihar and West Bengal) and Himalayan region including (Nepal, Jammu and Kashmir, and Assam). On the basis of this analysis, he prepared a list of important nectar and pollen yielding plants of these regions including *Eugenia* sp., *Nephelium* sp., *Sapindus* sp., *Citrus* sp., *Putranjiva* sp., *Plectranthus* sp., *Brassica* sp., *Holoptelea* sp., *Alnus* sp., *Borassus* sp., and some palms. It was inferred that the names given to various honeys are not corroborated by their pollen composition. Similar pollen analyses of 13 honey samples from Uttar Pradesh revealed the dominant pollen grains of Euphorbiaceae, *Nephelium* sp., Myrtaceae, Liliaceae, Rosaceae, Meliaceae, Brassicaceae and *Rumex* sp. (Sharma and Nair, 1965).

Chaubal and Deodikar (1965) carried out melissopalynological studies on different honey samples of the Western Ghats so as to identify the botanical sources of these samples. They found: *Rosa multiflora, Brugmansia candida, Paracarym malabaricum, Impatiens balsamina, Ocimum canum, Heracleum concanense, Polygonum chinensis* and *Litsea stocksii* as the best honey sources. Other minor honey sources were: *Justicia procumbens, Thelepaedale ixiocephala, Lobelia nicotianaefolia, Lasiosiphon eriocephalus, Scutia indica* and *Dysophylla salcifolia*. Sharma (1970) studied the bee flora of Kangra area of Himachal Pradesh by pollen load analysis from the month of June to August. Twenty pollen types were identified with the preference of bees for pollen the family Poaceae. Other anemophilous pollen plants visited by bees were from families Cyperaceae, Arecaceae, Chenopodiaceae and Urticaceae. Similar pollen load studies conducted in the month of September, revealed 13 more pollen types which included *Mimosa* sp. and *Phoenix* sp, in high frequencies. Chenopodiaceae, Poaceae and *Phoenix* sp. were the three anemophilous taxa represented in pollen loads. Sharma (1972) studied the pollen grains or *Datura stramonium* and suggested this to be an important honey plant besides its medicinal value in the temperate and warm regions of India.

Chaturvedi (1973) analysed 192 pollen loads from the Banthra area of Lucknow, collected during the months of January to April. During January, all loads were unifloral with the dominance of Brassicacae pollens but in February, *Asphodelus* sp. and Brassicacae pollens were the most common types. Asteraceae and Cucurbitaceae pollens were dominant during March. Cucurbitaceae pollens were also collected during April together with *Citrus* sp., and Poaceae pollens. Analysis of 213 pollen loads collected during July to October from Banthra (Lucknow) showed that all except six of the loads were unifloral. A total of 17 pollen types were identified with *Sesbania* sp., Poaceae, *Sesamum indicum* pollen being dominant (Chaturvedi, 1977).

Chaudhari (1977) evaluated 80 important bee plants of the Punjab by visual and microscopical analyses of pollen loads and honey samples. The major sources of pollen and nectar recorded were: *Trifolium* sp., *Fagopyrum* sp., *Polygonum* sp., *Medicago* sp. and *Melilotus* sp., etc. Shah (1978) described Break Mushik *(Salix aegyptica)* as the saviour bee plant of Kashmir. Whereas, Rao and Seethalakshmi (1978) confirmed honeybees foraging on sorti variety of paddy in Karnataka through microscopical analysis of pollen loads.

Suryanarayana (1978) gave general information on the distribution, flowering period and other botanical aspects of *Carvia callosa*. Microscopical analysis showed 13,000 to 21,000 pollen grains per 10 gm of Karvi honey. Pollens of *Senecio* sp., *Smithia* sp., *Impatiens* sp. and Poaceae were found to be associated with it. Pollen analysis of 14 samples from different parts of India revealed more pollen grains with reticulate than with non-reticulate surfaces. One of the samples contained pollen grains only from *Eucalyptus* sp. (Ganguly, 1979, Ganguly and Chanda, 1980). Seethalakshmi (1980) conducted melissopalynological studies on 12 honey samples from Maharashtra, Bihar, Jammu and Kashmir, Uttar Pradesh, Andhra Pradesh, Karnataka, Kerala and Tamil Nadu States of India. These studies indicated that Indian honeys fall under the categories of Groups I to III of the International Commission of Bee Botany, i.e., honeys having an absolute pollen count from 10,000–5,00,000 per 10 gm of honey. A total of 44 pollen types were identified, and it is inferred that honeys from the same locality in the same season may have a similar pollen spectrum for the associated species but their percentages may differ. Important sources identified were: *Syzygium cumini, Nephelium litchi, Isodon rugosus, Brassica* sp., *Eucalyptus* sp., *Tamarindus indica, Hevea brasiliensis* etc. Chaubal (1980) conducted melissopalynological studies on different honey samples from Padgaon (Maharashtra). This study revealed that some members of families such as Myrtaceae, Combretaceae, Lamiaceae, Acanthaceae, Rubiaceae etc. are amongst the major bee plants of this region. He also gave the botanical description of plant sources, their flowering period, the value of the nectar source and honey colour. The honey from this area was mostly of unifloral type. Chaubal and Kotmire (1980) gave a floral calendar or bee forage plants of Sagaramal (Maharashtra) based on microscopical studies. Important plants recognized were: *Amaranthus* sp., *Zea mays, Vitex negundo, Albizia lebbeck, Eucalyptus* sp., *Oxalis* sp., *Impomoea* sp., *Plectranthus* sp., *Brassica* sp., *Bombax* sp., *Sapindus* sp., *Tamarindus* sp., etc. Mondal and Mitra (1980) carried out pollen analysis of six honey samples from the Sunderban area of West Bengal. All the samples contained pollen of *Phoenix* sp. *Bruguiera* sp., *Aegiceras* sp. and *Sonneratia* sp. Suryanarayana (1980) suggested *Hevea brasiliensis* as an important nectar source in the tropics. Suryanarayana et al. (1981) conducted melissopalynological studies on 15 honey samples from Pune. The absolute pollen count varied from 3,400 to 42,000 in Jamun honeys and 4,500 to 18,133 in Litchi honeys. The wide variation in the absolute pollen count in the same type of honey suggested that both regional and seasonal variations in pollen and nectar output existed. Chanda and Ganguly (1981) studied honey samples from different parts of India including Kerala, Karnataka, Andhra Pradesh, Orissa and West Bengal. Most of the samples had pollen of entomophilous plants with a small percentage of anemophilous types. On the basis of microscopical analysis of the honey samples, they identified the different biozones from where the samples originated. Chaturvedi (1983) carried out pollen analysis of autumn honeys of the Kumaon region of Uttar Pradesh. Both unifloral and multifloral honeys were identified. The main honey plants were: *Eucalyptus* sp., *Brassica* sp., etc. A similar palynological study was conducted by Sadruddin and Tripathi (1985) on the honey samples from eastern Uttar Pradesh. Microscopic analysis of honey samples showed 27 pollen types including *Emblica officinalis, Brassica compestris, Adhatoda zeylanica* sp., *Morus alba, Eucalyptus* sp., *Drypetes* sp., *Azadirachta indica* and *Moringa pterygosperma*. Nair (1985) reviewed the important pollen and nectar plants of India. Some of them are: *Mangifera indica*, *Berberis* sp., *Alnus nepalensis* and *Ricinus communis*. A graph was prepared showing seasonal forage and colony cycles. Singh (1962) reviewed the major and minor sources of pollen and nectar found in India. He classified the important plants according to their economic and botanical status. The following categories of bee forage have been discussed: fruits, vegetables, ornamentals, crops, herbs, bushes, shrubs and forest and avenue trees. Some of the major sources are: *Citrus* sp., *Pyrus* sp., *Syzygium* sp., *Plectranthus* sp., *Cedrela* sp., *Brassica* sp., *Rosa* sp., *Fagopyrum* sp., *Medicago* sp., *Melilotus* sp., *Trifolium* sp., *Taraxacum* sp., *Berberis* sp., *Eucalyptus* sp., *Ehretia* sp., *Salix* sp., *Sapindus* sp., etc.

Phadke (1965) found *Thelepaedale ixiocephala* widely distributed in the western ghats, forming dense growths at elevations above 500 metres. Octennial flowering occurs after the monsoon from November to January and proves to be an abundant source of nectar and pollen. As a bee plant, it is considered even more important than the related *Carvia callosa*. Bee forage studies on ornamental plants in the Mahabaleshwar hills showed *Phlox drummondii* as a good pollen source, but the little nectar produced by this plant is inaccessible to honeybees owing to its long corolla tube (Suryanarayana and Thakur, 1966). Similar studies by Deodikar and Thakar (1966a) stressed the need for the utilization and improvement of the local flora as bee pasturage. They also observed that during times of acute pollen shortage, bees collected fungal rust spores such as those of *Cystophora oleae*.

Suryanarayana (1966) attempted to evaluate the natural vegetation of the western highlands, foothills and eastern plains of Karnataka. Diwan and Rao (1969) surveyed the bee flora of Karnataka and reported that *Acacia* sp., *Dalbergia* sp., *Lagerstroemia entada* and *Grewia* sp., were the most important nectar and pollen sources. Deodikar (1970) studied the bee flora of Jammu and Kashmir region of northern India. The major honey plants listed during May-June were: *Sapindus* sp., *Acacia* sp., *Dalbergia* sp., *Grewia* sp., *Trifolium* sp., and *Rumex* sp., whereas, during September–October, *Zea mays, Ziziphus* sp., *Trifolium* sp., *Medicago* sp., were the important honey plants. In a similar attempt for the evaluation of bee flora for different species of *Apis* at Ludhiana it was revealed that *Trifolium alexandrinum, Eucalyptus* sp., *Terminalia arjuna, Brassica campestris, Eruca sativa, Medicago sativa, Acacia* sp., *Gossypium* spp. etc., were the important bee plants (Atwal et al., 1970). Narayana (1970) reported *Carvia callosa* as the best nectar plant in South India, whereas, Jayarathnam (1970) reported *Hevea brasiliensis* as another important honey source of South India.

