Asian Bees and Beekeeping

Progress of Research and Development

Editors
M. MATSUKA • L.R. VERMA
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UMA PARTAP

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Proceedings of Fourth Asian Apicultural Association International Conference, Kathmandu, March 23–28, 1998

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Foreword

The Asian continent is the richest in the world in honeybee species diversity. A number of species e.g. *Apis cerana, A. dorsata, A. florea* and *A. laboriosa* are indigenous to the region. In addition, *A. mellifera* has been introduced to the region and is being widely used for honey production. Recently more species of *Apis* have been identified in Asia, but firm confirmation of these is yet to be obtained. Beekeeping with the Asiatic hive bee, *Apis cerana* has been a tradition and a part of cultural heritage of people in Asia in general, and in mountain areas of the Hindu Kush-Himalayan (HKH) region, in particular. It is an important food and income generation activity for small and marginal farmers, the landless and weaker sections of society living at or below subsistence level. Beekeeping plays an equally important role in rural mountain development as pollinator of agricultural and horticultural crops. With integrated beekeeping efforts, there is a great potential for increasing crop productivity, and conserving forest and grassland ecosystems, thereby maintaining biological diversity.

Bee scientists in different institutions in Asia and the HKH region are making efforts to innovate new methods of beekeeping research and development. However, these efforts are being done on individual institution level and therefore, a need to have a common platform to share this scientific knowledge and information was felt. Asian Apicultural Association (AAA) created by some scientists of the Asian continent provides such a common platform to share knowledge and information on Asian bees and beekeeping. AAA is an organization networking scientists and development workers interested in Asian bees and beekeeping. AAA makes efforts to encourage research on biology and management of different honeybee species found in Asia. Thus, the main objective of AAA is to promote the exchange of scientific and general information relating to honeybee sciences and apiculture in Asia, and to encourage and assist international cooperation in the study of problems of common interest. In order to provide a platform to share knowledge and information, AAA had been organizing a conference every two years since 1992 when the first founding general meeting was held in Bangkok, Thailand.

AAA and ICIMOD jointly organised Fourth AAA International Conference in Kathmandu during March 23-28, 1998. Over 150 people including scientists, researchers, development workers, beekeepers, and donors from over 24 countries of Asia, Europe, and Australia attended this Conference. Two Workshops – one on Bee Diseases and Pests and another on Beekeeping Extension in Remote Mountain Areas – were also organised before the Conference. The former Workshop had been intended by the APIMONDIA Standing Commission on Bee Pathology, and co-organised with AAA and ICIMOD. This publication is an outcome of the knowledge and information shared during this Conference and the Workshops.

This book presents an overview of bees and beekeeping R&D in Asia and highlights the issues related to conservation and management of the Asian hive bee, *Apis cerana*. New frontiers of bee biology research covering diverse topics such as evaluation and selection of *Apis cerana* populations, and effect of synthetic queen pheromone on behaviour and honey production of *Apis cerana* and *Apis mellifera*. Recent findings in bee diseases and pest control and innovations in apiary management are explained. A section on production, processing, properties, and marketing of different bee products - honey, beeswax, royal jelly, and propolis has been provided. In addition, new advances in crop pollination research through beekeeping and experiences in extension covering topics ranging from beekeeping needs and extension methodology in hills and mountain areas to the role of various research and development institutions in promoting sustainable beekeeping are given in detail.

We sincerely acknowledge the financial support provided by Austroprojekt for the Conference and publication of the Proceedings.

We appreciate the efforts of AAA members in their headquarters at Japan, particularly Dr. Jun Nakamura and Mrs. Hitomi Enomoto who were the key driving force in organising the Conference. Similarly, in ICIMOD, several people particularly Beekeeping Programme staff worked hard to make the Conference a success. Finally, we would like to express our appreciation for the efforts of the editors in compiling hundreds of papers presented during the Conference and bringing out the proceedings in the present form.

Finally, we do believe that this publication will be of use to scientists, development workers, students, beekeepers, NGOs, planners as well as donors committed towards the cause of Asian bees and beekeeping.

Egbert Pelinck
Director General, ICIMOD
May 26, 1999

Mitsuo Matsuka
President, AAA
May 26, 1999

Preface

Asia is home to a number of honeybee species, the most common being *Apis cerana, Apis florea, Apis dorsata,* and *Apis laboriosa.* These species are native to the region whereas *Apis mellifera* has been introduced to increase honey production and is becoming popular among commercial beekeepers. In addition to these, a number of other species of *Apis* have been identified, confirmation of most of which has not been made so far. Beekeeping is an important food and income generating activity in countries of Asia. Asian Apicultural Association (AAA) devotes itself to address the issues related to Asian beekeeping organises Conference every two years to discuss the progress in beekeeping research and development in Asia. International Centre for Integrated Mountain Development (ICIMOD) is devoted to integrated mountain development to help promote an economically and environmentally sound mountain ecosystem and poverty alleviation in the Hindu Kush-Himalayan region is running a programme on promotion and development of beekeeping through indigenous *Apis cerana* for the past eight years.

In an effort to share knowledge and information, AAA and ICIMOD jointly organised Workshops on bee diseases and beekeeping extension and Fourth AAA International Conference in Kathmandu during March 23-28, 1998. The present book is an outcome of the papers presented in the Conference and Workshops. The book contains seventy-two chapters grouped into seven parts.

Part One has one major Chapter, which presents an overview of issues and initiatives in Asian Bees and Beekeeping. It describes the genetic diversity of *Apis cerana* in the Hindu Kush-Himalayan region particularly India and China, and at the same time highlights the issue of declining populations of the species in the region. The authors advocate the need to conserve *Apis cerana* and suggest strategies for conservation of this indigenous bee species. Country reports explaining the status of beekeeping in Bangladesh, Japan, India, South Korea, and Thailand are also included. Efforts of ICIMOD in promoting conservation of *Apis cerana* through developing and promoting beekeeping with this indigenous bee species in the Hindu Kush-Himalayan region are also highlighted. Excerpts from the Welcome Addresses by Director General of ICIMOD and President of AAA and the Chief Guest's Address have been adjusted within boxes. Resolutions passed during the Workshops and the Conference are also presented within boxes. The authors also emphasise the need of establishing a Regional *Apis cerana* Research and Training Centre for future development of beekeeping with *Apis cerana* in South and Southeast Asian region.

Part Two consists of eleven chapters explaining new frontiers of bee biology research. It covers diverse topics such as evaluation and selection of *Apis cerana* populations, differences in body colour expression between Asian and European bee species, and effect of synthetic queen pheromone on behaviour and honey production of *Apis cerana* and *Apis mellifera.* Migration of *Apis dorsata* in northern Thailand have been discussed in Chapter 9 and first ever report of occurrence of *Apis florea* in Saudi Arabia has been given in Chapter 10. In addition, findings on ecobiology of wild bee species, *Apis florea* and *Apis dorsata* in semi-arid and subtropical climates have been reported in Chapter 11 and 12 respectively.

Part Three reports recent findings in bee diseases and pest control. This part contains twelve chapters. Chapters 13-18 were presented and discussed during Workshop on Bee Diseases and Pests. Among these Chapters 13-15 are on Thai Sac Brood Virus disease and chapters 16-18 are on *Varroa* mites. There are three more papers on *Varroa*, other mites, and parasites (Chapter 19-21). There is an interesting paper (Chapter 24) on accelerated degradation of a commonly used highly toxic pesticide carbaryl by acclimated bacteria found in *Apis cerana* bees.

Part Four reports innovations in apiary management to maintain an apiary of healthy bee colonies and increase honey production and crop pollination through beekeeping. This part contains eleven chapters (Chapters 25-35) and explains innovative methods (sugar-feeding and liquid protein diets etc.) and techniques (beehives and other equipment) of managing different species and races of bees for enhanced production. Of specific interest is a paper by Dr. K. Amano (Chapter 28). Dr. Amano explains how non-stinging *Apis mellifera* bees can be induced using gamma radiation. Many people are still scared of being stung by the bees. Producing non-stinging *Apis mellifera* would bring revolution in using this bee for honey production and crop pollination. Research findings of different scientists on different types of beehives both traditional and improved, and performance of bees in them in different parts of Asia has been presented in four chapters 32 to 35.

Part Five reports the production, processing, properties, and marketing of different bee products such as honey, beeswax, royal jelly, and propolis through seven chapters (Chapters 36-42). A very interesting piece of research, the role of honey produced by different bee species in Ayurvedic medicines, has been discussed in Chapter 39. Part six reports new advances in crop pollination research through beekeeping. It contains seventeen chapters (Chapters 43-59) explaining how to manage bees for crop pollination, pollination strategies to enhance fruit set in apples, research on the use of bees in pollination of fruit, vegetable and oilseed crops in hilly and mountain areas. This section also includes research results explaining comparative effectiveness of *Apis cerana* and *Apis mellifera* in pollinating different crops. In addition, comparative attractiveness to bees of different crops blossoming simultaneously in the same area and its impact on their pollination has been given in Chapter 54. Another paper on foraging competition between *Apis cerana* and *Apis mellifera* and its impact on crop pollination has been presented in chapter 55. Findings of these two studies are very important in planning / managing pollination of different crops blooming at the same time using beekeeping. Chapter 56 explains the importance of managing agroforestry to enhance crop pollination and promote beekeeping in an area. In addition, a new computer based method to identify bee flora has also been given in chapter 58.

Part seven presents experiences in beekeeping extension. There are thirteen chapters (Chapters 60-72) in this section. Chapters range from beekeeping needs and extension methodology in hills and mountain areas to the role of various research and development institutions in promoting sustainable beekeeping. In addition this sections provides information on traditional beekeeping methods and indigenous knowledge of beekeeping and potential of beekeeping as a self-employment opportunity for women in hilly and mountain areas.

As pre-Conference exercise two Workshops were organised - one on Bee Diseases and Pests and another on Beekeeping Extension in Remote Mountain areas. However, there were two full-fledged Sessions on these topics in the Conference also. So we found it confusing to present papers on the same subject under separate sections for Workshop and Conference Sessions. Therefore, the Workshops papers have been included in the relevant Parts to avoid unnecessary confusion to the readers. Six papers including three papers on Thai Sac Brood Virus Disease and three on *Varroa* mites were presented in Workshop on Bees Diseases and Pests. These papers are included as Chapters 13 to 18 under Part 3 on Recent Findings in Bee Diseases and Pest Control. In Beekeeping Extension

Workshop, only one paper was presented by Dr. Naomi M. Saville, which is included as Chapter 61 under Part 7 on Experiences in Beekeeping Extension.

Some of the authors submitted only abstracts and some of the papers were very small (abstracts) of half a page length. We therefore, decided to put such papers as box with relevant papers. These papers are fully acknowledged with authors' affiliation etc. in the boxes as well as in the Contents page.

As is true with every publication, it comes into shape because of the co-operation, support, and encouragement of several individuals. Editors have done their part and their names are there, but at this stage we shall like to thank and record appreciation of 'behind the scene' remarkable efforts of few key people. We sincerely appreciate the efforts of Mrs. Hitomi Enomoto and Dr. Jun Nakamura of Asian Apicultural Association in Honeybee Science Research Centre, Japan who helped compiling the papers. Mrs Enomoto was also a vital link between AAA and ICIMOD.

It would not have been possible for AAA to bring out this publication without the support and personal efforts of Mr. Egbert Pelinck, Director General of ICIMOD. Since ICIMOD took the responsibility to publish it, he was the driving force behind pushing the whole process of publication and offering generous financial support and staff time. Similarly, Dr. Tej Partap, Head, Mountain Farming Systems Division, ICIMOD supervised the whole process of publication. He deserves special appreciation in putting the present publication in shape by providing his constructive comments in reorganising and reshaping the contents of the publication. Not only that, he also played a key role in negotiating with the publisher - Oxford and IBH, New Delhi.

Likewise, we appreciate co-operation of authors to share their research findings and observe time schedules. Lastly, ICIMOD as an institution deserves much appreciation and thanks from members of AAA for being an excellent host and for co-operation in publishing this Volume. We also appreciate interest shown by Oxford and IBH, New Delhi in publishing the proceedings.

May, 1999 Editors

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Overview of Asian Bees and Beekeeping

Chapter 1

Asian Bees and Beekeeping: Issues and Initiatives

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Beekeeping is an important component of agriculture and rural development programmes in many Asian countries. The role of beekeeping in providing nutritional, economic and ecological security to rural communities of Asia cannot be overlooked as it has always been linked with their cultural and natural heritage. At the household level, beekeeping is an additional income-generating activity. This, being a non-land-based activity, does not compete with other resource-demanding components of farming systems. In the crop fields, pollination activities of honeybees are important, as they contribute to the increased productivity.

Honeybee Diversity in Asia

The asian region is the richest in the world in honeybee species diversity. At least five different species of honeybee are found. Among these, *Apis dorsata, Apis florea, Apis laboriosa* and *Apis cerana* are native. *Apis mellifera* has been introduced for commercial beekeeping. *Apis florea, Apis dorsata* and *Apis laboriosa* are wild in nature and cannot be kept in the hives. *Apis cerana* and *Apis mellifera* are only honeybee species that can be kept in the hives for honey production and crop pollination.