Saraf (1972) reported 110 species of plants useful to bees in the Kashmir valley. Important species are: *Pyrus, Prunus, Brassica, Aesculus, Polygonum, Plectranthus, Impatiens, Fagopyrum* etc. *Plectranthus rugosus* was found as an excellent source of nectar during the autumn season. Similarly, Singh and Singh (1971) and Atwal and Goyal (1974) also identified *Plectranthus rugosus* as the major honey plant in the Kashmir and Kullu valleys respectively. Deodason (1972) reported the rubber plant *(Hevea brasiliensis)* as an important nectar source in South India and honey from this plant is white to golden yellow in colour. Chandran and Shah (1974) studied the major pollen and nectar plants of the Kodai hills of Tamil Nadu. Major sources were: *Prunus domestica, Bidens pilosa, Ageratum conyzoides, Coffea arabica, Pyrus communis, Syzygium cumini, Cedrella toona, Jambosa munronii, Eucalyptus globulus* and *Erythrina myosorensis*. Dhaliwal and Atwal (1974) identified *Trifolium alexandrinum* as the major honey plant in the Punjab. Phadke and Naim (1974) suggested *Nephelium litchi* as the best source of nectar and pollen in Pusa (Bihar), whereas Nair and Singh (1974) discussed the importance of *Antigonon leptopus* and *Moringa pterygosperma* as source of pollen and nectar. They described the flower morphology and pollen grains of both plants.

Shah (1975) described the main bee flora of the Kodai hills of Tamil Nadu. Major bee plants are: *Celtis cinnamome, Eriglossum* sp., *Bidens pilosa, Ageratum conyzoides, Olea diocia, Cedrella toona, Coffea arabica, Emblica officinalis, Eucalyptus* spp. etc. Salvi (1975) studied the bee flora of Pathankot and revealed berseem, litchi, mustard and a variety of fruit crops to be the important bee forage plants. Similarly, Satyanarayana (1975) reported *Syzygium cumini, Acacia sinuata* and *Vernonia* sp. as the major honey plants of Karnataka. Naim and Phadke (1976) investigated 40 nectar and pollen plants of Bihar. Some of the important plants are: *Syzygium cumini, Pongamia* sp., *Trifolium alexandrinum, Antigon* sp., *Cosmos* sp., *Sesamum orientale, Nephelium litchi, Moringa pterygosperma* etc.

Thakar et al. (1962) have divided India into four major regions from the beekeeping point of view, the southern peninsular region, Northeast region, Indo-Gangetic plains and northern hill region. In these regions, bee forage is mainly derived from wild arboreal species like *Terminalia* sp., *Dalbergia* sp., *Quercus* sp. Along the higher elevations, *Berberis* sp., *Rhododendron* sp., *Salix* sp., *Robinia* sp., *Aesculus* sp., etc. constitute major source of bee forage. A number of orchard crops like apples, pears, plums, almonds, peaches, walnuts and annual crops such as maize, *Brassica*, beans and a variety of vegetables and ornamentals are very useful during the buildup period. Shah and Shah (1976) discussing the bee forage of the Kashmir valley, suggested that *Brassica, Prunus, Pyrus, Fagopyrum, Impatiens, Rosa, Plectranthus, Robinia pseudoacacia* etc., were the major species of plants visited by honeybees in Kashmir valley. *Plectranthus* spp. were the sources of surplus honey during the autumn season. Uppin (1978) stressed the importance of planting *Eucalyptus* spp. in India for better honey production, whereas, Shah and Shah (1979) found *Robinia Pseudoacacia* and *Robinia ambigua* to be main sources of nectar in the Kashmir valley. Singh (1979) reported strawberry *(Fragaria vesica)* as an important honey plant in Jeolikote (Uttar Pradesh), whereas, Seethalakshmi and Percy (1979) found *Borassus flabellifer* to be an important pollen source in Tamil Nadu. Chandran et al. (1983) identified cardamom *(Elettaria cardamomum)* as a major bee plant in South India. Diwan and Vartak (1980) identified 400 species of bee forage plants in Karnataka and relevant information was given regarding the occurrence, abundance, distribution and flowering times of these plants. Major sources are: *Terminalia* sp., *Dillenia* sp., *Careya arborea, Nothopegia* sp., *Impatiens* sp., *Cania* sp., *Plectranthus* sp., etc. Rajan (1980) listed the important trees yielding pollen and nectar to the bees in Karnataka. Among them are: *Albizia* sp., *Eucalyptus* spp., *Mangifera indica, Nephelium litchi, Terminalia* sp., and *Syzygium cumini* to be the major nectar source (Srivastva and Tripathi, 1980). Krishnaswamy (1980) discussed the introduction and propagation of important bee plants in Chickmagalur area of Andhra Pradesh. Such plants were *Schefflera* and *Wendlandia* sp. and it was suggested that their plantation may increase the honey yield. Hazel nut, *Corylus colurna* was reported as the first bee forage source available after the long winter in the Kashmir valley. The flowers are yellow in colour and bloom from February to March (Shah, 1981). Suryanarayana and Mohana Rao (1982) reported *Dombeya mastersii* as an important ornamental bee plant in India, whereas, Dutta et al. (1983) reported that the *Amomum occuleatum* plant tranquilizes *Apis dorsata* in the Andaman islands.

Verma (1983) formulated a floral calendar of 58 bees plants of Jeolikote area of Uttar Pradesh. The best sources of nectar recorded are: *Madhuca* spp., *Berberis* sp., *Rubus niveus, Olea glandulifera, Allium cepa, Nephelium litchi* and *Prunus*. A similar survey of bee flora in Uttar Pradesh revealed *Nephelium* sp., *Trifolium* sp., *Rumex* sp., *Polygonum* sp., *Shorea robusta, Rosa moschata, Pyrus* sp., *Prunus* sp., *Eucalyptus* sp.,*Plectranthus* sp. etc. as the major honey plants (Singh, 1983; Singh et al., 1983). Mohana Rao and Suryanarayana (1983) also reported *Brassica* sp., *Helianthus annuus, Prunus* sp., *Pyrus* sp., *Melilotus* sp., *Fagopyrum* sp., *Trifolium alexandrinum* etc., as potential bee plants of Uttar Pradesh. Nehru et al. (1984) conducted studies on the off-seasonal bee forage of *Apis cerana* in Kerala. Their results revealed a synchrony in the activities of bees and the flowering periods of plants during various seasons of the year. The rubber plant *Hevea brasiliensis* provided forage from January to March and was the major source of pollen and nectar. Fifty-one off-seasonal bee plants have been listed that are useful to honeybees during the dearth period. Phytosociological studies on *Apis mellifera* and *Apis cerana* in the Punjab revealed that both species of honeybees collected pollen and nectar from 89 plant genera belonging to 42 families. Some potential sources of surplus honey are: *Eucalyptus* sp.,*Trifolium* sp., and *Phaseolus* sp., *Brassica* sp., *Helianthus annuus, Gossypium* sp. and *Citrus* sp. (Sarwan and Sohi, 1985).

Sharma and Raj (1985) have discussed the bee flora of the Kangra Shivaliks and its possible impact on the beekeeping industry. Important honey plants are: *Brassica campestris, Rosa moschata, Rubus* sp., *Eucalyptus* sp., *Dalbergia sissoo, Bauhinia variegata, Ehretia* sp., *Mangifera indica, Litchi chinensis, Adhatoda vasica, Sapindus detergens, Syzygium cumini* etc. Similarly, Saraf (1985a) has discussed the bee flora of Gurej region of Jammu and Kashmir. Some of the important floral resources are: *Taraxacum* sp., *Rumex* sp., *Fragaria* sp., *Medicago* sp., *Melilotus* sp., *Fagopyrum* sp., *Impatiens* sp., *Trifolium* sp., *Viola* sp., *Betula* sp., etc. About 75 per cent of the honey produced in this area is from *Fagopyrum sagittatum*. The honey obtained from this plant is amber coloured with a strong flavour (Saraf, 1985b). Mohana Rao (1985) reported Khesari as an important bee plant of Muzaffarpur (Bihar), whereas, Mohanrao and Nair (1985) found that several varieties of mango *Mangifera indica* are visited by *Apis cerana*. Mishra and Kumar (1987) have stressed the importance of planting certain bee plants such as *Acacia* sp., *Aesculus* sp., *Bauhinia* sp., *Dalbergia* sp., *Eucalyptus* sp., *Grevillea* sp., *Nephelium* sp., *Prunus* sp., *Salix* sp., *Sapindus* sp., *Toona* sp., *Terminalia* sp., etc. for social forestry programmes.

Sharma (1989) made an extensive melissopalynological and botanical study on the honey plants of Himachal Pradesh. Major nectar plants listed by her investigations as per norms of International Commission on Bee Botany are as follows:

Brassica napus, Impatiens glandulifera, Ehretia acuminata, Eruca sativa, Plectranthus spp., *Toona ciliata, Eucalyptus* spp., *Syzygium cumini, Dalbergia sissoo, Medicago sativa, Melilotus* spp., *Robinia pseudoacacia, Trifolium* spp., *Fagopyrum sagittatum, Malus domestica, Prinsepia utilis, Prunus* spp., *Pyrus* spp., *Nephelium litchi, Sapindus* spp., *Scrophularia* spp., and *Tilia* spp.

The major pollen plants included *Brassica napus, Berberis lycium, Eruca sativa, Eucalyptus* spp., *Trifolium* spp., *Plantago* spp., *Punica granatum, Portulaca glandiflora, Malus domestica, Prunus* spp., *Pyrus* spp., *Rosa moschata*. The pollen spectrum of honey samples of *Apis cerana* collected during different seasons in the Shimla hills is summarized in Table 9.3 and the seasonal frequency of the pollen grains of different bee plants of the Shimla hills of Himachal Pradesh is given in Table 9.4.

Shahid and Qayyum (1977) listed 13 major and 109 minor plants of the North-West Frontier Province of Pakistan. Major nectar flow was recorded from: *Trifolium* spp., *Plectranthus rugosus, Eriobotrya japonica, Campestris, Acacia modesta* and *Dalbergia sissoo*. Manzoor and Muhammed (1980) found *Helianthus annuus* as a important honey plant in Pakistan. Makhdoomi and Chohan (1980) surveyed the bee forage in West Punjab and North-West Frontier Province of Pakistan identifying the major nectar sources as: *Plectranthus rugosus, Eriobotrya japonica, Eucalyptus* spp., *Adhatoda vasica, Acacia modesta, Cedrella toona, Trifolium alexandrinum* and *Medicago sativa*.

Dewan (1980) identified 36 bee plants by visual observation in Bangladesh, the most important being: *Brassica* spp., *Zizyphus* spp., *Toona* etc. Dimshi a mustard-like crop is being introduced as a good source of pollen (Dewan, 1984). Similarly Alam and Zannat (1980) found *Shorea robusta, Acacia* sp., *Albizia* sp., *Helianthus annuus, Vitex* sp., *Brassica napus, Citrus*, sp., *Nephelium litchi* etc. as good nectar sources in Bangladesh.

Focke (1968) performed pollen analysis of 33 honey samples from China and found *Trifolium* sp., *Robinia* sp., *Frangula* sp., *Tilia* sp. and *Lamium* sp. as the major bee plants. Deh-Feng and Wen-Cheng (1981) have also discussed the honey resources of China identifying more than one thousand species of nectar plants. The most important being: *Brassica campestris, Astragalus, Vicia sativa, Robinia* sp., *Medicago* sp., *Melilotus* sp., *Tilia* sp., *Nephelium* sp., *Fagopyrum* sp., *Eucalyptus* sp. and *Citrus* sp. Yue-Zhen (1984) has discussed the important bee plants of China. Some of the major sources are: *Vicia* spp., *Brassica* sp., *Robinia* sp., *Tilia* sp., *Melilòtus* sp., *Fagopyrum* sp., *Gossypium* sp., *Eucalyptus* spp., *Citrus* sp., *Zizyphus* sp.

According to Shikui and Zaiji (1989), *Eurya* sp. is a very important plant in the hilly areas of southern China. Beekeepers in China have yet to harness its full potential, and a few researchers working on this plant have proved that this is a very important source of nectar and pollen for honeybees. In China more than 80 species of *Eurya* are found, and they are scattered over the vast tropical and sub-tropical hilly areas. There are about 10 species of *Eurya* that flower during autumn, winter, and spring and they are important from the beekeeping point of view. The flowering period lasts for 10 to 15 days. *Eurya* honey is transparent or light amber. It does not granulate readily. Yield of *Eurya* honey per colony varies from 10 to 40 kg. The Chinese bees, *Apis cerana*, produce three times more honey from this plant than the European bees, *Apis mellifera*. *Eurya* honey is rated highly in China.

Honeys from a few plant species belonging to the family Ericaceae are poisonous to man. Crane (1989) reported *Arbutus unedo*, a strawberry tree containing arbutin (a glucoside): *Kalmia latifolia* a mountain laurel containing acetylandromedol, *Rhododendron ponticum* and *Rhododendron anthopogon* containing andromedotoxin/acetylandromedol, as toxic agents. According to Kafle (1984) many Rhododendron honeys in the Nepal Himalaya are not toxic except *Rhododendron anthopogon* which grows above 4200 m, so honeys harvested below this altitude should be safe. However, Kerkvliet (1981) studied studied components of toxic honey from the unknown *Rhododendron* species purchased at 1500 m, 40 m east of Lukla in Nepal, and reported grayanotoxin analogues as the toxic agents.

9.3 NECTAR SECRETION STUDIES

Nectar is secreted in various plant species from specialized structures called nectaries. The nectaries of nectiferous tissues may occur in many

Table 9.3: Pollen spectrum of the honey samples of *Apis cerana* collected during different seasons in Shimla hills, Himachal Pradesh, India

Season	Colour of honey	Unifloral or multifloral	Predominant pollen type	Secondary pollen types	Important minor pollen types	Minor pollen types
Spring	Yellowish brown	Unifloral	*Brassica* sp.	*Salix* sp.	*Chenopodium* sp., Rhamnaceae, Papilionaceae, Asteraceae, Tridaceae, Rosaceae and Plantaginaceae	*Trifolium* sp.
Summer	Yellowish brown	Multifloral	—	*Trifolium* sp.	*Rumex* sp., *Fagopyrum* sp. *Plantago* sp., *Ageratum* sp., *Taraxacum* sp., Berberidaceae, Amaranthaceae, Labiateae and Asteraceae	*Helianthus* sp.
Rainy	Dark brown	Multifloral	—	*Impatiens* sp., *Fagopyrum* sp., and *Polygonum* sp.	*Trifolium* sp., *Plantago* sp., *Rumex* sp. *Taraxacum* sp., *Medicago* sp., and Asteraceae	*Helianthus* sp.
Autumn	Brown	Unifloral	*Impatiens* sp.	*Taraxacum* sp., and Plantaginaceae	*Ageratum* sp., *Taraxacum* sp., *Aster* sp. *Fagopyrum* sp., *Polygonum* sp.,	*Salvia* sp., *Chenopodium* sp. and *Tagetes* sp.

					Scrophulariaceae, Papilionaceae, Asteraceae, Polygonaceae and Capparidaceae	
Early winter	Yellowish white	Unifloral	Rosaceae	*Taraxacum* sp.	*Chenopodium* sp., Geraniaceae and Gentianaceae	*Salvia* sp.
Late winter	Yellowish white	Unifloral	Rosaceae	Brassicaceae and Chenopodiaceae		

Source: Sharma, 1989.

Table 9.4: Seasonal frequency of the pollen grains of different bee plants of Shimla hills, Himachal Pradesh (India) as identified through honey analysis (expressed as percentage of total number of pollen grains)

Plant species	Season					
	Spring	Summer	Rainy	Autumn	Early winter	Late winter
Ageratum sp.	–	8.08	–	9.56	–	–
Amaranthus sp.	–	0.94	–	–	–	–
Amaranthaceae	–	8.60	–	–	–	–
Aster sp.	–	–	–	–	–	–
Asteraceae	6.99	7.11	15.71	5.66	–	–
Berberidaceae	–	10.29	–	–	–	–
Brassica sp.	54.74	–	–	–	–	–
Brassicaceae	–	–	–	–	–	32.00
Capparidaceae	–	–	–	3.38	9.52	–
Chenopodium sp.	9.04	–	–	2.28	24.63	–
Chenopodiaceae	–	–	–	–	–	33.00
Fagopyrum sp.	–	5.34	28.87	8.76	–	–
Gentianaceae	–	–	–	–	10.52	–
Geraniaceae	–	–	–	–	–	–
Helianthus sp.	–	0.76	0.93	–	–	–
Impatiens sp.	–	–	43.03	50.15	–	–
Iridaceae	5.12	–	–	–	–	–
Lamiaceae	–	8.53	–	7.40	–	–
Leguminosae	7.53	–	–	–	–	–
Medicago sp.	–	–	5.49	–	–	–
Plantago sp.	–	8.56	13.93	–	–	–
Plantaginaceae	4.09	–	–	16.08	–	–
Polygonum sp.	–	–	20.17	6.60	–	–
Polygonaceae	14.93	–	–	4.94	–	–
Rhamnaceae						
Rosaceae	4.14	–	–	–	52.00	67.00
Rumex sp.	–	14.22	10.08	–	–	–
Salix sp.	16.50	–	–	–	–	–
Salvia sp.	–	–	–	0.51	0.98	–
Scrophulariaceae	–	–	–	8.35	–	–
Tagetus sp.	–	–	–	1.93	–	–
Taraxacum sp.	–	6.24	9.03	43.85	–	–
Trifolium sp.	2.06	32.40	10.08	–	–	–

Source: Sharma, 1989.

parts of the flowers such as receptacle, petals, sepals, and bases of filaments and pistil. The total nectar content and sugar concentration in the floral and extra floral nectaries is of prime importance to the beekeeping industry because it acts as a precursor of honey and helps in deciding the honeybee preferences in favour of a particular plant species.

Some investigators have conducted studies on the nectars of various plant species in the Asian continent. Haragsim and Machna (1969) analysed the sugars present in the nectars of Japanese sophora *(Sophora japonica)* by paper chromatography. Glucose, fructose and sucrose were present in larger amounts than melazitose and maltose and this plant nectar was placed in the SFG groups. Similar studies by Suzuki et al. (1969) on *Thea sinensis* showed that only sucrose was present in the nectar of this plant. Echigo (1970) determined the sugar contents of pumpkins and milk vetch by gas-liquid chromatography using an internal standard. Results for pumpkin nectar were: glucose (27.29%), fructose (35.47%) and sucrose (30.61%), whereas milk vetch showed 29.25 per cent glucose and 35.42 per cent fructose with mannitol as the internal standard. Nectar sugar concentration studies on *Hevea brasiliensis* revealed that it was low in the early morning (30%) and high at 1000 hours (80%). The average concentration was 75 per cent in this plant (Wongsiri et al., 1985).

Fahn (1948) investigated the daily secretion of 66 indigenous and cultivated plants of Israel. The sugar contents of these species varied from 0.13 mg to 2.48 mg per flower. A definite relationship was found between the size of the nectary and the quality of nectar secreted, but no such relationship was established with the concentration of the nectar. He also found variations in the ratios of sucrose to glucose and fructose in different plant species. Temperature, humidity, soil moisture, time of the day, age of flower and root pressure were the important factors influencing nectar secretion (Fahn, 1949). Studies by Rowley (1976) on the sugars of 40 common Philippines nectars showed that, sucrose, glucose and fructose constituted 2–95 per cent of total sugars. Maltose was also detected in two species and confirmed by infrared spectroscopy.