The Asian Honeybee, *Apis cerana*

Genetic diversity

Based on the morphometric characteristics and mitochondrial DNA analysis, three subspecies of *Apis cerana* have been identified in the Himalayan region. These included *A. cerana cerana, A. cerana himalaya* and *A. cerana indica* (Verma, 1992; ICIMOD, 1994). Similarly, five subspecies of *A. cerana* including *A. cerana cerana, A. cerana skorikovi, A. cerana abaensis, A. cerana hainanensis* and *A. cerana indica* representing different eco-geographic zones have been identified in Chinese Himalayas (Zhen-Ming *et al.*, 1992). These subspecies also have further locally adapted populations 'the ecotypes' that differ from each other in several biological and economic characters. For example, there are three ecotypes of the subspecies *A. cerana himalaya* that correspond to geographic distribution in the Naga and Mizo hills, the Brahmaputra valley and Khasi hills, and the foothills of the northeast Himalayas (Singh *et al.*, 1990). In China subspecies *A. cerana cerana* has five ecotypes namely Guangdong-Guanxi type, Hunan-Hubei type, Yunnan type, North China type and Changbaishan type (Zhen-Ming *et al.*, 1992). In some parts of the Hindu Kush-Himalayas, *A.*

cerana cerana matches the European hive bee, *A. mellifera*, in honey production and has potentials for further genetic improvement.

The diversity at risk

Beekeeping with *Apis cerana* is a common practice among rural communities in Asia. Traditionally, the farmers have been keeping this species in log-, wall-, pitcher-, and box hives. This bee has a gentle temperament, is industrious, has qualities of cleanliness and can be handled easily. However, this is not popular among commercial beekeepers because of its low honey yield and undesirable behavioural traits such as excessive swarming and absconding and producing large number of laying workers. Therefore, the European honeybee, *Apis mellifera* has been imported to the region and has become popular among commercial beekeepers. It maintains prolific queens, has less swarming and absconding tendencies and produces more honey and beeswax.

As a result of promotion of beekeeping with *Apis mellifera*, populations of *Apis cerana* are declining rapidly threatening its extinction in the Himalayan region. The process of extinction has already started and the species is endangered in the hilly areas of Afghanistan, Bhutan, Bangladesh, China, Myanmar, Nepal, Pakistan and to some extent from India (Crane; 1992,Verma 1993; ICIMOD 1994). In western Indian Himalayas where there is a centuries-old tradition of beekeeping with *A. cerana* government institutions are busy replacing their *A. cerana* stocks with *A. mellifera*. In the Kashmir region of the northwest Himalayas where *A. cerana* matches *A. mellifera* in body size and honey production only a few per cent of *A. cerana* colonies are left. Thus the long-established craft of beekeeping with *A. cerana* is being destroyed in the entire Hindu Kush-Himalayan region. Similarly, in Japan, beekeeping with *A. cerana* has been completely replaced by *A. mellifera*, and only a few beekeepers and research institutions are raising *A. cerana* colonies (Sakai, 1992). In China, among over 8.5 million colonies of honeybees only 30 per cent are *A. cerana* (Zhen-Ming *et al.*, 1992). In South Korea, only 16 per cent of beekeeping is with *A. cerana*; the remaining has been replaced by *A. mellifera* (Choi, 1984).

Studies carried out by ICIMOD have shown that in HKH region at present there are only few areas where *Apis cerana* can be found. These include the mountain areas of Nepal and India and Yunnan Province of China (ICIMOD 1994; Bangyu and Tan 1996). In Pakistan, where *Apis mellifera* was promoted much more vigorously, the last strains of *Apis cerana* survive with a few villagers in the Kalash valley of Chitral. It is being realised that if this process of replacement of *Apis cerana* with *Apis mellifera* continues for another decade, it may lead to complete extinction of the Himalayan bee.

In the Himalayan region, Nepal was the biggest gene pool of *Apis cerana* until 1990. There was a ban on the importation of *Apis mellifera*, and beekeeping with this native bee flourished well throughout the country. This ban was lifted in 1990 and *Apis mellifera* was imported in large scale. Within this decade it replaced the native *Apis cerana* in the plains and up to mid-hills. *Apis cerana* now remains with mountain farmers of remote areas like Jumla, Humla and Jajarkote. *Apis mellifera* has not arrived in these areas due to inaccessibility, and also that the farmers find it difficult to apply winter management practices such as keeping the colonies warm, feeding sugar, and migrating to low hill areas. The decline in the populations of *Apis cerana* from Himalayan region will have bad consequences for biodiversity and agricultural productivity.

Factors contributing to declining diversity

In seeking ways to conserve genetic diversity of *A. cerana*, it is necessary to have a clear understanding of the major threats that this species is facing in its native habitat. Main factors contributing to decline in *Apis cerana* populations include environmental perturbations such as loss of habitat quantity and quality, introduction of more productive European honeybee, *Apis mellifera*; pathogens and diseases especially Thai sac brood virus (TSBV) and European foulbrood (EFB) infections; human predation like traditional honey hunting, and pesticide hazards; behaviour like frequent swarming, absconding and robbing; and production of a large number of laying workers.

The need to conserve *Apis cerana*

One may argue that when there is a more productive bee like *Apis mellifera*, why should we save a less productive bee? The following discussion might provide the answer to this. First, *Apis mellifera* is more suitable for commercial beekeeping. However, beekeeping in many areas of the HKH region is a small household activity providing some income and nutrition to the poor mountain people for which *Apis cerana* is much more suitable. Second, *Apis mellifera* may produce more honey than *Apis cerana* during honey flow season, but needs much more sugar feeding during dearth period which the poor farmers do not afford. Moreover, the race of *Apis mellifera* imported to Asia is highly cold susceptible. It is generally migrated from mountains to warmer areas during winter. As a result, pollination of early blooming mountain crops is adversely affected. If not migrated to warmer areas it requires a lot of winter management. But the high mountain races of *Apis cerana* are cold resistant and suitable for stationary beekeeping. These match *Apis mellifera* in behaviour, honey production and maintenance of prolific queens. Another very important argument in favour of *Apis cerana* is that this bee is less prone to attack of wasps and is resistant to the common mites like *Varroa jacobsonii* and *Tropilaelaps clarae*. Bee diseases like *Nosema* which are serious threat to beekeeping with *Apis mellifera* do not affect *Apis cerana*. Moreover, *Apis cerana* in the mountain areas of the region has comparative advantage over *Apis mellifera* in crop pollination. It is an excellent pollinator of mountain crops which bloom during early spring season such as almond, apple, pear, plum and different vegetable seed crops.

Value of Conserving Honeybee Diversity

The natural products that honeybees produce are honey, royal jelly, pollen, propolis, beeswax and bee venom. These materials have been widely used as nutritional food and for medicinal and pharmacological purposes since ancient times. These products have both consumptive and productive value because they can be consumed by family or these can be commercially harvested for exchange in formal markets throughout the world. However, besides these direct resources, honeybees provide non-consumptive benefits of conserving botanical resources that may far outweight direct values when they are computed. These social insects deal with primary functions of the ecosystem that involve reproduction including pollination, gene flow and cross-fertilisation, and maintenance of biodiversity, environmental forces and species that influence the acquisition of useful genetic traits in economic species and maintenance of evolutionary processes. These non-consumptive benefits can be harnessed to the maximum extent through the use of native bee species such as *A. cerana* rather than with the exotic *A. mellifera*.

Strategies for conserving *A. cerana*

Stock improvement

Many subspecies of *A. cerana* are at present not economically viable. However, preliminary research carried out on honey production potential of different populations of *Apis cerana* have found that there are three sub-species of *A. cerana* in the Indian and Nepal Himalayas. These include *A. cerana cerana, A. cerana himalaya and A. cerana indica* (Verma 1990a; 1992; ICIMOD 1994). Similarly, China has five sub-species, i.e., *A. cerana cerana, A. cerana skorikovi, A. cerana abaensis, A. cerana hainanensis* and *A. cerana indica* (Zhen-Ming *et al.*, 1992). Among these sub-species, the bees of *A. cerana cerana* found in the high altitudes areas of Jumla (Nepal), Himachal Pradesh and Kashmir (India), and northern China are larger in size, more productive and comparable to *A. mellifera* in terms of honey production and other behavioural characteristics (Zhen-Ming *et al.*, 1992; ICIMOD 1994; Partap and Verma 1997).

Research efforts are now needed to multiply the colonies of this highly productive subspecies, i.e., *A. cerana cerana* through selection, breeding, and mass queen rearing. Selection and breeding programmes of this superior genotype are required to produce a bee suitable for intensive management. To achieve stock improvement, colonies of *A. cerana cerana* should be accumulated at a central location and research to identify superior genotypes conducted. Another important prerequisite for stock improvement is to evolve an efficient queen-rearing technique for *A. cerana* and also establish isolated mating stations for pure-line breeding. The latter is essential because artificial insemination in *A. cerana* has unexpectedly turned out to be a difficult task because of the low volume of semen ejaculated by drones (Verma, 1990b).

Research on apiary management

During the course of evolution, *A. cerana* has developed certain behavioural characteristics such as frequent absconding and swarming that are essential for survival of colonies but undesirable from a beekeeping point-of-view. Lack of sufficient bee flora, excessive handling, exposure of colonies to summer sunshine and incidence of sacbrood virus diseases have been identified as major causes of absconding. Management practices such as sugar-feeding, provision of shade and providing a queen gate at the hive entrance significantly reduce absconding. One of the most effective ways of reducing frequent swarming is to follow a selection programme against this undesirable trait. The removal of newly constructed queen cells during the active swarming season also helps check swarming considerably. Currently, recurrence of sacbrood virus epidemics after an earlier cycle during 1982–86 has threatened beekeeping with *A. cerana* throughout its range. Some colonies are still resistant to this disease and in the absence of any effective chemical control, vigorous selection needs to be followed (Verma, 1992).

Research on disease management

Thai sac brood virus disease is at present one of the most serious constraints in beekeeping with *A. cerana*. The identification of the causal organism of the disease has been reconfirmed. Control measures such as the administration of antibiotics, antiviral chemotherapy developed by the Chinese Institute of Apicultural Science, provision of brood frames for diseased colonies, introduction of new queens, mechanical removal of affected brood, strengthening of affected colonies by uniting them have been tried by several workers. The conclusions drawn are;

- The disease starts appearing in colonies in spring when honey-flow season begins.
- Usually weak colonies are more susceptible than stronger colonies.
- About two to three generations of brood in affected colonies suffer the worst attack but later all affected colonies start recovering
- The best way to check the disease is to keep colonies strong by uniting the adult bees of weak ones and discarding affected brood.
- In severely affected colonies, sterilisation of hive and combs with formalin also reduces the incidence of disease.

Research on crop pollination

Apis cerana shows distinct advantages for pollination of agricultural crops. These include longer foraging hours, earlier initiation of foraging activity, short flight range, low cost of colony management during dearth periods, no foraging competition with other native bee species and non-*Apis* pollinators, and co-evolution with native crops, etc. (ICIMOD, 1994). Keeping this in view, promotion of beekeeping with *A. cerana* appears to be essential for enhancing the productivity of farming systems. Unfortunately, in the developing countries of south and southeast Asia, the role of bees and beekeeping for enhancing the productivity of agricultural crops has often been underestimated. The development of agriculture in the twenty-first century will therefore necessitate reorientation of present crop production technologies. Along with making use of physical inputs like fertilisers and irrigation managing cross-pollination through honeybees will also become essential for maintaining productivity. Thus, there is a need to create awareness amongst policy makers, planners and aid agencies about promoting bees and beekeeping as an important component of present-day strategies for sustainable agriculture in Asia (Verma, 1990a).

Zonation of beekeeping areas

In those countries of south and southeast Asia where *A. mellifera* has already been introduced, the beekeeping industry is facing a dilemma. In order to resolve this, zonation of beekeeping areas for *A. cerana* and *A. mellifera* appears to be a logical solution. Based on the past several years' experience, it is now well documented that for subtropical regions *A. mellifera* especially the *ligustica* race is well suited. In temperate regions, beekeeping with *A. cerana* is better suited. It is so because subspecies/ecotypes of this native bee are more prolific and its genotypes are superior to its counterparts in subtropical regions. Such zonation of *A. cerana* and *A. mellifera* into eco-geographic zones has been especially successful in China. India is following the same strategy. This would go a long way in solving the problem of interspecies competition, and both species could be complimentary.

Asian Apicultural Association 'AAA'

The Asian Apicultural Association (AAA), established by scientists from the Asian region, provides a common platform to exchange knowledge and information. AAA is an organization that networks with scientists and development workers interested in Asian bees and beekeeping. Although, so far, the AAA is not a big organization, it encourages research on the biology and management of honeybee species found in Asia. The main objective of AAA is to promote the exchange of scientific and general information relating to honeybee sciences and apiculture in Asia and to encourage international co-operation in the study of problems of common interest.

—Excerpts from Welcome Address delivered by AAA President, Prof. M. Matsuka during Fourth AAA Conference, Kathmandu, 25th March 1998

Status of Beekeeping in Asia

In recent years, great strides in modernising beekeeping with native and exotic honeybee species are being made in the eco-geographic zones of the Asian region. China, at present, is the major producer and exporter of honey and other hive products in the world. Similarly, India has taken the lead in south and Southeast Asia in utilising honeybees for pollination purposes to boost yield and improve quality. In other countries of the region, efforts are being made to develop beekeeping along modern scientific lines. However, constraints such as lack of basic infrastructure, skilled manpower, training, extension, and facilities for basic and applied research mean that the situation is far from satisfactory despite ideal climatic conditions and availability of diverse floral resources throughout the year. Described below is the current information on the status of beekeeping in some of the Asian countries provided by Asian Apicultural Association (AAA) Chapter delegates in their Countries.