In China, Ye and Zhong (1981) studied the nectar secretion of a citrus trees. They divided nectar secretion into three stages: initiation, nectar accumulation at the base of the flower, and withering. Maximum nectar production was during the first three days. Murrell and Nash (1981) investigated the nectar secretion by toria *(Brassica campestris)* in Bangladesh. Maximum nectar was secreted at about 0900 hours and decreased thereafter. Later on, Murrell et al. (1982) studied the nectar secretion in eight varieties of *Lotus corniculatus*. The volume produced per umbel ranged from 2.33 μl to 5.07 μl. It was concluded that aroma and nectar production were not always closely correlated, but nectar yield was directly related to the cross-sectional area of functional phloem in the peduncle.

In India, Montgomery (1958) evaluated 38 plant species for their nectar-sugar concentration. Species showing the highest average (50% or more) were: *Polygonum, Lonicera, Aster, Helianthus annuus* and *Bidens*. Working on similar lines, Sharma (1958) determined the sugar concentration of nectars of some Punjab honey plants. Sugar concentrations of the major sources of honey were: *Brassica* sp. (45–52%), *Citrus* sp. (40–44%), *Cedrella* sp. (36%) *Berberis* (48%) peach and pear (70%) and *Tecoma grandiflora* (14%). Raya (*Brassica juncea*) had the highest average sugar concentration of 52 per cent. Sharma (1972) conducted studies on the open and closed flowers of *Datura stramonium*. In open flowers, the nectar contained 3.96% sugar, whereas, in closed flowers it was 2.36%. Satyanarayana (1975) observed that sugar concentration in nectar of *Syzygium cumini* varied from 15 to 72% whereas, in *Allium cepa*, it ranged from 67% to 75% (Mohana Rao and Lazar, 1980).

Sharma (1980) conducted studies on nectar concentration of 23 different plant species and revealed that sugar concentration varied from as low as 14 per cent in *Tecoma grandiflora* to as high as 70 per cent in peach and pear. Silver oak *(Grevillea robusta)* nectar had the highest percentage of sugar, 79 per cent. Average sugar concentration of some of the major honey plants varied from 35 to 52 per cent. Diwan and Vartak (1980) suggested that moist soil, fine sunshine, a gentle cool breeze, humid weather and wider variations in daily temperature are beneficial for good nectar secretion. Nectars with sugar concentration of 20 to 40 per cent seem to be generally preferred by bees. Dhaliwal and Bhalla (1980) correlated honeybee numbers with nectar sugar concentration.

Gupta et al. (1984b) studied the nectar sugar production in different cultivars of cauliflower *Brassica oleracea* var. *botrytis*. Among the five cultivars, selection-25 and selection-1 produced the largest amounts of sugars. The maximum amount of nectar sugar accumulation in the flowers was 0.247 mg after 24 hours of flower opening. The activity of nectar gathering by honeybee was low during morning hours, but quite high during noon and evening hours. Similarly, in peach *Prunus persica*, the amount of sugar secreted in 24 hours ranged between 0.19 and 2.38 mg. Flordasun and jewel cultivars secreted the maximum sugar among all the cultivars (Mishra et al., 1985). False acacia *(Robinia pseudoacacia)* showed a nectar sugar concentration of 53 to 75 per cent and its honey potential has been estimated to be about 500 kg per hectare (Gupta and Dogra, 1987). Wild cherry *Prunus puddum* was also evaluated for its nectar properties and honey potentials by Reddy and Gupta (1987). Nectar sugar concentration in this species varied from 12.60 to 18.10 per cent. Honey potential of *Prunus puddum* is calculated to be 34 kg per 100 trees.

Some researchers have attempted to study the hourly fluctuations in the nectar sugar concentrations of different crops. Phadke (1964) observed that sugar concentration in the nectar of *Carvia callosa* increased from morning to around 1400 hours and then remained almost constant. He proposed that these variations were due to the fluctuations in temperature patterns. Similarly in *Thelepaepale ixiocephala*, sugar concentration in the nectar increased from 35 to 40 per cent at 0800 hours, to 64 per cent at about 1500 hours, and then decreased slightly after 1600 hours (Phadke, 1965). Tanda and Goyal (1977a,b) noted fluctuation in the sugar concentration of nectar of desi cotton (*Gossypium arboreum*). Sugar concentration increased from 24 per cent at 0900 hours to 33 per cent at 1500 hours. Similar studies by Chandran et al. (1983) on cardamom revealed an increase in sugar concentration from 37 per cent at 0700 to 43 per cent at 1400 hours. He concluded that sugar concentration increased with the increase in atmospheric temperature and decrease in relative humidity.

The pollination biology of *Ipomoea kentrokaulos* indicated an increase in sugar concentration from 52 per cent at 0900 hours to 71 per cent at 1700 hours. Extra floral nectar is produced at the junction of the pedicel with the flower at the rate of 8 μl per day (Reddy and Reddi, 1982). Shakuntala Nair and Wakhle (1983) investigated the nectar secretion in rubber trees *(Hevea brasiliensis)*. Sugar concentration in the nectar was determined by a hand refractometer from 0800 to 1030 hours daily for ten days. The sugar concentration increased from 39.50 per cent at 0800 to 73.0 per cent at 1030 hours and this increase followed a increase in temperature and a decrease in relative humidity. Working on the same lines, Shakuntala Nair (1983) evaluated the importance of litchi *(Nephelium litchi)* as a nectar source and revealed that sugar concentration ranged from 61 per cent at 0630 hours to 78 per cent at 1100 hours in this plant. The quality of sugar produced by a flower in 24 hours ranged from 0.75 to 12 mg with a mean of 5.078 mg. Gupta et al. (1984a) observed the variations in the sugar concentration of nectar of *Plectranthus rugosus* from 26.5 per cent in the morning to 54 per cent in the evening hours. The average nectar load of *Apis cerana* and *Apis mellifera* was 18 μl and 27 μl respectively from this plant species. Nectar sugar studies on raya *Brassica campestris* revealed that is sugar concentration increased from 0900 hours (15.2 per cent), reached a peak at 1400 hours (40.4 per cent) and later decreased (Tanda, 1984).

Some investigators have also estimated the reducing and non-reducing sugars of different plant species by chromatographic techniques. Prasannakumari (1963) showed that nectar of coconut belonged to Suc-Fru-Glu type with the dominance of fructose and glucose. Singh and Sharma (1972) estimated the reducing and non-reducing sugars of four phenotypes of *Impatiens balsamina*. White phenotype was the most efficient sugar producer (23.10 to 27 mg/g fresh weight) followed by red (19.80 to 25.80 mg/g); pink (19.05–23.80 mg/g) and purple (16–2.72 mg/g). Paper chromatography of nectar sugars showed that *Moringa* flowers contained 0.90 per cent of reducing and 11.81 per cent of non-reducing sugars (Nair and Singh, 1974). Studies on nectar of *Pyrostegia venusta* by Gowda and Anjaneyalu (1979) indicated that it contained sucrose, fructose and glucose in the ratio of 1.5 : 1 : 1. Stored nectar contained small amounts of oligosaccharides having RF values lower than sucrose. Reddy et al. (1980) studied the floral reward and honeybee visitation rates in the soapnut tree. Pistillate flowers produced nearly three times more nectar than staminate flowers. Nectar was sucrose predominant type (85.5 per cent) and glucose and fructose 7.25 per cent each. Analysis of nectar sugars of *Carvia callosa, Thelepaepale ixiocephala, Schefflira roxburghi* and *Grevillia robusta* was done by Wakhle et al. (1981). The common sugars recorded was done by Wakhle et al. (1981). The common sugars recorded in nectars were sucrose, glucose and levulose. The nectar of *Carvia* was richest in sugars.

Biochemical studies by Sharma (1989) on the nectars of some important honey plants revealed that sugar content was 0.132 to 0.397 mg in *Plectranthus rogosus*; 0.171 to 0.298 mg in *Plectranthus gerardianus*; 0.114 to 0.277 mg in *Plectranthus coetsa*; 0.132 to 0.251 mg in *Prunus cerasoides*; 0.064 to 0.238 mg in *Adhatoda zeylanica* 0.059 to 0.199 mg in *Prinsepia utilis*; 0.059 to 0.197 mg in *Prinsepia utilis*; 0.059 to 197 mg in *Rosa moschata*; 0.062 to 0.170 mg in *Berberis lycium* and 0.085 to 0.159 mg in *Rubus laxiocarpus*. Sugar content was more in *Plectranthus* spp. and *Prunus cerasoides* than other plants studied in the present investigators. In all the species of plants, the sugar content was more during the evening hours than in the morning hours (Table 9.5).

9.4 POLLEN COLLECTING BEHAVIOUR OF *APIS CERANA*

Earlier studies on the pollen-carrying capacity of *Apis cerana* were made by Cherian et al. (1966) in South India. The mean weight of pollen pellets carried by the Indian hive bee honeybee ranged from 24 to 25.4 mg on different plant species. The pollen-carrying capacities of the plain and hill strains of *Apis cerana* were also studied by Punjabi et al. (1969) in Kashmir. He reported that the percentage of pollen load to body weight was 29 per cent, 28 per cent, and 27.8 per cent for apple, maize and mustard crops respectively. The hill strain of *Apis cerana* carried heavier pollen loads in relation to their body weight than the strains in plain areas. Bisht and Naim (1979) reported the

Table 9.5: Hourly fluctuations in sugar content (mg/flower) of some important honey sources in Shimla hills, Himachal Pradesh, India

Time in hours

Plant species	0800 (X ± S.E.)	1100 (X ± S.E.)	1500 (X ± S.E.)	1700 (X ± S.E.)
Plectranthus rugosus	0.132± 0.016	0.212± 0.015	0.265± 0.080	0.397± 0.026
Plectranthus gerardianus	0.171± 0.026	0.217± 0.014	0.263± 0.060	0.298± 0.037
Plectranthus coetsa	0.114± 0.052	0.159± 0.049	0.240± 0.035	0.277± 0.043
Prunus cerasoides	0.132± 0.016	0.203± 0.077	0.197± 0.045	0.251± 0.033
Adhatoda zeylanica	0.064± 0.002	0.092± 0.002	0.218± 0.033	0.238± 0.027
Prinsepia utilis	0.059± 0.003	0.071± 0.005	0.066± 0.003	0.199± 0.014
Rosa moschata	0.059± 0.002	0.081± 0.002	0.155± 0.052	0.197± 0.077
Berberis lycium	0.062± 0.001	0.080± 0.002	0.166± 0.040	0.170± 0.069
Rubus lasiocarpus	0.085± 0.003	0.103± 0.005	0.119± 0.006	0.159± 0.007

X ± S.E. = Mean ± standard error about mean.
Source: Sharma, 1989.

average weight of pollen collected by *Apis cerana* from mustard crops as 8 mg.

The pollen load analyses from summer Hill and Navbahar apiaries of Shimla by Sharma (1989) revealed that heavier pollen pellets were collected in March (13.72 mg); April (13.07 mg); May (14.42 mg); June (14.72 mg); September (13.29 mg); and October (12.40 mg), whereas the pollen loads collected during July (7.24 mg); August (7.34 mg); November (8.25 mg); December (7.93 mg); January (5.66 mg); and February (7.17 mg) were lighter in weight. Thus, *Apis cerana* collected heavier pollen pellets during spring, summer and autumn as compared to the rainy and winter seasons. The percentage of pollen load in relation to body weight of the bee was maximum in May, and minimum

Table 9.6: Seasonal variations in the weight of pollen loads in relation to the body weight of *Apis cerana* (workers) during different months of the year in Shimla hills, Himachal Pradesh, India

Month	Body weight of the bee (mg) Mean ± S.E.	Weight of the pollen pellet (mg) Mean ± S.E.	Percentage ratio of pollen load to the body weight
March	58.84±0.67	13.72±0.22	23.32
April	59.35±0.67	13.07±0.23	23.10
May	59.97±0.49	14.42±0.21	24.04
June	59.75±0.47	14.72±0.20	24.64
July	58.21±0.49	7.24±0.16	12.45
August	58.02±0.48	7.34±0.21	12.65
September	59.27±0.80	13.29±0.19	22.42
October	58.95±0.46	12.40±0.20	22.73
November	57.38±0.86	8.25±0.14	14.39
December	56.80±0.54	7.93±0.11	13.96
January	56.91±0.53	5.66±0.09	9.94
February	58.51±0.80	7.17±0.18	12.26

S.E. = Standard error about mean
C.V. = Coefficient of variation
Source: Sharma, 1989.

in January (Table 9.6).

This may be due to favourable weather in the summer and autumn which results in the maximum honey flow conditions due to the availability of a large number of bee plants. Verma (1987b) reported that Kashmiri strain of *Apis cerana* carried significantly heavier pollen pellets (10.46 mg) than the Himachali strain of this species (7.95 mg). Verma and Dulta (1986) observed that worker bee of *Apis mellifera* (9.24 to 12.22 mg) carried significantly heavier pollen pellets as compared to *Apis cerana* (14.62 mg) on apple crops.

Some investigators have tried to study the colour of pollen loads collected by *Apis cerana* during different seasons of the year. Phadke (1964) reported that *Apis cerana* collected pink coloured pollen pellets from *Carvia callosa*. Deodikar (1964) emphasized that the characteristic colour shade of each pollen load helped to trace its floral origin. Suryanarayana and Thakar (1966) observed yellow coloured pollen loads in the corbicula of the Indian honeybee from *Phlox drummondii*. Studies on pollen loads of *Apis cerana indica* in the Kashmir valley indicated that yellow coloured pollen pellets were mostly collected as they came from *Trifolium* sp., and *Brassica* sp., *Helianthus annuus*, *Medicago* sp., *Meliotus* sp., and *Plantago* sp. (Shah and Shah, 1976).

In Pathankot area of Punjab, Chaudhari (1978) observed mixed pollen loads during December to March. However, Jhajj and Goyal (1979) did not find mixed coloured pollen pellets for this species at Ludhiana (Punjab). Mattu (1982) observed pollen pellets of different colours such as yellow, white, red, orange, brown and green, including those of mixed type in the Shimla hills, but the yellow coloured pollen pellets were collected predominantly throughout the year by *Apis cerana*.

Bisht and Pant (1968) reported that *Apis cerana* gathered pollen pellets throughout the year under Delhi conditions. The highest pollen-gathering activity was recorded from January to March, whereas May to June were periods of lesser activity. Later he also observed the pollen-gathering activity of *Apis cerana* and *Halictus* sp. as pollinators on roses. He reported very little preference of *Apis cerana* for rose flowers as compared to *Halictus* sp. The pollen-gathering activity of these pollinators was maximum in March and April (Bisht, 1975). Later Naim and Phadke (1976) divided the annual foraging cycle of *Apis cerana*, season-wise in Pusa, Bihar. January to March was the peak period of the pollen-collection activity, whereas honey-storing activity was maximum during March and April. Reddy (1980) noted the maximum foraging activity of the Indian honeybee in July and it was minimum in January at Bangalore. Singh (1981) found that pollen was collected throughout the year by *Apis cerana* at Saharanpur in Uttar Pradesh with the maximum activity in October. However, in the Shimla hills the peak period of foraging activity was in May and June (Mattu and Verma, 1985).

Rangarajan et al. (1974) studied the foraging acativity of *Apis cerana* and *Apis florea* on *Helianthus annuus* bloom, and reported maximum activity from 0600 to 100 hours, whereas 1200 to 1430 hours was the period of limited activity. Tanda and Goyal (1979 a,b) observed peak periods of pollen collection by *Apis cerana* and *Apis mellifera* in the morning and nectar collection in the afternoon on *Gossypium* sp. at Ludhiana. Subbareddi et al. (1980) found that both *Apis cerana* and *Apis florea* collected pollen and nectar until noon, and from then onwards they collected only nectar on *Sapindus marginatus* trees.

Verma (1983) found the peak period of pollen collection of *Apis cerana* was between 0800 and 1100 hours in February to March and July to September, while nectar collection was maximum between 1200 and 1400 hours during February to April and October to November in Jeolikote in (Uttar Pradesh) Gupta et al. (1984a) studied the foraging behaviour of *Apis cerana* and *Apis mellifera* on *Plectranthus* bloom at Rampur (Himachal Pradesh). The maximum number of pollen gatherers of *Apis cerana* was seen during 0700 to 0900 hours, whereas nectar collection activity reached a peak at 1200 hours. *Apis mellifera* showed peak pollen collection activity between 0900 and 1000 hours. Mattu and Verma (1985) conducted studies on the annual foraging cycle of *Apis cerana* in the Shimla hills. Foraging data showed the following hours of peak activity during the various seasons of the year: summer (0800, 1000 and 1600 hours); rainy (0900 and 1000 hours); autumn (0900, 1000 and 1200 hours); early winter (0900 and 1400 hours); late winter (1100 hours); and spring (0800 and 1100 hours).

Regarding the seasonal fluctuations in the proportion of different categories of bees, Cherian et al. (1947) found that the number of nectar collectors of *Apis cerana* was uniformly higher as compared to the pollen gatherers, and this proportion was maintained throughout the year in Coimbatore, South India. Reddy (1980) recorded pollen plus nectar collectors in greater number than pollen or nectar collectors in Bangalore. He further reported greater seasonal variations in pollen over nectar or water collectors. Foraging studies on *Apis cerana* in the Shimla hills revealed that the percentage of nectar collectors was greater than pollen, or pollen plus nectar collectors in all the seasons of the year and greater seasonal variations were observed in the percentage of nectar collectors as compared to other categories of foraging bee (Mattu and Verma, 1985). Similarly, Verma and Dulta (1986) while studying the foraging behaviour of *Apis cerana* and *Apis mellifera* on apple bloom, found that nectar collectors outnumbered pollen collectors in both the species.

Hamakawa and Morimoto (1967) compared the foraging activity of *Apis cerana* and *Apis mellifera* from April to November, in Japan. Foraging behaviour was similar in both the species, however, the former species foraged more frequently in the spring season. Hamakawa (1968) further studied the foraging behaviour of *Apis cerana japonica* and *Apis mellifera* on the flowers of *Parthenocissus tricuspidata* and did not find any differences in their foraging preferences. Tanda and Goyal (1979 a,b) also found similarity in the foraging behaviour of *Apis cerana* and *Apis mellifera* with only slight differences. They concluded that no bee of either species collected mixed pollen on all the foraging trips on the same day. Pollen availability was maximum in the morning and decreased in the afternoon because by that time some pollen foragers of both the species changed to nectar collection, however, they resumed the collection of original pollen next morning.

Peculiar foraging behaviour of *Apis cerana* and *Apis mellifera* was studied by Chaudhari (1977) in the Kangra valley. Both species of bees collected loads of wheat flour from different places such as godowns, houses, etc., but after some time this activity was stopped and the bees resumed their foraging activity on different crops. Fungal spores were not brought in by any of the honeybee species.

It is amply clear from this review of available literature on melissopalynology and ecophysiology that the Indian subcontinent is far less explored for its honey plant potential as compared to other continents of the world. The Hindu Kush-Himalayan refrain itself is bestowed with such enormous and diversified bee flora, because of its topography, that it can compete with any other region of the world for honey potential, if exploited properly. Many regions in the Himalayan belt are even much less explored for their bee flora. The present studies are aimed at bridging this gap in the knowledge of honey plants through melissopalynology supplemented by ecophysiological investigations on selected plants of melissopalynological importance.

9.5 ECOPHYSIOLOGY OF *PLECTRANTHUS* SP.

In the temperature and sub-temperature region of the Hindu Kush-Himalaya, *Plectranthus* sp. is a predominant and excellent source of nectar for honeybees. This common shrub is found in great abundance covering large naked hilly and semi-hilly areas, and honeybees collect surplus honey from this plant.