Bangladesh (N. Islam, Bangladesh Institute of Apiculture, Mohammadpur, Dhaka)

Three species of honeybee including *Apis cerana, A. dorsata, A. florea* and one species of stingless bee, *Trigona iridipennis* are indigenous to Bangladesh. Among these, *A. cerana indica* is easy to handle, and can produce 2–3 kg of honey every 10–15 days during spring honey-flow season. This productivity has tremendous potential for apiculture development for Bangladesh. Bangladesh Institute of Apiculture (BIA) has been established to promote beekeeping for integrated rural development. The main objective of the Institute is to introduce beekeeping to the rural poor in order for them to

> **Beekeeping Promotion in Nepal**
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> Beekeeping is a traditional household activity of our Nepalese farmers throughout the mountain areas. Both beekeeping and honey have fascinated our people throughout the ages, and at the same time given income and supplied nutrition to the rural poor, marginal farmers and the landless. Beekeeping is a part of the socio-cultural heritage of the Nepalese people. Beekeeping plays an important role in helping the rural poor not only through beehive products for their additional income generation but also increasing the production of their crops, fruits and vegetables through cross-pollination which is also vital from our food security point-of-view. Nepal is rich in bee flora and has many indigenous bee species, both wild and domesticated. While these are in need of conservation and promotion, traditional beekeeping also needs to be improved and modernized. His Majesty's Government of Nepal also attaches great importance to beekeeping and has placed it in a priority sector. The Agriculture Prospective Plan, adopted by His Majesty's Government, stresses developing this sector further over the years. There are two national beekeeping institutions with several working units all over the country. There are many more private institutions and apiaries throughout the country. These are all engaged in various fields of beekeeping such as training, production and marketing.
>
> *—Excerpts from Address by Chief Guest, Dr. Prakash Chandra Lohani, Minister of Agriculture, HMG, Nepal, Fourth AAA Conference, Kathmandu, 25th March 1998*

earn an additional income, and to promote bee pollination of agricultural and horticultural crops. Organizing Bangladesh Beekeepers' Association (BKA) is the ultimate goal of BIA.

India (V.K. Mattu, Department of Biosciences, HP University, Shimla, Himachal Pradesh)

Approximately 236,000 beekeepers keep 678,000 colonies of *Apis cerana* and *A. mellifera* in India. Exotic *A. mellifera* was introduced in the mid-1960s in the northern India but it spread to southern India only recently. Migratory beekeeping is also practised in some parts. Estimated production of honey from *A. cerana* is 6500 t, *A. mellifera* is 2700 t and from *A. dorsata* the estimates are of 18,000 t. Total value of this honey is estimated about six million US dollars. Average yield of honey in India is 8–10 kg/colony for *A. cerana*, 10–15 kg/colony for *A. mellifera*, 10–25 kg/colony for *A. dorsata* and 0.5–2 kg/colony for *A. florea*. There is a vast difference in the price of raw and processed honey. Raw honey costs about US$ 0.6–1.2 per kg and processed US$ 1.4–3.6 per kg. No substantial production of pollen and other products is reported. India enjoys tremendous ecological diversity. A variety of honey plants exists in different agro-climatic zones but most promising are *Brassica, Robinia, Syzygium, Nephelium, Plectranthus, Helianthus, Eucalyptus, Dalbergia, Butea, Carvia, Citrus, Grewia, Hevea, Toona, Trifolium, Terminalia* spp., etc. Acarine, nosema and Thai Sac Brood Virus are the most important diseases. Thai Sac Brood Virus, which killed almost 80 per cent of *A. cerana* colonies in the 1980s, is still prevalent in some parts of the country. Wax moths, mites, wasps and birds also pose problems. Other constraints are frequent swarming, absconding, robbing; mating and foraging competition between native and exotic bee species; pesticide poisoning; and invasion of pests and pathogens. Beekeeping research is being conducted by universities and institutes in Himachal Pradesh, Pune, Haryana, Bangalore, Kerala, Tamil Nadu, Uttar Pradesh, Punjab, and Jammu and Kashmir. The state departments of agriculture and horticulture look after extension work and provide training to farmers and entrepreneurs. However, the most important training centre is Central Bee Research and Training Institute (CBRTI), Pune. Many projects are underway in universities and institutes. Major one is the 'All-India Co-ordinated Project on Honeybee Research and Training' at Hisar. Locally organized development projects have been funded by CARE-India, SIDA, Oxfam, YMCA, Action Aid and others. Many books on Indian beekeeping and related subjects are published. Among Indian journals, the most important is the English quarterly *'Indian Bee Journal'* published by the All-India Beekeepers' Association, Pune.

Japan (T. Yoshida, Honeybee Science Research Centre, Tamagawa University, Machida-Shi, Tokyo)

There are 6261 beekeepers keeping 199,846 *Apis mellifera* colonies (registered in January 1996). About 102,465 colonies are being used for pollination in glasshouses (mainly for strawberries) and 31,187 outside. *Apis cerana* is kept by hobby beekeepers without registration. National production of honey is 3,138 t. Approximately 41,592 t of honey is imported, and 108 t exported. Production of beeswax is 48.8 t. Royal jelly production is 5.8 t; 398 t are imported. Pollen production is 4 t. Recently propolis has become popular health food and is imported from Brazil and China. Prices of bee products vary as follows: domestic honey 1500–2500 yen per kg depending on nectar source; imported honey 500–1250 yen per kg; and royal jelly approx. 10,000 yen per 100 g. The most popular honey source is Chinese milk vetch (*Astragalus sinicus*) but its cultivation has decreased to 168 km^2; orange is 840 km^2 and apple is 337 km^2. Wild *Robinia pseudoacacia* is also popular. *Varroa* mites and giant hornets are the main pests. American Foul Brood (and European Foul Brood) is a legally designated disease. About 0.5 % of colonies are incinerated every year. Recently, *Bombus terrestris* (approx. 40,000 colonies) has been introduced from abroad for pollination of tomatoes in glasshouses. Honeybee Science Research Center (HSRC) at Tamagawa University, Tokyo acts as an office for Asian Apicultural Association, and as IBRA branch library for eastern Asia. There is also the Japan Beekeeping Association (JBKA). Several Japanese books on beekeeping and related subjects, and *Honeybee Science* (quarterly journal) are published by HSRC, Tamagawa University.

South Korea (K.S. Woo, Department of Agriculture Biology, College of Agriculture and Life Sciences, Seoul National University, Suwon)

According to 1996–1997 reports, there are approximately 39,678 beekeepers keeping 719,224 bee colonies. These include 399,764 colonies of *Apis mellifera* and 319,460 of *Apis cerana*. Korea produces approximately 8,299 t of honey, 255 t pollen, 31 t royal jelly, 46 t beeswax and 19 t propolis. The prices of bee products in Korea are as follows: honey approximately US$ 5.7 per kg, pollen US$ 16.2 per kg, royal jelly US$ 26.7 per kg, beeswax US$ 2.0 per kg, and propolis US$ 33.3 per kg. *Comus officinalis, Brassica napus, Buxus microphylla, Malus pumila, Castanea crenata, Robina pseudoacacia, Styrax japonicus, Allium fistulosum, Tilia amurensis, Laeocarpus sylvestris, Sesamum indicum,* and *Rhus chinensis* constitute important bee flora of the country. In addition to producing honey and other bee products, honeybees, *Apis mellifera* and *A. cerana* play important role as pollinators for strawberry and Chinese melon in glasshouses. Bumble bees are also being used for tomatoes. Apicultural organisations include Apicultural Society of Korea, which publishes a biannual Korean Journal of Apiculture since 1985 and organizes annual conferences. Korean Beekeeping Association (KBA) organised Apiexpo 1997 in Inchon. KBA publishes monthly Newsletter and organizes meetings. Another organisation is Institute of Korean Beekeeping Sciences (IKBS) in Seoul National University, which organizes extension education courses for beekeepers. It published *Advanced Beekeeping Management* (in Korean) in 1997. IKBS also organises regional education programme in different provinces. Endemic bee diseases in Korea include American Foul Brood, chalk brood, and nosema, and mites *Varroa jacobsoni, V. underwoodi* and *Tropilaelaps clareae*.

Thailand (S. Boongrid, Department of Agricultural Technology, Ramkhamhaeng University, Bangkok)

Thailand has many species of tropical bees (both *Apis* and non-*Apis*) including the honeybee, *Apis mellifera*. The population of indigenous bees has decreased due to deforestation and use of pesticides. Two hundred and ten beekeepers keep approx. 120,000 colonies of *A. mellifera* for

Asian Apicultural Association
Recommendations for Regional Action on Extension Activities

- Assist in the development of beekeepers' associations
- Be a facilitator for networking amongst beekeeping farmers, entrepreneurs and NGOs
- Publish a directory of all organizations involved in beekeeping development
- Publish and spread information as to the advantages of *A. cerana* bees.
- Define policy inputs to promote beekeeping with indigenous honeybees

—Recommendations made during a special workshop held during Fourth AAA Conference on Beekeeping Extension in Mountain Areas in Kathmandu, 24th March 1998

Promoting Beekeeping in Mountain Areas for Improving Livelihoods

Beekeeping is considered an important component of integrated rural development; one that can contribute to poverty alleviation and environmental conservation. Linking agriculture, including beekeeping, with enterprise development is a major challenge for two of ICIMOD's thematic Divisions: Mountain Farming Systems, and Mountain Enterprises and Infrastructure. Beekeeping for pollination is of great importance to mountain farming systems; it may not be of direct interest to individual farmers but is essential for overall rural development. As such, genetic conservation of different bee species and varieties for enterprise development and income generation in mountain development is important. Honey and other hive products are of high value, low volume and low perishability. These are major considerations when promoting crops and products in mountain areas that often suffer from inaccessibility to goods, services and markets.

—Excerpts from Welcome Address delivered by Director General of ICIMOD, Mr. E. Pelinck on the Inauguration of Beekeeping Workshops in Kathmandu on 23rd March 1998

honey, royal jelly and pollen production; wax is a by-product. 2000–3000 t of longan honey are produced each year: 60 per cent is exported to Taiwan and the rest is sold in the domestic market. About 1000 t of lychee, sesame, kapok, sunflower, bitter weed and wild flower honey is also produced annually and sold in local markets. 50 t of royal jelly is produced annually from 100 apiaries, about 12,167 kg was exported to Japan in 1994 and 8865 kg in 1995. The rest is sold in domestic markets and to other countries in the form of fresh royal jelly, encapsuled royal jelly, or freeze-dried royal jelly. About 80 t of bee pollen are harvested each year, and exported to Taiwan and Japan or used for domestic consumption. Some is kept for feeding to bees. 80 t of beeswax is collected annually and used for making wax foundation and candles, and for industrial purposes. *Tropilaelaps clareae* and *Varroa jacobsoni* are the main pests. Wasps, *Vespa* spp., attack *A. mellifera* during June–October. There has been an outbreak of chalk brood disease. There are no control measures against the major honeybee pests. Beekeeping activities are mainly carried out by universities including Ramkhamhaeng University and Chulalongkorn University, and Ministry of Agriculture. Ramkhamhaeng University activities include a proposal for a project entitled 'Conservation of insect pollinators for sustainable agriculture along with the use of the European honeybee for pollination of tropical fruit crops in orchards'. The aims are to reduce pesticide application rates, to augment local insect pollinators, and to further understand the pollination process for each crop. Chulalongkorn University activities include projects for academic research. Department of Agriculture and Department of Agricultural Extension of Ministry of Agriculture are helping to solve problems of beekeeping, and doing research on bees. Besides, many other organizations also have activities on bees and beekeeping. There is no Thai beekeeping journal. Beekeeping researchers usually send their papers to agricultural magazines and/or journals. There are many Thai books on beekeeping.

Conserving *Apis cerana* in the Hindu Kush-Himalayan Region: An ICIMOD Effort

Beekeeping should not be considered in the context of individual country only. In fact, issues relating to the problems and potentials become rather clear when thinking about beekeeping in a regional context. At present, the biggest issue is the conservation of native *Apis cerana* and the debate about introduction and promotion of *Apis mellifera* for beekeeping in the HKH region. *Apis mellifera* is being introduced to the region and promoted vigorously for commercial beekeeping. As a result of this introduction populations of native *Apis cerana* are declining and the species is becoming extinct in its native habitat. Therefore, there is need to make efforts to check the importation of *Apis mellifera* at least in those areas of the HKH region where potential subspecies of *Apis cerana* exist and can be promoted for beekeeping. ICIMOD has been for the past eight years implementing a programme to conserve native *Apis cerana* in the HKH region. Besides promoting beekeeping with this bee in mountain areas, it is trying to convince government and non-government organizations to support beekeeping with *Apis cerana*. One strategy that ICIMOD is adopting for the conservation of *Apis cerana* is based on its potential and efficiency as pollinator of early blooming mountain crops, which essentially require cross pollination.