Plectranthus (Family: Lamiaceae) commonly called "Shain" has three common species in this region:

i) *Plectranthus rugosus*
ii) *Plectranthus geradianus*
iii) *Plectranthus coetsa*

Out of these, *Plectranthus rugosus* is the most abundant species particularly in the Himachal Pradesh region of northern India. This perennial shrub grows on stony hillsides at an altitude between 900 and 2400 m above sea level, and is gregarious in nature. It blooms from mid-August to November is a source of surplus unifloral honey in autumn.

Flowers of *Plectranthus rugosus* are about 0.4 cm long in small cymes forming racemes. Its calyx is bell-shaped and the corolla tube is two-lipped. It has four stamens arranged in unequal pairs, lying along the lower lip of the corolla (Collett, 1971). Ecophysiological studies on *Plectranthus rugosus*, an important honey plant of northern India suggest that 100 per cent germination of seeds of *Plectranthus rugosus* occurred at 25, 28 and 30°C after 168, 144 and 120 hours of incubation. Mean size of the bud and flowers of this species was 0.54 mm^2 and 0.98 mm^2 respectively. Average number of healthy flowers per plant was 38 mm^2 (Table 9.7). *Plectranthus* spp. help in rebuilding the deleted strength of honeybee colonies due to the rainy season, and good colonies can yield up to 20 kg of honey per colony from this source. This species of plant is very attractive to the Asian hive bee, *Apis cerana* because the bulk of honey produced comes from this plant species (Sharma, 1989).

Table 9.7: Floral data on different phenotypic characters of *Plectranthus rugosus*

S. No.	Phenotypic character	Mean ± S.E.
1.	Number of flowers/branch	6.10 ± 0.69
2.	Number of healthy flowers/plant	88.20 ± 0.51
3.	Time for the complete opening of flowers (hours)	78.45 ± 0.18
4.	Size of buds (mm^2)	0.54 ± 0.01
5.	Size of flowers (mm^2)	0.98 ± 0.01
6.	Number of branches with flowers	9.90 ± 0.79

S.E. = Standard error about mean.

Source: Sharma, 1989.

In the Himachal Pradesh and Kashmir regions, the annual honey yield depends upon environmental factors, especially good rainfall during the monsoon season, which in turn affects nectar production by the *Plectranthus* spp. Keeping in view the importance of this honey plant as a major source of honey, Sharma (1989) studied in detail the foraging behaviour of *Apis cerana* and *Apis mellifera* on this plant species and the results are summarized as follows:

Foraging data on *Apis cerana* and *Apis mellifera* in relation to *Plectranthus rugosus* bloom showed that peak hours of foraging activity were between 0900 and 1100 hours for *Apis cerana* and between 1000 and 1200 hours for *Apis mellifera*. Fluctuations in the percentage of pollen, nectar, and pollen plus nectar collectors were observed in both the species of honeybees. Nectar collectors outnumbered pollen collectors in both *Apis cerana* and *Apis mellifera*. The mean ratio of pollen and nectar collectors was 1:2:41 for *Apis cerana* and such ratio was 1:1:51 for *Apis mellifera*. Nectar collectors of *Apis cerana* were significantly more numerous ($P<0.01$) than those of *Apis mellifera*, whereas, the number of pollen collectors was significantly smaller ($P<0.01$, $P<0.05$) for *Apis cerana* than *Apis mellifera* during different hours of the day except at 0900 hours. There was no significant difference between pollen plus nectar collectors of both species of honeybees except at 1300 hours. *Apis cerana* spent on an average 3.18 seconds, whereas, *Apis mellifera* spent 2.41 seconds on each flower per visit. *Apis cerana* (18.38) visited significantly ($P<0.01$) smaller number of flowers per minute than *Apis mellifera* (22.79), however, the Indian honeybee (2.14 seconds) took significantly more ($P<0.01$) time to shift from one flower to another as compared to the European honeybee (1.50 seconds). There was no significant difference between these two species of honeybees with regard to; distance covered from flower to flower and number of branches visited per minute. A worker bee of *Apis mellifera* (Mean weight, 11.67 to 12.82 mg) carried significantly heavier pollen loads (P<0.01) than *Apis cerana* (Mean weight, 9.85 to 10.60 mg). The duration of a foraging trip was significantly longer (P<0.01) for *Apis mellifera* as compared to *Apis cerana* (see Tables 9.8 and 9.9).

Table 9.8: Foraging data of *Apis cerana* F. and *Apis mellifera* L. on *Plectranthus* bloom during the flowering season in Shimla hills, Himachal Pradesh, India

Parameter	*Apis cerana* (A)				*Apis mellifera* (B)			
Time spent per flower per bee per visit (seconds)	3.18±0.57				2.41±0.44			
Number of flowers visited per bee per minute	18.38±0.97				22.79±0.43			
Time taken to shift from one flower to another (seconds)	2.14±0.11				1.50±0.18			
Distance covered from flower to flower (cm)	1.63±0.34				1.85±0.21			
Number of branches visited per bee per minute	1.83±0.19				2.16±0.36			
Pollen load per bee at different hours X of the day (mg) S.E.	(0900) 10.65 ± 0.34	(1100) 10.60 ± 0.28	(1300) 9.85 ± 0.26	(1500) 10.27 ± 0.29	(0900) 12.15 ± 0.37	(1100) 12.82 ± 0.29	(1300) 12.05 ± 0.39	(1500) 11.67 ± 0.37
Duration of a foraging trip (minutes)	16.63±0.34				19.88±0.39			

Mean value for forty observations taken during the period of *Plectranthus* bloom for four colonies each of *Apis cerana* F. and *Apis mellifera* L.

S.E. = Standard error about mean.

Number of flowers visited per minute, pollen load and duration of a foraging trip: B >A (P < 0.01)

Time taken to shift from flower to flower: A >B (P < 0.01)

Time spent per flower, distance covered from flower to flower, number of branches visited by both the species did not differ significantly (P > 0.05).

P < 0.01 = highly significant
P > 0.05 = non significant

Source: Sharma, 1989.

Table 9.9: Percentage of pollen nectar and pollen plus nectar collectors of *Apis cerana* and *Apis mellifera* at different hours of the day during *Plectranthus* flowering in Shimla hills, Himachal Pradesh, India

Category of bee	0900 hours		1100 hours		1300 hours		1500 hours		1700 hours	
	Apis cerana	*Apis mellifera*	*Apis cerana*	*Apis mellifera*	*Apis cerana*	*Apis mellifera*	*Apis cerana*	*Apis mellifera*	*Apis cerana*	*Apis mellifera*
Pollen collectors (P)	40.00	39.00	29.50	42.50	22.50	35.50	21.00	33.50	21.50	26.50
Nectar collectors (N)	57.00	47.50	67.00	49.00	69.00	59.50	67.50	60.50	62.50	50.00
Pollen plus nectar collectors (PN)	3.00	5.50	3.50	2.50	6.00	1.50	5.50	3.00	9.00	8.00
Ratio of pollen collector and (P:N) nectar collector	1:1.43	1:1.22	1:2.27	1:1.5	1:3.07	1:1.68	1:3.21	1:1.81	1:2.91	1:1.89

Mean values for forty observations taken during the period of *Plectranthus* bloom for four colonies each of *Apis cerana* and *Apis mellifera*.
At 0900, 1100, 1300, 1500, 1700 hours, N > P for *Apis cerana* and *Apis mellifera* ($P < 0.01$)
At 1100, 1300, 1500 hours, (P) of *Apis mellifera* > (P) of *Apis cerana* ($P < 0.01$)
At 1700 hours, (P) of *Apis mellifera* > (P) of *Apis cerana* ($P < 0.05$)
At 0900, 1100, 1300, 1500, 1700 hours, (N) of *Apis cerana* > (N) of *Apis mellifera* ($P < 0.01$)
At 1300 hours, (PN) of *Apis cerana* > (PN) of *Apis mellifera* ($P < 0.01$)

Note: Other bees (1 to 5%) may be water collectors at different hours of the day.
$P < 0.01$ = highly significant
$P < 0.05$ = significant.

Source: Sharma, 1989.

9.6 LINKAGES OF BEEKEEPING TO SOCIAL FORESTRY

In many countries of the Hindu Kush-Himalaya, the concept of social forestry is at present being strongly advocated. This programme involves plantation of multipurpose tree species on private, marginal and submarginal lands which cannot support agriculture, and which will thus meet the fuel, fodder and manure requirements of rural populations. Social forestry programmes will not only help in generating income and employment for the rural poor but will also help to conserve natural resources and especially prevent over exploitation of forest resources.

One of the prerequisite for the development of beekeeping in the Hindu Kush- Himalaya is the expansion of bee forage areas so that nectar and pollen yielding resources are available throughout the year. Such expansion by planting exclusively good honey yielding plants may not always prove economical to farmers. The list of honey plants as shown in Table 9.1, however, clearly shows that there are certain plant species which, besides acting as good sources of pollen and nectar, have also other economic uses to the farmers. Such multipurpose plant species provide close linkages between beekeeping and social forestry.

In the Hindu Kush-Himalaya, the beekeeping industry is still mainly forest-based and more than 80 per cent of the honey produced in many countries comes from wild bee colonies through traditional honey-hunting methods. However, the present declining trend in total forest areas in the Hindu Kush- Himalaya is also posing a serious threat to the beekeeping industry because now sufficient flora is not available and as a result of this, population of wild species of honeybees is declining at an alarming rate and some of them are on the verge of extinction. In such a rapidly deteriorating situation, the only solution to save the beekeeping industry is to combine beekeeping with the social forestry programme by bringing more and more areas under plantation of such plants, which, besides their other economic uses, will also help in harvesting surplus honey.

As a matter of fact, both the beekeeping and social forestry programmes are complementary to each other. By including pollen and nectar yielding plants into social forestry programmes, it is possible to increase the total bee colony carrying capacity of an area which will enhance the total production of hive products such as honey, beeswax and royal jelly. These hive products are the sources of food and cash income to farmers living at or below subsistance levels and thus diversify the rural economy and broaden the food base.

Epilogue

The present book is one in ICIMOD senior fellowship series in which the status, scope and strategies for beekeeping (apiculture) development in south and southeast Asia in general, and the Hindu Kush-Himalaya countries in particular, have been reviewed. In the first five chapters in this book, the major concern is the importance of apiculture in providing food, nutritional economic and ecological security to rural people. In the last four chapters, the present status of the science and technology of beekeeping in this region, has been reviewed. The main conclusions and recommendations derived from each of these chapters are as follows:

MOUNTAIN PERSPECTIVE AND APICULTURE

Mountain areas due to their specific environmental and resource characteristic have comparative advantages in specific activities. Efforts, should therefore, be diverted to activities/options that fit in very well with mountain characteristics and also negate the side effects of processes and factors contributing to unsustainable situations in the mountains. Apiculture (beekeeping) possesses attributes that can satisfy these requirements. For example, inaccessibility as a major mountain characteristic, plays a less constraining role in apiculture because hive products are characterized by low weight, high value, non-perishability, high storage capacity and easy transportation. Beekeeping offers options for communities in the economically marginal category because it is a low investment activity (unless operated on a commercial scale). In addition, it is flexible enough to match any scale of operations or any category of manpower (children, women and old people) and hive products are in demand both locally and in foreign markets. It is, therefore, ideally suited for small farmers living at or below the subsistence level. Apiculture being a non-land based activity, does not compete with other resources demanding components of farming systems. At micro-level, apiculture is an additional income-generating activity and at macro-level, investment may be quite high but there is greater use of the temporal and spatial diversity of mountain resources that otherwise go unutilized. The pollination activities of honeybees are an important integration function, as they contributes to the sustainability and diversity of agriculture and botanical resources in general, and thereby contribute to increased productivity and environmental health.

Although, opportunities for apiculture occur in the mountain regions of all continents and at latitudes ranging from 0°, at the equator, to latitudes as high as 50°N and 30°S, still there are special difficulties in promoting and developing apiculture in many developing countries of Asia in general, and in many parts of the Hindu Kush-Himalayan region in particular. Constraints such as high altitude, severe climate, native bee genetic resources and bee forage do not limit apicultural development programmes in the region. Certain constraints such as poverty, remoteness, lack of education, and, in some regions, lack of apicultural traditions to some extent, come in the way of the development and promotion of beekeeping. Problems such as deforestation, soil erosion and degradation of watersheds are other factors responsible for the loss of natural habitats of honeybees and decline in honey plant resources.

In our attempts to alleviate poverty by using beekeeping as life-support system, we should concentrate our attention on aligning our proposals according to the background of the people we are trying to help. In areas where the educational level is higher and transport is easier, beekeepers can learn to work at a higher technological level and obtain good income from apiculture. But in poorer areas, we must promote types of apiculture, and of hives, that can conform to the general way of life of the people.

INTEGRATED RURAL DEVELOPMENT AND APICULTURE

In the overall context of human resource development in the Hindu Kush-Himalayan region, efforts must be made to raise the economic and social status of the neglected and underprivileged rural communities and integrate them into social and economic life of the whole rural population. In this task, small farmer's projects such as beekeeping can play an important role. Beekeeping has great self-help potentials as it offers varied possibilities, several advantages and great promises to a developing economy. Even rough estimates show that modern beekeeping can contribute millions of dollars through the sale of hive products and pollination services. For example, amongst the Hindu Kush-Himalayan countries, China is the second largest producer and the biggest exporter of honey in the world. In India, where major thrust in apiculture is on pollination of entomophilous crops by honeybees, more than 150 million bee hives are needed for the purpose. Similarly, initiative efforts are being made in other countries of this region to develop beekeeping industry on modern scientific lines.

Besides poverty, malnutrition among the underprivileged children and lowered workings capacity of the adult population offers serious constraints within the overall context of human resource development in the Hindu Kush-Himalayan region. In order to alleviate such nutritional problems, greater emphasis should be laid on food diversity through the production of supplementary foods. The different natural hive products such as honey, pollen, royal jelly not only broaden the food base of poor rural communities but also help in solving the problem of Protein-Energy Malnutrition (PEM) caused by an overall shortage of calories and proteins in the diet. These hive products along with beeswax, propolis and bee venom have also been used for centuries all over the world for medicinal and pharmacological purposes. Extensive research on the chemical and biological properties of different hive products in recent years has shown that these contain elements found in food and pharmaceutical products. Thus beekeeping technology which is low in investment, appropriate in scale and operations, safe and affordable, provides both food and nutritional security to the rural communities.

Yet another dimension of the beekeeping enterprise is the role it can play in the development of rural women and children because the work is not heavy, allows time flexibility, provides gainful employment close to home and financial independence to housewives. A few successful women entrepreneurs engaged in modern beekeeping in this region provide a good example for others to follow.

MOUNTAIN CROP PRODUCTIVITY AND APICULTURE

The vital role that honeybees play in enhancing the productivity levels of mountain crops such as temperate fruits, vegetable, oils, fodder and spice seeds has often been underestimated in the Hindu Kush-Himalayan region. On the contrary, bee pollination researchers carried out in western countries reveal that the main significance of honeybees and beekeeping is in cross-pollination, whereas hive products such as honey and beeswax are of secondary value. Many cultivated crops do not yield seeds or fruits without the cross-pollination of their flowers by honeybees or other insect pollinators. Other agronomic practices like manuring, fertilizers, biocides and irrigation are quite cost-effective and these may not yield the desired results without the use of honeybees for enhancing the productivity levels of different cultivated crops through pollination. It is not only self-sterile varieties/cultivars which require cross-pollination but also the self-fertile forms, which would also produce more and better quality seeds and fruits if pollinated by honeybees and other insects.

Himachal Pradesh in northern India is the only region which has taken a lead by adopting a planned bee pollination programme as the case of the essential inputs for improving the quality and yield of temperate fruit crops, particularly apples. However, in other temperate areas, it has not been adopted as an integral part of mountain crop production technology, despite the fact that all these hilly areas have rich traditions of beekeeping. The main reasons for this are ignorance and lack of technical know-how on the part of agricultural extension agencies and farmers. A small practical manual on the role of honeybees and other insect pollinators in modern farm management technology should be published in order to educate extension workers and farmers.

There is over-reliance in the developing countries of this region on the use of chemical methods for the control of pests and diseases of agricultural and horticultural crops. Farmers use blanket applications due to their lack of knowledge as to what to use and when. As a result of this, several beneficial pollinating insects are threatened with extinction by the excessive use of biocides. There is also lack of legislation to prohibit the use of pesticides in ways that kill bees. Keeping in view these constraints, protection and fostering of beneficial insects, particularly, honeybees in the Hindu Kush-Himalayan region, should be an integral part of every pest control programme. Necessary legislation should be introduced to regulate the use of biocides and methods of integrated pest management should be adopted.

STATUS AND ECONOMICS OF APICULTURE

Economic analyses carried out in the Hindu Kush-Himalayan countries reveal that beekeeping can be taken up both at the household and commercial level to generate additional income and employment. Beekeeping with native *Apis cerana*, required only low cost technology and even the poorest person can engage in this with very little support. On a commercial scale, beekeeping with exotic *Apis mellifera* does require higher investments, but there is wide margin of profit.

At present, there are no standard methods available for economic studies on apiculture. Economic studies carried out so far are based on data from pilot projects and personal experiences of bee specialists rather than by economists. The level of profits at the farm level may not be that high, as indicated in these studies. Also, in such studies, indirect benefits of honeybees as pollinators of cultivated and wild plant species have not been quantified. Thus there is a need for systematic studies of the economic and profitability of beekeeping for different target groups of the mountain areas of the Hindu Kush-Himalayan region. Such studies will help in determining the potential beekeeping areas and potential value of apicultural development for the mountain people.

TRADITIONAL AND MODERN APICULTURE

Apiculture is being carried out in the mountain regions of the Hindu Kush-Himalaya at all technological levels. In many of these regions, honey hunting has given way to traditional beekeeping with fixed comb hives and in some of them traditional apiculture has been wholly or partly replaced by the use of top-bar hives with movable combs or, more commonly of movable framehives. Honey collection from the wild nests of *Apis dorsata/laboriosa* is a very ancient art (about 12,000 years old) and still a common practice in the Hindu Kush-Himalayan region. Such honey hunting methods involve killing the entire brood as well large number of adult bees. As a result of this practice, and also due to mass deforestation, these wild species of honeybees face the danger of extinction with serious ecological consequences. In such areas, efforts should be made to introduce modern hive beekeeping as a substitute.

Different types of indigenous bee hives evolved under different beekeeping traditions show remarkable similarities in shape and designs throughout the Hindu Kush-Himalayan region. These traditional bee hives (hollowed logs and wall recesses and boxes of various dimensions, and designs) in use even today, reflect the remnants of the ancient bee knowledge and replica of honey collection techniques being practised by mountain farmers through centuries. However, use of these traditional hives has several disadvantages both to the beekeepers and honey consumers in terms of different bee management practices and quality control of different hive products. This has necessitated the need for the introduction of modern hive beekeeping which has its origin possibly in India among the Hindu Kush-Himalayan countries. As a result of continuous efforts for the last three decades, Indian Standard Institution (ISI) have laid down the design and specifications of Type A (Newton type) and Type B (Joelikote village type) hives for beekeeping with *Apis cerana*. These hive standards developed in India are now being used with modifications in other countries of the Hindu Kush-Himalaya, such as, Afghanistan, Bangladesh, Bhutan, Burma, Nepal and Pakistan. Similarly, the "national standard" bee hive for beekeeping with *Apis cerana* has been developed in China also.