Changing mind-set about beekeeping

The traditional way of thinking is that beekeeping is done for honey production. The idea of using bees for crop pollination is relatively recent and has received less attention in the Hindu Kush-Himalayan region. Importation of *Apis mellifera* has been done under similar initiative. However, the recent trend of diversification of mountain agriculture from traditional cereal crops to high value cash crops, fruits and vegetables, require insects for cross pollination, since most commercial varieties of these crops are essentially cross-pollinated.

Conservation and Development of *Apis cerana* in the Himalayan Region: An ICIMOD Programme

Within ICIMOD's overall mandate of poverty alleviation and environmental conservation in the Hindu Kush-Himalayan region, documentation and sharing of information are our prime activities. The Hindu Kush-Himalayan region is well known for its ecological, biological and cultural diversity, which are also reflected in the number of bee species and varieties as well as the different management practices adopted by rural households for harvesting honey and other beehive products. While the traditional management practices were very appropriate for the subsistence economies that prevailed in this region until quite recently, the transition towards a monetary economy poses new challenges for beekeeping with respect to both opportunities and problems. The opportunity to derive income from marketing honey and beehive products responds very well to the rightful aspirations of rural households to improve their livelihoods. The challenge before you is how to contribute your knowledge to increasing productivity, in particular by combating diseases, and improving the quality of honey and other beehive products as well as their marketing, without losing sight of the sometimes lesser known and more intangible values of beekeeping such as pollination and conservation of genetic diversity. It was these challenges and concerns that motivated ICIMOD five years ago to begin a programme addressing issues related to the most mountain-specific of all bee species in the world, *Apis cerana*, the Asian honeybee.

—Excerpts from the Welcome Address delivered by Director General, ICIMOD, Mr. E. Pelinck, Fourth AAA Conference, Kathmandu, 25th March 1998

Within the Hindu Kush-Himalayan region there are already reports of declining fruit crop yield and crop failures due to lack of adequate pollinators in intensive cash crop farming areas (Partap and Partap 1997). Moreover, many crops e.g. almond, apple, cherry, pear and plum, and various seed vegetables bloom during early spring season when natural insect pollinators are not available for the pollination of these crops due to various reasons (Partap and Partap 1997). Therefore, need for insect pollinators, especially honeybees has increased in the recent years.

Asian Apicultural Association: Resolution

AAA puts on record the valuable financial and logistical support provided by the Federal Chancellery of Austria and ICIMOD in organizing the Fourth Conference in Kathmandu, Nepal. Considering that beekeeping is an important, income-generating, eco-friendly activity and that honeybees play an important role in boosting the productivity of mountain crops and conserving biodiversity through pollination, beekeeping R & D programmes fit well in ICIMOD's mandate and assigned functions. AAA, therefore, resolves to encourage ICIMOD to continue its research, training and extension programme at the regional level.

Conclusions and recommendations

- Throughout Asia, great strides are being made in modernising beekeeping with indigenous and exotic honeybee species in different eco-geographic zones. However, constraints such as lack of basic infrastructure, skilled human resources, research, and training and extension facilities mean that the beekeeping industry in Asia still requires considerable support. Therefore, AAA resolves that for further development of beekeeping in Asia, co-ordinated and systematic efforts be made to establish Asian Bee Research and Training Centre in the region. Such a Centre should have a continuing internationally funded programme in beekeeping training and research.
- Sustainable development of agriculture in the twenty-first century will need to integrate pollination activities of honeybees as they contribute to the sustainability and increased productivity of different farming systems. However, in developing countries of Asia, the role of bees in crop pollination is underestimated. *Apis cerana* shows distinct advantages over *A. mellifera* for pollination of agricultural crops. AAA, therefore, resolves that policy makers, planners and aid agencies be sensitised to promote beekeeping with *A. cerana* as an important component of strategies for sustainable agriculture and rural development.
- *Apis cerana* is a vital component of our natural ecosystem. However, natural populations are suffering precipitous decline and the species is threatened with extinction. Keeping this in view, conservation is essential for the maintenance of biodiversity. AAA resolves that international organizations encourage projects to conserve this genetic resource by promoting *A. cerana* beekeeping. AAA further resolves that the activities and programmes of the new '*Apis cerana* Conservation and Promotion Working Group' be strengthened.
- In some parts of the Hindu Kush-Himalayan region, productive subspecies and geographic ecotypes of *A. cerana* with commercial potential similar to *A. mellifera* have been identified. AAA resolves that further research work on *A. cerana* genetic diversity, selection and testing based on economic and biological characters be continued under similar environmental conditions on a regional basis.
- Beekeeping extension is a process by which skills and knowledge are exchanged. There is a need for greater understanding of how best to carry out this process. Therefore, AAA resolves an extension network be formed and time and facilities to deal with this growing and important area provided.
- *Tropilaelaps clareae, Varroa jacobsoni* and Thai Sac Brood Virus Disease pose serious threats to bees in Asia. Therefore, AAA resolves that basic and applied research under the ecological conditions of each member country be carried out and a special workshop be held on bee pathology during the next AAA Conference in Thailand.
- The Beekeeping Project in ICIMOD has made significant progress on various aspects of beekeeping with *Apis cerana*. This includes the comparative advantage of *A. cerana* as a pollinator, bee botany and melissopalynology, genetic diversity research, appropriate technologies such as the straw hive, Jumla top-bar hive and farmer-participatory extension in beekeeping. AAA, therefore, resolves that these significant findings be tested and disseminated widely.
- AAA recommends to member countries that policies on fair marketing of bee products are formulated and implemented to the benefit of farmers and users.

—Resolution Passed during Fourth International Conference, Kathmandu, 25–28th March 1998

Farmers are, however, trying to manage the pollination of their cash crops through different ways. For example, in Himachal Pradesh, in the Northwest Indian Himalayas, honeybees are being used for apple pollination. There are very few private pollination entrepreneurs who rent

Asian Apicultural Association
Recommendations on Bee Diseases Research

- Major constraints on all forms of beekeeping in subtropical and tropical Asia are diseases or endemic mites, pests and predators. These reduce the economic potential of beekeeping and its role in pollination.
- Notable problem of *Varroa jacobsoni* is one reason but equally serious is the problem of another mite, *Tropilaelaps clareae*
- It is not easy to control mite pests in *A. mellifera* bees since chemical methods are limited in effect. It requires a mixture of management, biotechnical and chemical control. Control programmes should be integrated instead of focused on parasite management only.
- It should be noted that mites cannot be eradicated as they are endemic in Asia and will re-infest treated colonies.
- Applied research needs to be expanded to the following fields: biotechnical and 'soft-chemical' control; *A. cerana* resistance to disease; and selection for 'resistant' *A. mellifera* bees.
- Thai Sac Brood Virus Disease (TSBVD) is an epidemic disease of *Apis cerana* not only in the Hindu Kush-Himalayan region, but also in other parts of Asia. As a consequence, the number of *A. cerana* beekeepers and colonies have been gradually declining making *A. cerana* vulnerable to extinction in Asia. Measures to reverse the trend are necessary.
- Relieve stress to colonies by feeding pollen and honey is an effective way to control Thai Sac Brood Virus disease.
- Other recommended measures include; removing all combs infested by TSBVD, requeening from healthy colonies, caging queens, ventilating hives, removing old and unoccupied combs, keeping colonies strong and healthy, and sterilisation of hives, equipment and combs.
- Bee flora and management are key factors for prevention of TSBVD in *A. cerana* colonies.
- Genetic studies on TSBVD have to be carried out because TSBVD appears for 2–3 generations.
- Migration of bees colonies from poor habitats to rich habitats to exploit new floral resources.
- Devise a simple and easy method to identify TSBVD in the field.
- Research on selective breeding of TSBVD-resistant *A. cerana*.

—Recommendations made during a special Workshop held during Fourth AAA International Conference on Bee Diseases and Pests Control in Kathmandu, 24th March 1998

bees for pollination. In Maoxian county in Aba Prefecture of Sichuan province in China honeybees are available for pollination but the apple farmers are doing mechanical pollination (hand pollination). This explains the need to promote ways that place more emphasis on the use of honeybees in the pollination of mountain crops.

Promoting *Apis cerana* for pollination

Studies on comparative effectiveness of *Apis cerana* and *Apis mellifera* in pollinating different crops have shown that *Apis cerana* is a better pollinator of crops flowering during spring season than *Apis mellifera* (Verma and Partap 1993; Partap and Verma 1994; Partap and Partap 1997). *Apis mellifera* is also a good crop pollinator, but the race of *Apis mellifera*, which has been imported to this region is highly susceptible to cold and need to be migrated to low hill areas during winter season. Therefore, it is not possible to use this bee for pollination of early blooming mountain crops. In northern areas of Pakistan, where fruit cultivation is common and *Apis mellifera* has been introduced on a large scale, pollination of temperate fruit crops is badly affected resulting in crop failures. The high mountain sub-species of *Apis cerana* is cold resistant and an excellent pollinator of early blooming mountain cash crops. Thus, there are great prospects for promoting this bee for crop pollination in hilly and mountain areas. Its conservation in the mountain areas is, therefore, essential to maintain the productivity and enhance the quality of high value crops.

Surveys conducted in the apple growing areas of India and China indicated that farmers need bee colonies for the pollination of their apples and other fruit crops but most beekeepers are not interested to rent bee colonies. This is because the farmers use lot of insecticides on their crops. These insecticides also kill honeybees and the beekeepers lose their bees. Therefore, to ensure safe pollination of cash crops, farmers can be given training on how to save bees from insecticides. Farmers can also be encouraged and trained to keep and manage their own bee colonies for pollination. So far, Himachal Pradesh is the only state where such efforts have been taken. In this small fruit growing State of Northwest Indian Himalayas, apple farmers are being encouraged by providing them bee colonies on a highly subsidised price and training them in beekeeping management. Similar efforts are required in other countries of the region.

Asian Bee Research and Training Centre

For future development of beekeeping with *A. cerana* in south and southeast Asia, a co-ordinated and systematic effort for establishing a Research-cum-Training Centre for Asian bees and beekeeping is essential.

In conclusion, conservation and management of native bees and the maintenance of a thriving beekeeping industry are essential for sustainable agriculture and rural development. Swaminathan (1986) in his foreword in the FAO Service Bulletin on Apiculture stated 'In spite of all global resolutions on food security, several hundred million children, women and men are going to bed hungry everyday, particularly in the countries of the South. Since prospects for global food security still appear grim at present, it will be necessary for developing countries 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 through pollination'.

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Part 2
New Frontiers of Bee Biology Research

Chapter 2

Evaluation and Selection of *Apis cerana* Populations for Brood-rearing Efficiency

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Introduction

The Asian honeybee, *Apis cerana*, is distributed throughout India. Owing to the vast physiographic diversity of the region different populations of *A. cerana* have evolved naturally. Although these geographic populations or ecotypes show morphological uniformity and can be crossed with each other, they often exhibit considerable variation with respect to biological and behavioural characteristics (Ruttner, 1987). These differences are important to the beekeeper because they relate to a variety of honeybee products and crop productivity. Correlations have been found in differences in brood cycles, amount of brood and brood-nest arrangement, swarming tendency and swarm emission, wax production, nectar storage and temperament (Ruttner, 1971).

Information available on brood-rearing by different populations of *A. cerana* is meagre. Earlier studies have been conducted in different agro-climatic regions but as such the figures available are variable (Bisht, 1966; Kapil, 1957; Saraf and Wali, 1972; Shah and Shah, 1981; Verma *et al.*, 1988). The present study was therefore designed and conducted with populations of *A. cerana* from three different regions established at a common location so that other factors being similar, the brood-rearing efficiency of the populations could be compared.

Materials and Method

The study was conducted at the University's *A. cerana* research and demonstration apiary. This is located at 1,256 m and lies between 31°50′ N, 76°59′ E. Colonies of *A. cerana* were brought from an altitude of about 2,700 m in Himachal Pradesh, Kashmir and Garhwal. Ten colonies each from Himachal Pradesh and Kashmir and five from Garhwal were established at the apiary. They were brought to equivalent status with respect to bee strength, brood and stores. Each colony was queen-right and had a newly mated queen. Brood-rearing efficiency was studied in terms of area under brood (comprising eggs, larvae and sealed brood) and prolificacy of the queen. Observations were recorded at intervals of 21 days during spring, summer, autumn and winter.

Research work on oriental honeybee, *Apis cerana*, in Pakistan

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The earliest record of *Apis cerana* breeding in Langstroth hives in the Punjab dates back to 1882–84. Sketchy research done on *A. cerana* bee farming is available in the form of 47 abstracts in proceedings of science conferences. Few detailed papers were published until 1987. In 1988, Muzaffar produced a Ph.D. thesis on management of *A. cerana* in Pakistan so as to encourage farmers and other people to adapt improved rearing technology for honey production and pollination of crops. The comprehensive research work included studies on competition with other *Apis* spp., supplemental feeding before and after nectar flow and its impact on honey yield, queen production, swarm prevention, clustering of bees, comb formation on *A. dorsata* wax, yield of migrated (8.1–16.9 kg/colony) and non-migrated colonies (4.7–5.7 kg/colony), honey production potential of Swat strain (14.4 kg/colony) and Marghalla strain (10.9 kg/colony), honey yield of feral colonies (1–5 kg/colony), and incidence and control of pests and diseases. Some 379 additional nectar and pollen source were recorded, floral calendar of Marghalla area and low-cost transitional hives were prepared. The insect and plant sources of honeydew honey, effects of honeybee pollination on ten crops and fruit trees, comparative performance of *A. cerana* and *A. mellifera*, and honeybee pollination and pest management in *Brassica* spp. crops were also investigated.

Results and Discussion

Table 1 indicates the total area under brood for the three *A. cerana* populations. It was observed that all three populations had maximum area covered with brood during spring followed by autumn and then summer. Brood-rearing continued through winter at a low rate. Prolificacy of the queen fell from 256–588 during spring to 45–216 in winter.

Analysis of the data revealed that there was significant difference ($p<0.05$) in the performance of Himachal Pradesh, Kashmir and Garhwal bees. The Kashmir bee was the best performer followed by the Himachal Pradesh population. A similar trend has been suggested by the morphometric studies of Mattu and Verma (1984) and Singh and Verma (1993). The three ecotypes showed significant difference in size in the order northwest Himalayan>central Himalayan> northeast Himalayan (Singh and Verma, 1993). Verma *et al.* (1988) also recorded a similar pattern of brood-rearing and egg-laying by *A. cerana* queens in Himachal Pradesh. Shah and Shah (1981) however, reported very high brood area (9032 cm^2) for the Kashmir bee. This difference can be attributed to the change in habitat and associated bee flora in the present study. Differential availability of nectar and pollen resources and climatic conditions have previously been reported to influence colony performance (Verma *et al.*, 1988).

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Table 1. Comparative performance of *A. cerana* ecotypes

Season	Brood area (cm^2)			Queen prolificacy (egg-laying rate/day)		
	Himachal Pradesh	Kashmir	Garhwal	Himachal Pradesh	Kashmir	Garhwal
Spring	1820.25 (121.5)	2415.5 (199.27)	1507.55 (203.45)	409.65 (32.53)	515.45 (29.38)	302.25 (32.15)
Summer	1561.22 (132.59)	1718.27 (176.29)	1142.86 (159.25)	166.66 (22.58)	205.71 (19.57)	106.67 (21.43)
Autumn	1741.27 (222.35)	2276.54 (231.51)	1358.33 (171.65)	307.44 (23.58)	419.81 (29.85)	198.25 (28.25)
Winter	710.48 (79.25)	949.14 (54.27)	563.25 (74.82)	98.65 (27.53)	109.83 (32.43)	70.03 (15.27)
Average	1458.30 (191.50)	1839.90 (202.50)	1142.80 (179.20)	245.60 (33.20)	312.7 (38.60)	169.30 (22.70)

Note: Values in parentheses are standard deviations.

Chapter 3

Differences in Body Colour Expression between European and Asian Honeybees

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Body colour is an extremely distinctive characteristic among honeybee species and subspecies. Woyke (1977) reviews earlier papers concerning the heredity of body colour in honeybees. The purpose of this investigation was to find the differences in body colour expression between European and Asian honeybees.

Material and Methods

Honeybees were reared or collected during 25 years in Poland, Germany, India, Afghanistan, Vietnam, China, Thailand and Malaysia (Borneo). Special instrumental crosses of queens and drones were made, or bees originating from natural matings were investigated.

Results

The gross appearance of the body colour of European honeybees is similar in workers, queens and drones. The Italian bee, *A. mellifera ligustica*, has a yellow abdomen with black bands (Fig. 1). The yellow and black colour is the same in all three forms of the bee; however, the pattern of the black areas is different. Gene *Y* is responsible for this body-colour expression. Within the same form of bee, variation in the pattern of the black area occurs. The variation is caused by several modifiers to expression of the major body-colour gene *Y*.

Workers, queens and drones of the black European bees, *A. m. mellifera*, *A. m. carnica* and *A. m. caucasica* are black (Fig. 2). They have small areas of yellow on the sides of the abdomen. Gene y^{bl} is responsible for this body-colour expression. The pattern on the abdomen varies. Modifiers of the major body-colour gene y^{bl} are responsible for the variation.

A cross between yellow Italian queen (gene Y/Y) and black European drone (gene y^{bl}) results in yellow hybrid workers (Y/y^{bl}). This occurs because yellow colour is dominant over black. The hybrid queens (Y/y^{bl}) produce two types of body-coloured drones: yellow and black. Wide variation in the colour pattern occurs, ranging from yellow to black. Two peaks of frequency distribution appear, one within the yellow range, and the other within the black. This occurs because the two major body-colour genes *Y* and y^{bl} are modified by several modifiers (Woyke, 1977).

The Asian *A. florea* queens and workers are yellow banded, and the drones are black (Fig. 3). The gene responsible for body-colour

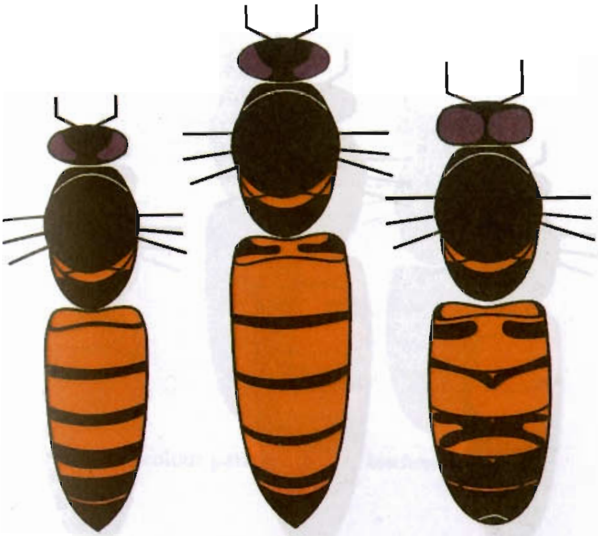

Fig. 1. Body-colour patterns in *Apis mellifera ligustica*.

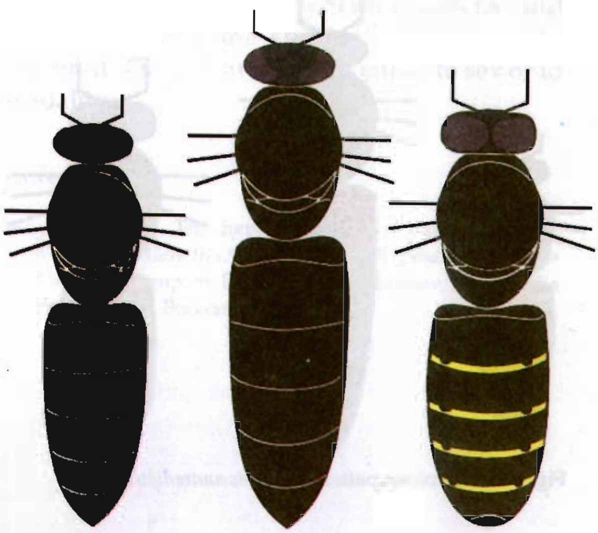

Fig. 2. Body-colour patterns in *Apis mellifera mellifera*.

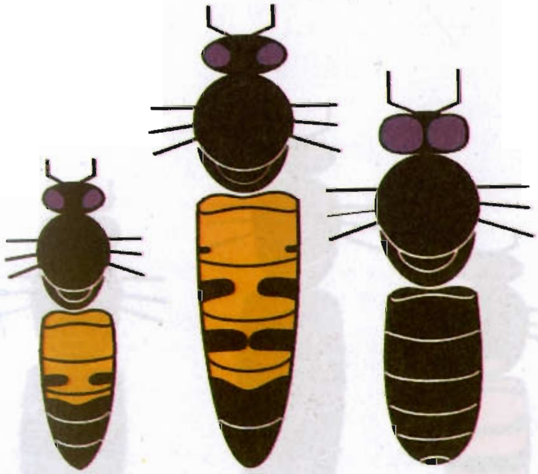

Fig. 3. Body-colour patterns in *Apis florea*.

expression in *A. florea* is designated *Fl*. Yellow queen produces black drones. A cross of yellow queen with black drone results in yellow workers. Drones produced by yellow laying-workers are also black. Thus, the expression of the *Fl* body-colour gene depends upon the sex: females (queens and workers) are yellow and males are black. However, the pattern of black and yellow colour is different in queens and workers. The queen has larger yellow areas than the workers. Thus, the expression of the patterns of body colour in the same sex depends upon their sexuality.

Apis andreniformis workers are yellow although they are the darkest of all five Asian honeybee species described here. Queens and drones are black (Fig. 4). A cross between a black queen and black drones results in yellow workers. Thus the expression of body colour is linked to sexuality. Infertile workers are yellow banded, and the sexes (queens and drones) are black.

Apis dorsata workers are yellow, and queens and drones are brown (Fig. 5). The thoraces of queens and drones are dark brown. The scutellum is brown. The abdominal segments are light brown, with darker brown areas or bands. The gene governing body colour in *A. dorsata* is designated *Do*. Crossing a brown queen with a

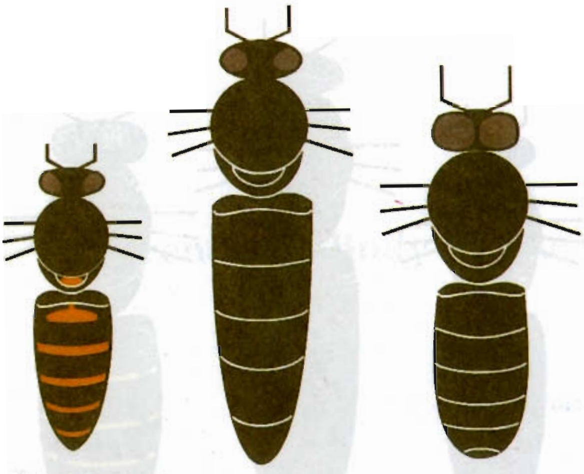

Fig. 4. Body-colour patterns in *Apis andreniformis*.

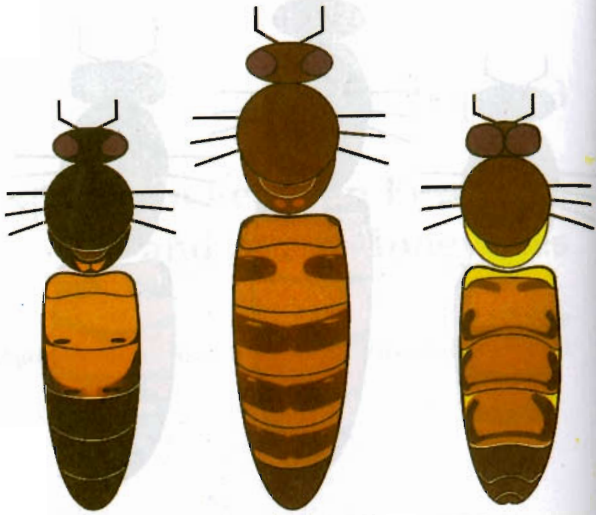

Fig. 5. Body-colour patterns in *Apis dorsata*.

brown drone results in yellow workers. Thus the expression of body colour in *A. dorsata* depends upon sexuality: infertile workers are yellow and sexuals (queens and drones) are brown.

Apis cerana workers are yellow, and queens and drones brownish-black (Fig. 6). The gene responsible for the expression of body colour in *A. cerana* is designated *Ce*. A cross between a brownish-black queen and a brownish-black drone results in yellow workers. Diploid drones reared by Woyke in 1974 in India were also brownish-black, like the haploids. Thus the expression of the body colour in *A. cerana* depends upon sexuality: workers are yellow and the sexuals (queens and drones, independently haploid or diploid) are brownish-black.

All three adult forms of *A. koschevnikovi* are dark brown banded. However, the light abdominal bands are light orange in workers and light brown in queens and drones. The gene responsible for the expression of body colour in *A. koschevnikovi* is designated *Ko*. A cross between a brown dark-banded queen and a brown dark-banded drone results in orange dark-banded workers. So, body-colour expression is linked to sexuality.

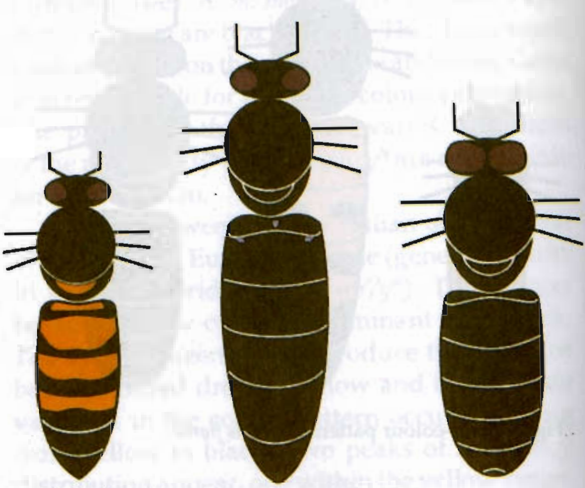

Fig. 6. Body-colour patterns in *Apis cerana*.