HIVE PRODUCTS

All ancient literatures of the Hindu Kush-Himalayan countries give details of honey as man's first food and first available sweet. Honey produced in China is up to international standards in quality, consistency and packing. Chinese honey also meets the standards of foreign food laws, and the pricing policy is consistent and competitive. In recent years, India has also laid down specifications for quality control of honey in terms of physio-chemical properties. However, in other countries of the Hindu Kush-Himalaya, there is hardly any policy being adopted for the scientific processing and marketing of honey which can easily earn hard currency. There is a need to recognize centrifugally extracted honey as distinct from the honey collected by traditional squeezing methods. The former should be used as "table or medicine honey" and squeezed honey only for industrial purposes with a separate pricing policy for each of these two types. In this region publicity through different media is also needed to popularize this nutritious food among the different categories of consumers. Since developed countries are potential markets, for honey export, all producing countries should follow the examples of China for its quality control. National honey boards and honey cooperatives should be established to look after all aspects of honey handling from hive to market with the strategy that storage and transport time is reduced to an absolute minimum. With the introduction of the European honeybee *Apis mellifera*, in some countries of the Hindu Kush-Himalayan region, honey production is likely to increase tremendously and processing and marketing problems are likely to become more serious as is happening now in northern India. Time is now ripe that different Governments take up these problems so that the beekeeping industry in this region can develop in a scientific and planned way.

Beeswax is another hive product widely used for several commercial purposes. In the Hindu Kush-Himalayan region, beeswax production from *Apis dorsata / laboriosa* colonies offers great untapped potentials and technologies for harnessing these should be developed. Except in China, only insignificant quantities of beeswax are collected, processed and marketed in other countries of this region. This is due mainly to ignorance, lack of marketing information and adulteration with other artificial ingredients, and requires immediate attention to boost its production.

China has taken the lead in Asia in the production and marketing of other hive products such as royal jelly, pollen, propolis and venom. These hive products have multipurpose uses and are good sources of earning foreign exchange. Keeping this in view, initiative efforts are being made in other Hindu Kush-Himalayan countries to exploit these commercially.

HONEYBEE RESOURCES

The Hindu Kush-Himalayan region is rich in bee resources. There are at present four or more species of honeybees in this region. Among these, the Asian hive bee, *Apis cerana*, is equivalent of the European hive bee, *Apis mellifera* because both can be domesticated and can build parallel combs. *Apis cerana* has many valuable characteristics of biological and economic importance. These include docile and industrious nature, less prone to attacks of wasps and high level of resistance to nosema disease and parasitic Asian mites (*Varroa jacobsoni* and *Tropilaelaps clarae* that plague *Apis mellifera*. *Apis cerana* can co-exist with other native bee species and requires least chemical treatment of colonies to control epidemics. However, this native bee species has not yet become very popular among beekeepers because of its several behaviour characteristics. These include frequent swarming and absconding, proneness to robbing, production of large number of laying workers and lower honey yields. These negative traits of *Apis cerana* vary from apiary to apiary depending upon the bee race and management efficiency.

There is a current movement in Asia to import allopatric *Apis mellifera* for commercial exploitation. Such introductions in northern India, the Northwest Frontier of Pakistan, parts of China, Japan and Thailand is now the basis of a flourishing beekeeping industries. The exotic bee species produces three times more honey than the native *Apis cerana* and is more suited to modern bee management technology. However, many importations of the exotic *Apis mellifera* have proved disastrous because of its allopatric nature, the introduction of new diseases and parasitic mites. There is now apprehension that importation of *Apis mellifera* would lead to the decline of *Apis cerana* population in its native habitat to a level that threatens its extinction as a genetic resource. *Apis cerana* has already become a rare species in Japan and parts of China. Before this happens in the Hindu Kush-Himalayan region, a conservation strategy through the development and promotion of beekeeping with this native bee species needs to be adopted to help maintain its genetic diversity. Such strategies first require the exploration and evaluation of different sub-species/geographic ecotypes of this native bee species and then improvement of the best of them through selective breeding, appropriate apiary management practises and biotechnological research.

The genetic diversity of *Apis mellifera* has been organized into 24 sub-species having varied economic usefulness. So far only three sub-species of *Apis cerana* are recognized, although there may be several more because of the wide range of its geographic distribution. The northern and high altitude sub species/ecotypes of *Apis cerana* is likely to yield valuable honeybee germplasm which may have commercial applications not only throughout Asia, but also in the western hemisphere where beekeeping with *Apis mellifera* is threatened with parasitic Asian bee mites and spread of aggressive Africanized bees.

In south and southeast Asia, there are some countries where the exotic *Apis mellifera* has not yet been introduced and attempts are being made to improve beekeeping with native *Apis cerana* through technical and financial assistance from different national, bilateral and international donor agencies. Unfortunately, such efforts have not yielded *satisfactory* results. One of the obvious reasons for the failures for these projects has been the transfer and unsuccessful application of the western bee management technology and expertise to improve beekeeping with *Apis cerana* in this region. This native bee species certainly requires different beekeeping management-practices and equipment because of its smaller body size, nest building behaviour, colony cycle, temperature regulatory mechanisms, foraging, colony defense and other behavioural characteristics. Some attempts have been made in India and China to improve the traditional methods of beekeeping with *Apis cerana* and in some parts of these countries *Apis cerana* matches *Apis mellifera* in honey production.

HONEY PLANT RESOURCES

The Hindu Kush-Himalayan region has very rich and diverse bee flora such as agricultural crops, temperate zone fruits, vegetable crops, grasses, bushes, shrubs, forests and avenue trees. However knowledge about the diversity of the native bee flora of this region is not yet comprehensive. Furthermore, there is continuous decline in bee floral resources in this region due to the degradation of forests and grassland ecosystems as well as changes in agricultural practices. This warrants greater attention on the part of the concerned national and international agencies involved in environmental management programmes. In order to improve the situations, honey plants should also be included wherever planting programmes are initiated with the threefold objectives of increasing surplus honey production, meet slack season needs during the dearth periods and to increase carrying capacity of a particular areas in terms of the number of bee hives it can sustain. Some efforts made in the past in this direction have yielded satisfactory results. For example, roadside plantations in Pakistan, the social-forestry programme in northwest India, and the community forestry plantation in Nepal, included several multipurpose plant species which included bee forage plants also. As a result of this, beekeeping has flourished in these areas. For commercial beekeeping, it may not be possible to have enough bee flora available at one particular locality, so beekeepers are migrating their colonies from one place to another in order to exploit these floral resources fully throughout the year and harvest additional honey crops. The best examples of such migratory beekeeping practices in the Hindu Kush-Himalaya are in the North West Frontier Province of Pakistan, Himachal Pradesh and the Kashmir region of northern India.

There are still large number of indigenous plant species in the Hindu Kush-Himalayan region, which have potential from the beekeeping point of view and these have not been fully tapped. So, instead of encouraging the introduction of exotic plant species for bee forage, which involve risks of one kind or another, emphasis should be laid on the preparation of detailed floral calendars, based on local flora, for each potential beekeeping area.

APICULTURAL TRAINING AND RESEARCH

The ecological resources of the Hindu Kush-Himalayan region offer great potential for the development of beekeeping. Due to ideal climatic conditions and diversity of bee and floral resources, this region can become a land of honey, provided there is adequate original planning on the part of policy makers as well as continuing commitment to the programmes. However, beekeeping in many countries of this region is still an old traditional household activity where native hive bee generally is kept in different traditional hives, honey is harvested by squeezing the whole comb and sold in pre-used utensils without any quality control standards. Although, beekeeping with *Apis cerana* has been closely linked with the cultural heritage of the mountain communities of this region, it has not developed on scientific lines as it has on a commercial scale with European honeybee, *Apis mellifera* is several advanced countries of the west. In the mountain parts of India (Kashmir and Himachal Pradesh) and China, modern methods of beekeeping have been adopted and basic infrastructural and technical knowhow also exists. However, in other countries of the Hindu Kush-Himalaya, beekeeping development programmes are still facing teething problems. Several countries in this region do not possess basic infrastructure, skilled manpower, extension and training facilities, or basic and applied research programmes for the advancement of apiculture. At present, scattered efforts being made for the promotion of the industry, particularly with the Asiatic species of honeybees, by different national and international agencies, have not yielded the desired results.

In order to fill these gaps, a coordinated effort is required. For this an International Centre for Apicultural Research and Training should be established in the region with the following mandate and objectives.

1) The overall objectives of this centre should be to generate and deliver improved beekeeping management technology through research and training on the Asiatic species of honeybees that would contribute to increased production and quality of different hive products as well as better bee pollination services—principally to the regional needs of south and southeast Asian countries—thereby providing cash income and nutritious food to the rural poor communities living at or below subsistence level.

2) To assist different Government agencies, beekeeping organizations and commercial enterprises to create a cadre of beekeeping experts by training them in both practical and scientific aspects of beekeeping.

3) To provide information and advisory services and also to act as a coordinating centre for international cooperation in beekeeping.

4) To assist different developing countries of this region to establish a national programme in beekeeping.

International Centre for Integrated Mountain Development (ICIMOD) located in Kathmandu, Nepal is possibly the most suitable platform to start initiating efforts to establish the proposed centre for apiculture. It should act as the coordinating agency and provide general liaison between different countries of the region, between aid agencies and Governments and thus help in the original planning of this centre.

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I. GENERAL

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II. SCIENTIFIC NAMES OF SPECIES

Professor L.R. Verma is presently a senior professional staff member at ICIMOD. Earlier, he was Dean and Head of the Bio-sciences Department in Himachal Pradesh University, Shimla, and Scientific Advisor in Apiculture to the Government of Himachal Pradesh, India. He obtained his Ph.D degree in 1972 from the University of Guelph, Canada and was also Alexander von Humboldt Research Fellow in J.W. Goethe University, Frankfurt, West Germany, from 1976-1978. In India, he has been principal investigator and coordinator of several research projects in the area of apiculture, pollination ecology, insect-pests of mountain crops and Himalayan eco-development. Prof. Verma has published more than 100 research papers in scientific journals of international repute and is on the editorial board of different research journals.

Currently, Prof. Verma is the chair-person of APIMONDIA International Commission on Asiatic Honeybee, *Apis cerana* and a member of APIMONDIA Commission on Bee Biology. His initiative efforts, has lead to the foundation of the Asian Apicultural Association. He has been actively involved as a consultant/advisor in several international beekeeping development programmes in different countries of Asia.

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O Bhutan	O Burma	O Bangladesh	O Afghanistan

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