Thus two main types of body colour expression were found. In European bees workers, queens and drones of the same

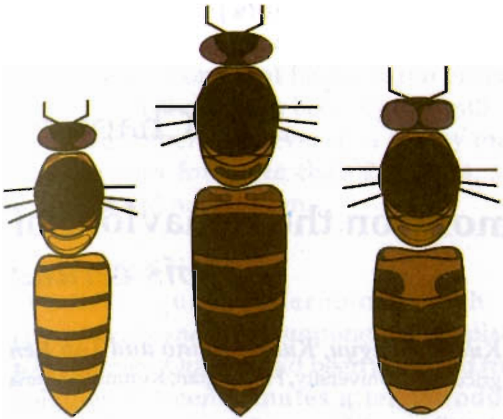

Fig. 7. Body-colour patterns in *Apis koschevnikovi.*

subspecies are of the same colour: black or yellow banded. In Asian bees, workers, queens, and drones of the same species are differently coloured. The colour is linked either to sex or to sexuality.

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Chapter 4

Effect of Synthetic Queen Pheromone on the Behaviour of *Apis cerana*

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Although there are many studies reporting the effects of synthetic queen pheromone, as yet no one has looked at its effect on *Apis cerana*. In 1993 the Chemical Department of Yunnan University succeeded on synthesising queen pheromone. In a primary test, its effect on *A. cerana* was evident. To improve honey production of *A. cerana*, this study systematically looked at the effect of synthetic queen pheromone on colony's initial reaction, gathering, colony discipline, worker-bee laying and queen-cell building.

Materials and Methods

The experiment was carried out at the Institute's apiary at Yunnan Agricultural University. Colonies of *A. cerana* of similar potency were selected and divided into test groups. Bees' response to the synthetic queen pheromone was observed and compared.

Synthetic queen pheromone is composed of 9-ODA, 9-HDA, methly-hydroxy benzoic acid-salt, 4-hydroxy-3-methyl phenyl ethanol and R-9HDA. A carrier for the pheromone was made of a cigarette filter or a filter paper and put into an ether solution containing the pheromone. After the ether volatilised, the carrier (now an artificial queen with 20 mg synthetic queen pheromone) was transferred to the hive.

Chemical analysis of worker pheromone component of Asian honeybees

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Report of pheromone gland chemistry of several honeybee species in Asia, *Apis cerana japonica* (Acj), *A. c. cerana* (Acc), *A. c. indica* (Aci), *A. dorsata* (Ad) and *A. andreniformis*. In Nasonov gland extracts of Acj, Acc and Aci none of the compounds known as Nasonov pheromone in *A. mellifera* (Am) was detected. Instead, linalool oxide was identified as the common component in *A. cerana*. 3-hydroxyoctanoic acid was identified as a major mandibular gland component in Acj, Aci and Acc. In Ad, 10-HDA was detected as the main component. Isopentyl acetate was identified in the sting gland of species tested. These results suggests that Asian honeybees developed different sets of chemicals as Nasonov and mandibular gland pheromones to those of Am.

Results and Discussion

Initial effect of pheromone on colony

Three minutes after the artificial queen was placed in a colony that had a queen or had just lost a queen, the worker bees begin to gather and fight each other. However, in a colony that had lost a queen for more than 24 hours, such a response did not happen.

Gathering action

Synthetic queen pheromone with three components and five components was placed in test colonies. Queens had been removed from all colonies. Fifteen minutes after introduction, worker bees gathered around the artificial queen and tried to attract other workers by passing on the scent. In a control colony, there was no such response. This shows that the synthetic queen pheromone has a similar effect in attracting *A. cerana* worker bees as real pheromone. It suggests that the pheromone could be used to attract free bees during the season of colony migration.

Effect on colony without a queen

Twenty-four hours after a queen has been lost from a colony, worker bees begin to show some disorder: foraging frequency decreases and worker bees release a scent at the hive entrance. Two queenless colonies with similar potencies were selected and an artificial queen placed in one of them. Workers began to surround it five minutes later, and within ten minutes the colony restored its discipline. The disorder in the control colony lasted until bees had built a new queen cell.

Inhibition of worker-bee laying

In a colony that has no eggs or brood, worker bees will begin to lay unfertilised eggs after the loss of a queen. These eggs develop into small, weak drones. When an artificial queen is placed into these hives, workers stop laying. In the test colonies, an artificial queen was introduced before workers started laying and prevented its occurrence.

Inhibition of queen-cell building

Forty-eight hours after the loss of a queen, worker bees begin to enlarge existing egg or brood cells and modify them into a queen cell. They start to feed royal jelly. In a test colony with an artificial queen, workers did not build a queen cell, whereas in a control colony a queen cell had been built only 24 hours later. If the queen cell was demolished and an artificial queen introduced, no more queen cells were built. If the artificial queen was taken away, worker bees begin to build a queen cell after 96 hours. This test showed that an artificial queen inhibited queen-cell building.

Conclusion

When synthetic queen pheromone is put into a queenless colony, the colony maintains its normal foraging action. Since there is no queen the colony becomes eggless and broodless; more worker bees will go foraging, and process and store honey which increases honey yield.

Effect of Synthetic Queen Pheromone on Honey Production of *Apis mellifera* and *Apis cerana*

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The Chemical Department of Yunnan University first composed synthetic queen pheromone in China in 1993. Its effect was tested on honey production of *Apis mellifera* and *A. cerana* during the blooming period of Chinese tallow tree.

Materials and Methods

Test site is by the Jingsa river at 950 m. It was mostly cloudy with some showers during the blooming season of Chinese tallow tree in June 1997. Temperatures were 26–32°C. Each selected colony of *A. mellifera* and *A. cerana* had eight combs with similar potency. Sixteen *A. mellifera* colonies (M) and 16 *A. cerana* colonies (C) were divided into four groups of four colonies: CA and MA, test colonies without queen; CB and MB, test colonies with virgin queen; CC and MC, test colonies with queen; CD and MD, control colonies with laying queen. 20 mg of synthetic queen pheromone on a carrier of cigarette filter was placed once a day for three days in the test colonies of CA group. Every three days honey was collected and weighed to find average honey production for each group.

> **Natural recovery of Chinese bee populations of Changbai mountains**
>
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> *Apiculture Science Institute of Jilin Province, Jilin City, Jilin, China*
>
> Chinese bee of the Changbai mountains, *Apis cerana*, had several thousands of years of no competition until *A mellifera* was imported in the 1920s. Over the next sixty years, the Chinese bee suffered a period of decline. However, after ninety years, the Chinese bee appears to be recovering alongside a rapid reduction of *A. Mellifera*. This is probably because the Changbai mountains have nectar sources and ecology, and remnants of the Chinese bee that are fit for natural recovery. Reduction of *A. mellifera* will promote development of the Chinese bee.

Results

Table 1 shows honey production of the *A. cerana* was increased by the presence of synthetic queen pheromone. The honey production of CA was increased 17.8% over CD, 16.3% over CC, and 13.5% over CB.

Double-cross honeybee breeding of Songdan

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On the basis of inbreeding selection, four high-purity stocks named C, D, R and H that had strong breeding, high honey yield, high royal jelly yield, low feed need, high hibernating ability, and good adaptation were selected as parents. Two kinds of double-cross bee were bred by hybridisation named SongDan I (C*D x R*H) and Song Dan 2 (R*H x C*D). Compared with the local *Apis mellifera*, honey yield increased 70.8% and 54.4%, royal jelly increased 14.4% and 23.7%, overwintering weakening rate reduced 11.9% and 5%, feed expenditure reduced 23.7% and 14.9%, and they showed greater superiority in produce.

Relationship between character diversity and environment factors of *Apis cerana* in Yunnan

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Relationship between five main morphological indexes of the forage bee and of main environmental factors were studied by means of principal component analysis (PCA) at 26 sample locations in Yunnan Province. It showed that effects of sunshine hours and active accumulated temperature on the forage bee's morphology are obvious, especially on the right forewing length. Effect of environment on elbow vein index and body length is least. Generally right forewing length shows a tendency to become short in more sunshine hours and higher accumulated temperature regions.

Table 1. Total honey production by *A. cerana* groups (kg)

Groups	First 14 June	Second 18 June	Third 23 June	Total
CA	10.4	12.0	14.0	37.1
CB	9.8	10.7	12.2	32.7
CC	9.4	10.1	12.4	31.9
CD	10.2	11.1	10.2	31.5

Special distribution future of *Apis cerana* forage in mountain regions

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Special distribution feature of *Apis cerana* forage in the high mountain region was studied by means of geostatistics. Its structure was described quantitatively by variograms. It showed that *A. cerana* forage is characterised clearly in special structure and its variograms took on directional features, especially at E or N in the long distance.

Biological diversity of *Apis cerana* hive

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Besides *Apis cerana* there are many other species of animal living in the hive. They belong to 3 phyla, 3 classes, 22 orders. The relationship for 17 species (34%) is predation; for 16 species (32%) is parasitism; for 9 species (18%) is mutualism; for 6 species (12%) is amensalism; and for 2 species (4%) is neutralism.

Table 2 shows that average honey production of each CA colony increased 17.7% over CD, 19.2% over CC, and 7% over CC colony.

Table 2. Average honey production per *A. cerana* colony (kg)

Groups	First 14 June	Second 18 June	Third 23 June	Total
CA	2.6	3.0	3.7	9.3
CB	2.5	2.7	3.5	8.7
CC	2.4	2.5	3.1	7.8
CD	2.6	2.8	2.6	7.9

Table 3 shows honey production of *A. mellifera* was increased by the presence of synthetic queen pheromone. Honey production of MA group increased 21.7% over MD, 16.3% over MC, and 11.1 % over MB.

Table 3. Total honey production by *A. mellifera* groups (kg)

Groups	First 14 June	Second 18 June	Third 23 June	Total
MA	14.4	15.7	19.5	50.00
MB	14.9	14.0	14.1	43.00
MC	14.3	14.8	14.9	44.10
MD	13.5	14.0	13.8	41.00

Table 4 shows that average honey production of each MA colony increased 21.5% over MD, 12.7% over MC, and 9.8% over MB.

Table 4. Average honey production per *A. mellifera* colony **(kg)**

Groups	First 14 June	Second 18 June	Third 23 June	Total
MA	3.6	3.9	4.9	12.4
MB	3.7	3.5	3.6	11.3
MC	3.6	3.7	3.8	11.0
MD	3.4	3.5	3.5	10.2

Discussion

When synthetic queen pheromone is put into a colony without a queen, the colony maintains its normal foraging action. Since there is no queen in the colony and so no eggs or brood, more workers can go foraging and so increase honey storage.

When synthetic queen pheromone is put into a colony with a virgin queen, the density of queen pheromone is increased, which postpones the virgin queen's mating and egg-laying. Consequently, more workers go foraging, and honey yield is increased.

When synthetic queen pheromone is put into a colony with a queen, worker bees believe that another queen has intruded and they begin to fight. After about one hour, they adapt themselves and behave normally. The high density of pheromone can restrain swarming, and so increase honey yield.

The study shows the effect of synthetic pheromone is more evident on *A. mellifera* than on *A. cerana*. This probably means that although the components of queen pheromone are similar in both bees there are some differences that require further investigation.

Acknowledgement

This project was completed under the guidance of Professor Kuang Bangyu.

Chapter 6

Major Constraints in the Performance of *Apis mellifera* and *Apis cerana* under Khumaltar Conditions

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Modern beekeeping was initiated in Nepal 15 years ago with the introduction of moveable-frame hives to rear *Apis cerana* (Kafle, 1992). However, most farmers still use traditional methods. Those who have adopted modern methods face problems such as frequent swarming, absconding, diseases and mites, robbing and pesticide poisoning. The exotic bee, *A. mellifera,* was introduced recently and demand is increasing. Although this species is popular, beekeepers have not been able to benefit fully from its advantages over *A. cerana* because of inefficient management practices. There is a lack of information on modern management practices for farm conditions under which either of the two species perform well.

Materials and Methods

This experiment was initiated at the Nepal Agricultural Research Council, Khumaltar in September 1995. Four healthy colonies each of *A. cerana* and *A. mellifera* with the same age of queen and equal numbers of frames were observed at seven days interval for three years. During each observation, problems were documented and efforts were made to mitigate them. The problems were occurrence of mites and diseases, swarming and queen-cell preparation, robbing during food shortage, and pesticide poisoning.

In the case of mite attack on *A. mellifera* colonies, a piece of cotton soaked with 5 ml of 85 % formic acid per colony was placed on the bottom board of the brood chamber and three applications of sulphur dust on alternate days at the rate of 1 gm per frame were made. For the control of Thai Sac Brood Virus Disease on *A. cerana,* firstly 250 mg of tetracycline dust mixed with 500 ml of sugar solution per colony was given and later a feed of 5 gm Bhaicare powder mixed with 500 ml sugar solution per colony was given. For the control of European Foul Brood in *A. mellifera,* three feedings of 250 mg tetracycline dust mixed with sugar solution per colony were given on alternate days. During dearth periods, artificial feeding of sugar solution was provided to both species depending upon the food store in the colony. During swarming, frequent checking was done and unnecessary queen cells were destroyed. Activities such as spraying of water, spreading of dust and grass pieces, and narrowing the entrance gate were done to reduce robbing. During severe pesticide poisoning the colonies were moved to a safe area.

Results and Discussion

Mite appearance and control

Two mite species, *Varroa jacobsoni* and *Tropilaelaps clareae*, attacked the bees. *Varroa jacobsoni* appeared in both species but *T. clareae* was associated mainly with *A. mellifera*. During the first two years, *V. jacobsoni* was a problem. Although mites were seen on *A. cerana*, their effect was not as critical as in *A. mellifera*, where infested colonies were significantly damaged. The main symptoms of mite attack in *A. mellifera* were punctured capping of brood cells inside the colony, restless crawling and staggering of bees around the hives, mite-infested dead larvae outside the hive entrance and disabled bees with rudimentary wings and legs around the hive. In the third year, *T. clareae* infestation was more problematic than *V. jacobsonii*. Up to five mites infested an individual brood cell. No multiple-mite parasitism was observed.

Application of 5 ml formic acid per colony at seven-day interval was found to be effective for controlling mites during winter whereas application of sulphur dust at the rate of 1 gm per frame was effective at other periods. Dates of mite infestation and treatment application are shown on Table 1.

Thai Sac Brood Virus Disease appearance and control

Thai Sac Brood Virus Disease (TSBVD) was extremely destructive to *A. cerana*. It was first observed in a colony nearby and then spread to experimental hives. All colonies of *A. cerana* were infected by TSBVD during April to August and November/December. The punctured cappings of sealed brood were seen at first and when the cappings were opened dead larvae in an upright position were found. The dead larvae were watery and formed a sac-like structure when pulled out of the cell. The disease was observed more in older larvae than in younger ones.

250 mg tetracycline mixed with 500 ml of sugar solution per colony was given to control it, but was not effective. So, 5 gm Bhaicare powder mixed with 500 ml of sugar solution per colony was given and was comparatively more effective. Dates of TSBVD appearance and treatment application are shown in Table 2.

European Foul Brood appearance and control

European Foul Brood (EFB) was destructive to *A. mellifera*. In 1995/96 it was not observed in *A. mellifera* but it appeared from February to June and August in the other two years. All colonies were infected. During infection many dead

Table 1. Mite appearance date and treatment application for control in *Apis mellifera*.

Control Treatments	1995/96	1996/97	1997/98	REMARKS
Formic Acid Application	5th December 29th October	3rd March Nov. 5 & 18th	Not applied	Effective during winter.
Sulphur Dust Application	13, 17 & 21st March, 4th April 17, 19 & 21st July	24 & 27th Nov., 1 & 4th Dec. 4, 6 & 8th Feb.	15, 17, 19, 25, 27 & 29th Nov.	Effective during other period

Table 2. TSBVD appearance date and treatment application for control in *Apis cerana*.

Control Treatments	1995/96	1996/97	1997/98	REMARKS
Bhaicare powder	10, 12 & 15th April, 1,2 & 7th Nov.	14 & 16th July, 4 & 6th Dec.	Not infected	Bhaicare powder controlled better than tetracycline.
Tetracycline	13th August.	Not applied	Not applied	

Table 3. European Foul Brood appearance date and treatment application for control in *Apis mellifera*.

Control treatments	1995/96	1996/97	1997/98
Tetracycline	Not appeared 6, 8 & 11th May	29 & 31st March, 21, 23 & 25 th August	2nd April, 9,11 & 13 th Feb. 23, 25 & 27 th June

Table 4. Average number of queen cells and their formation period in *Apis mellifera* and *Apis cerana*.

Year	*Apis mellifera*		*Apis cerana*	
	AV. NUMBER	PERIOD	AV. NUMBER	PERIOD
1995/96	3.66	27th Feb. - 10th March	4.00	5 - 12th March
1996/97	6.00	23rd Feb. - 10th March	9.33	23rd Feb-11th March.
1997/98	2.50	17 - 25th Sept	3.00	26th Sept - 21st Oct.
AVERAGE OF THREE YEARS	4.00		5.40	

Table 5. Artificial feeding date for *Apis mellifera* and *Apis cerana*.

Year	*Apis cerana*		*Apis mellifera*	
	WINTER	RAINY	WINTER	RAINY
1995/96	25th Dec.,6 & 25th Jan., 12th Feb.	19th July	25th Dec., 6 & 25th Jan., 12th Feb.	16 & 19th July., 23 rd Aug
1996/97	23rd Dec., 13 & 18th Jan., 2nd Feb.	12 & 27th July, 13th Aug.	23rd Dec., 4, 13 & 25th Jan., 2nd Feb.	23rd June, 6, 12 & 30th July, 11 & 23rd Aug.
1997/98	22 & 30rd Dec., 6 & 18th Jan.	17 & 23rd Aug	22 & 30th Dec.	4, 20 & 30th Jan., 3rd Feb.

larvae were observed outside the hive entrance. Unsealed dead larvae of almost the same age were also observed in the comb cells. Later they decomposed and as a result turned black and produced a bad smell.

Three feeding of 250 mg tetracycline mixed with 500 ml of sugar solution in a 1:1 ratio at one-day intervals was an effective control. Date of EFB infection and treatment application are shown in Table 3.

Number and period of queen-cell formation

Maintenance of an appropriate balance in a colony's bee population is important and was done by destroying unnecessary queen cells at regular intervals. The number of queen cells was higher in *A. cerana* than in *A. mellifera*. Up to 12 queen cells were found in a single frame. However the average number of queen cells was four in *A. mellifera* and 5.4 in *A. cerana*. The swarming tendency was lower in *A. mellifera* than in *A. cerana*. The swarming period was from February to March and September to October in both species (Table 4).

Dearth period and artificial feeding

December, January and February during winter and June, July and August during the rainy season were identified as dearth periods. Sugar solution in a 1:1 ratio was fed artificially to both species; a pollen substitute was not needed. The three-year observation data suggest that *A. mellifera* needs 4–5 feedings whereas *A. cerana* needs only 2–4 feedings (Table 5).

Robbing

Robbing tendency was observed during dearth period in both species. However it was severe during December/January and July in 1995/96 and in November during 1997/98. This is probably owing to varying weather conditions over the years. In 1995/96 robbing was done by *A. mellifera* to *A. cerana* but during 1997/98 both species robbed *A. cerana* colonies. However it was difficult to distinguish whether it was from experimental colonies or from apiaries nearby. When robbing took place, the weaker colonies of *A. cerana* were completely destroyed within a short period of time. During 1997/98, robbing occurred in all colonies of *A. cerana*, and only three strong colonies defended it. This problem was reduced by spraying water or dusting. It was also reduced to some extent by narrowing the entrance gate.

Pesticide poisoning

Pesticide poisoning is another serious problem and it occured at Khumaltar during the month of March every year. In 1997 all experimental colonies were badly affected. In general, strong colonies were affected more than weaker ones. The symptoms were dead or dying bees extending their tongue/proboscis, abnormal movement, spinning and crawling around, and inability to fly. Inside the brood chamber, younger larvae of the same age were found dead inside their cells. Aggressive behaviour and attacks by guard bees of foragers were also observed.

Conclusion

Although this experiment is of a preliminary nature, some major constraints to the performance of *A. mellifera* and *A. cerana* have been identified under Khumaltar conditions. Some management practices have also been identified to overcome the problems encountered.

Acknowledgements

Authors are highly grateful to Mr D.N. Manandhar, Chief, and Mr B.K. Gyawali, Senior Scientist, Entomology Division, NARC for providing facilities and continuous encouragement. We would like to thank sincerely other senior scientists and technical officers of the Entomology Division for providing suggestions and interest in our study. Our appreciation and thanks go to Mr J.D. Neupane and Mr S.P. Nepal for help in collecting data during the study.

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Chapter 7

Status of Beekeeping in Himachal Pradesh

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India has enormous potential for beekeeping due to abundance of bee flora and bee-friendly climatic conditions. For the development of beekeeping, floral calendars have already been prepared for different states and regions (Kohli, 1958; Rahman and Singh, 1941; Roy and Hamid, 1987; Sharma and Gupta, 1993; Sharma and Raj, 1985). Himachal Pradesh is unique in having different agro-climatic zones with varying bee flora that help to sustain beekeeping in the state. Broadly, the state can be divided into four agro-climatic zones sub-tropical and low hills (up to 914 m); sub-temperate, subhumid mid-hills (915-1523 m); wet-temperate high hills (1524-2472 m); and, dry-temperate high hills and cold deserts (above 2472 m). Surveys made on different aspects of beekeeping in these agro-climatic zones are presented in this paper.

Sub-tropical and Low-hill Zone Beekeeping

Potential sites

Some parts of this zone, especially adjoining the plain areas of the neighbouring states of Punjab, Haryana and Uttar Pradesh, are suitable for keeping bees based on the density and type of bee flora available throughout the year. Potential areas for beekeeping (Figure 1) are Nurpur block of Kangra, Santoshgarh, Una-Jhalera to Luharbi areas of Una and Paonta valley of Sirmour where smaller units of colonies can be kept around the year. Other beekeeping pockets in this zone that could be exploited to a limited extent are Barotiwala-Nalagarh area of Solan, Dosarka-Kala Umb area of Sirmour, Ichhi, Shahapur, Indora areas of Kangra and Umb-Mubarkpur area of Una. Surplus honey is collected during spring-summer from mixed flora that include *Brassica, Eucalyptus, Citrus, Litchi, Toona, Syzygium, Dalbergia, Trifolium, Ehretia, Sapindus, Acacia,* etc. In addition, large numbers of supporting flora are also available throughout the year. August to October is the dearth period. Rest of the zone has sparsely distributed bee forage and thus is not suitable for practical beekeeping.

Number of bee colonies and beekeepers.

The University maintains 125 *Apis mellifera* colonies and University HPKV, Palampur also keeps 150 bee colonies at different research stations in this zone. The State Horticulture Department has 1300 colonies of *A. mellifera* and 25 *A. cerana* at various locations. In addition, there are about 300 professional beekeepers, having abut 9800 *A. mellifera* and 100 *A. cerana* colonies. There are about 600 *A. cerana* colonies also existing in log and wall hives (traditional). Despite the existence of major beekeeping pockets and huge numbers of bee colonies, only

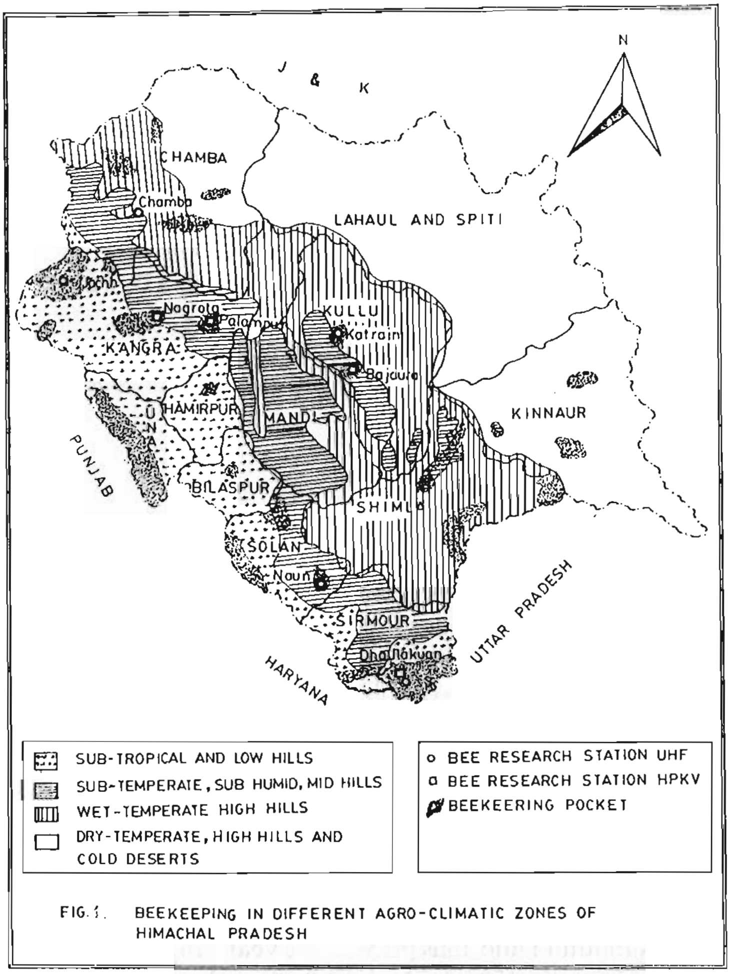

Fig. 1. Beekeeping in different agro-climatic zones of Himachal Pradesh

about 200 *A. mellifera* colonies are maintained under stationary beekeeping and 5–10 kg honey is extracted from each colony annually. Migration of colonies is practiced from hills to plain areas of neighbouring states in a routine manner during October-November to exploit winter bee flora.

Sub-temperate, Sub-humid Mid-hill Zone Beekeeping

Potential sites

In this zone, spring-summer is the honey-flow season. However, in some areas there is a second honey-flow during autumn. The bee flora available for spring-summer honey-flow is almost the same as that found in subtropical and low-hill areas, but the density is lower. However, stone fruits constitute an important build-up source for bees in the zone. Important beekeeping areas include Ranital, Dehra, Tanda-Nagrota areas (Kangra), Kunihar-Arki, Solan areas (Solan) and Panarsa area (Kullu).

Autumn honey-flow is during September-October when there is general dearth of bee flora in other parts of the state. Sources include the wild bush 'chichri', *Plectranthus rugosus* and 'wild cherry' *Prunus puddum*. Honey-flow from

Plectranthus is, however, erratic depending on good rains for growth in monsoon and intermittent rains during flowering for nectar flow. Major pockets enriched with this bush (generally along rivers) are Chamera-Kharamukh, Salooni-Bhanda and Tisa-Baragarh areas of Chambas Chirgaon-Annu, Kumarsen-Nogli, Jakhari-Jeori and Dodra-Kwar areas of Shimla and a few lower areas along the Sutlej river in Kinnaur where large number of bee colonies are migrated to avail the flow. Honey is extracted during October from autumn honey-flow sources. The famous white honey for which Himachal is known all over the country comes from this bushy flora. This honey is sold at a premium price.

Number of bee colonies and beekeepers

In this zone, the State's Horticulture Department keeps about 730 colonies of *A. mellifera* and 45 *A. cerana*. The University has 75 *A. mellifera* and 45 *A. cerana* colonies in this zone. HPKV (Agriculture University) has only 25 *A. mellifera* colonies. There are about 110 commercial beekeepers having 6250 colonies of *A. mellifera* and 120 of *A. cerana*. In addition, there are about 1700 *A. cerana* colonies in traditional hives (log and wall hives). Commercial beekeeping in this zone is exclusively dependent on migratory beekeeping.

Wet-temperate High-hill Zone Beekeeping

Potential sites

This zone has limited potential for stationary beekeeping that is possible only using *A. cerana*. However, migratory beekeeping using *A. mellifera* is possible in some areas that have an abundance of the autumn honey-flow source of buckwheat, *Fagopyrum esculantum*, that is grown as a food crop. In some areas *Plectranthus* is also available. These areas are Holi and Lahal of Bharmour (Chamba), Nichar and Sanagla Tehsils of Kinnaur and Dodra-Kwar of Shimla. Private beekeepers migrate their colonies to avail the autumn honey-flow in these pockets.

Number of bee colonies and beekeepers

There are about 15 private beekeepers having about 1600 *A. mellifera* and 75 *A. cerana* colonies in this zone. In addition, the State Horticulture Department also maintains 325 *A. mellifera* colonies. This zone has about 1950 A. cerana colonies in traditional hives. After availing buckwheat flow during August-September, beekeepers migrate their colonies to accessible Plectranthus-rich pockets, and thereafter to the plains. Migration with A. cerana (in modern hives) is practised by beekeepers of Chamba area.

Dry-temperate High-hills and Cold Deserts Zone Beekeeping

In this zone because of unfavourable conditions and lack of bee forage, beekeeping is not commercially practised. However during autumn some beekeepers do migrate their colonies to some areas, e.g., Gebong and Pooh in Kinnaur, for buckwheat flow.

Migration

In Himachal Pradsh migration between hills and plains is a routine procedure adopted by commercial beekeepers. During October-November, colonies are migrated from the hills to the plains of Punjab, Haryana, Uttar Pradesh and also to Rajasthan until the first week of June to avail Brassica, Eucalyptus, Trifolium and Helianthus flow. A few beekeepers utilise the Litchi flow in Dehradun area of Uttar Pradesh from the end of March until the third week of April and then bring the colonies back to the plains until the first week of June. After migration of colonies back to their parent state, a few beekeepers utilise Acacia catechu (khair) nectar in areas such as Nalagarh, Kunihar-Arki Kala Umb, Bilaspur, Hamirpur, Dehra, lower Chamba, etc. Thereafter, colonies are migrated to areas rich in Fagopyrum and Plectranthus during August and migrated back to plains in October-November. However, some beekeepers of Chamba area prefer to bring their colonies back from the plains during April so as to avoid the harsh summer and avail hill flora of Berberis, Robinia, Eucalyptus, Dalbergia, Sapindus, etc. Through migration, 30–50 kg of honey/colony/year is harvested by commercial beekeepers. Beekeepers produce more than 50 per cent profit from their investment in beekeeping through the sale of honey and bee colonies. Beekeepers of Himachal Pradesh and Government agencies within the state collect 500 t of honey annually from more than 20,000 A. mellifera and 4300 A. cerana (traditional and modern hives) colonies.

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Monitoring Foraging Range of *Apis mellifera* in the Central District of Tokyo through Dance Communication

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In the centre of downtown Tokyo there is an apiary. It is only a few kilometres away from Shinjuku business district, one of the busiest areas of the city. However, the apiary produces as much as 1000 kg of honey each year from every 20 *A. mellifera* colonies. We tried to make clear the background of such high yield in the central district of Tokyo, Shinjuku, focusing on the following points.

- How far do bees forage?
- From which plants do they gather food?
- How do they adapt to the urban environment?

The results were compared with the similar research made on Tamagawa University Campus, which is located in a suburban housing area of Tokyo, relatively rich in green vegetation (Sasaki et al. 1993).

Materials and Methods

A glass-walled observation hive was set up in a house adjoining the Shinjuku apiary for one year (August 1995 to August 1996). Foraging sites of the colony in the observation hive were inferred and plotted on a map by reading the recruitment dances made. The angle between the direction of tail-waggling run and that of gravity, and the

Proboscis extension reflex (PER) for bee odour and non-volatile surface wax components: analysis of nestmate discrimination

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Memory/learning are extensively involved in honeybee social life. PER was adopted to analyse 'nest-mate discrimination' as an important function of the colony system. 1.5M sucrose solution was used as reward (positive unconditioned stimulus: US+) and 2M NaCl solution as punishment (US–) to let the bees discriminate odour or non-volatile surface was (conditioned stimulus). As conditioned stimuli, substrances washed out from workers of *Apis mellifera* (CS+) and *A. cerana japonica* (CS–) were used. Workers of *A. mellifera* could read, memorise, and discriminate odours of self-synthesised and environmental origin, both of which are absorbed temporarily on to body surface and dispersed spontaneously. Bees could also discriminate non-volatile (treated under *vacuo*) crude wax compounds of *A. mellifera* and *A. cerana japonica*. In these wax components, acidic fraction contaning free fatty acids was more readily memorised than hydrocarbon and neutral-alkaline fraction.

duration of waggle run were evaluated to estimate the location of the foraging site. An equation for Japanese *A. mellifera* calculated in a previous study was used for converting duration to distance (Sasaki *et al.* 1993).

Results

The average distance to foraging sites was 0.9 km. The most frequent distance plotted by reading the dances of the foragers was within 100 m. In comparison, the average foraging distance of a colony on Tamagawa University Campus was estimated at 2.1 km.

The foraging sites of the Shinjuku colony changed from season to season. Workers expanded their foraging range up to 2 km in September when flowers are scarce. However, they foraged within 0.8 km in October and November when various autumn flowers bloom. The same is the case in spring. When cherry blossoms come out in abundance in April, they foraged within 0.3 km. Thus, their foraging activity changed according to blooming season of the forage sources.

On Tamagawa campus, on the contrary, the average foraging distance increased to 2.5 km in April and May, and to 2.6 km in the blooming season of November. The foraging range in the central city of Tokyo is significantly narrower than that of the suburbs.

Bees forage towards promising sites. Most of the flights (47 %) were made between north and east of the apiary where there are some old residential quarters left among the busy streets and tall buildings. In the limited space, people grow flowers and flowering trees around their houses. Although large natural green area is scarce in the central city, honeybees bring their locating ability into full play to concentrate their foraging activities on good sources.

Discussion

What are possible reasons that allow an urban environment to have high honey productivity?

Rich food sources

The shorter foraging range raises the colony's foraging efficiency. For example, it is known that honeybees forage only several hundred metres in a food-rich environment, while where resources are poor, they fly as far as 14 km. It is true that foraging resources in Shinjuku is quite limited and patchy, but the bees' foraging range turned out to be narrower than that in Tamagawa. The suburban Tamagawa University Campus has more green vegetation, but the food sources that are favoured by honeybees are not always rich there. In short, more profitable food sources could be found and exploited in a closer range in the urban city than in the suburbs throughout a year.

Competition for flower resources

Poor pollinator fauna such as other bees, syrphid, flies, butterflies and beetles probably result in the lower competition for nectar and pollen sources in the city. Also in Tamagawa Campus, a large number of hives (ca. 100 colonies) might also increase competition between honeybees, in addition to other pollinators. These competitors will lower the colony's foraging efficiency and force them to forage to distant flowers.

Adaptation to spacio-temporally scattered resources

It is generally believed that honeybees, especially temperate *A. mellifera*, prefer large patches of flowers such as a plantation. However, the results from a survey of foraging sites suggest that the colony in the city efficiently utilised the highly scattered patches of flowers of street trees, parks, schools and small flower pots planted by residents. These flower sources are scattered both spatially and temporally (seasonally).

On the basis of the present results, we confirmed an advantage of scattered apiary allocation to secure efficient honey production.

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Chapter 9

Migration of *Apis dorsata* in Northern Thailand

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Migration is the act of an animal moving from one spatial habitat to another usually to exploit new resources. It is usually seasonal. In the western honeybee (*Apis mellifera*) colony migration is unusual (Chandler, 1976; Fletcher, 1975), but in the open-nesting Asian species — *A. dorsata, A. florea* and *A. andreniformis* — migration is a normal part of the seasonal cycle (Wongsiri et al. 1996). Adaptive explanations for colony migration in these open-nesting species are poorly understood. However, migration may increase colony fitness by improved food availability, enhanced out-breeding (Oldroyd *et al.*, 1996) and reduction in brood-parasite pressures. Colonies may migrate (abscond) in response to predator pressure and other reasons, for example, when combs are examined after colony departure they often contain no brood or pollen indicating absconding can occur because of imminent starvation.

The purpose of this study was to determine the causative factors of colony migration in *A. dorsata* in northern Thailand. Three possible factors that may initiate *A. dorsata* migration were examined: predators, parasites pressure and environmental conditions.

Materials and Methods

Study sites

The migratory behaviour of *A. dorsata* was observed at 27 established nesting sites in three locations in northern Thailand. These nesting sites were classified into control sites (non-hunted areas: Chiang Mai) and hunted sites (Mae Tung Ting and Mae Hong Son) where colonies were seasonally harvested during the main honey-flow season.

Meteorological data

Meteorological records of northern Thailand were obtained from the Agriculture Extension Division, Department of Agriculture, Chiang Mai University, Chiang Mai (Table 1). There are three seasons: rainy (June–October), winter (November–February) and summer (March–May). January is the coldest month with partial cloud, strong wind and thunder showers. Temperature gradually increases from February and often exceeds 36°C in the summer (May).

Determining effect of predator disturbance

Fifteen colonies (N=12, n=15) were hunted in the traditional way using professional honey-

Table 1. Meteorological data of Chiang Mai city, northern Thailand

Month	Air temperature (°C)						Relative humidity (%)						Rainfall (mm)			Wind speed (km/day)		
	1995		1996		1997		1995		1996		1997		1995	1996	1997	1995	1996	1997
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min						
Jan	-	-	30.6	12.2	29.8	12.7	-	-	89.8	38.0	92.0	37.2	-	0.00	0.00	-	54.3	63.3
Feb	-	-	30.7	15.5	32.5	13.0	-	-	87.7	44.0	81.8	32.0	-	47.5	0.00	-	73.0	77.4
Mar	-	-	35.8	19.0	35.5	17.4	-	-	87.7	44.0	79.4	41.0	-	19.1	0.35	-	86.4	80.7
Apr	-	-	36.2	22.2	30.6	20.2	-	-	77.2	39.0	80.6	50.7	-	209.6	0.80	-	93.1	96.2
May	-	-	34.9	23.5	36.4	23.6	-	-	79.1	47.6	77.3	32.4	-	117.1	0.28	-	96.3	108.2
Jun	-	-	33.5	23.4	34.1	24.2	-	-	84.7	56.6	78.4	52.4	-	107.0	0.20	-	106.9	97.3
Jul	-	-	32.6	23.6	32.2	23.2	-	-	88.5	67.1	85.6	66.8	-	142.0	219.3	-	86.0	81.9
Aug	-	-	31.7	23.0	32.0	23.4	-	-	91.9	71.0	90.8	72.0	-	267.0	223.9	-	75.0	78.0
Sept	-	-	32.7	22.8	32.1	22.8	-	-	91.9	66.7	90.7	67.9	-	257.4	107.2	-	74.0	63.9
Oct	-	-	33.0	21.9	33.8	22.0	-	-	91.4	60.8	91.9	59.9	-	257.2	148.9	-	64.5	65.2
Nov	30.1	19.6	31.7	19.8	31.6	19.5	91.2	59.0	92.8	56.7	89.3	52.3	20.5	156.8	19.8	6.8	60.2	65.2
Dec	29.1	14.3	39.8	15.2	20.8	16.9	90.7	69.0	91.8	46.2	92.1	46.7	0.00	0.00	0.00	6.7	68.9	66.3

Source: Department of Agriculture, Chiang Mai University.

hunters during the main season (March–April) (Wongsiri *et al.*, 1996). After hunting, the colonies were regularly observed and the absconding date recorded.

Determining parasite pressure

Adults bees were collected directly from nests in the evening around 1730 h after the bees had stopped flying and killed in 90 % ethanol. Dead bees were examined microscopically for mites. Sealed brood was cut open randomly and checked by opening caps. Any mites were counted and recorded. Similarly, when colonies migrated (absconded), deserted combs were immediately checked and the number of mites counted.

Determining effect of environmental conditions

A single-comb open-nest honeybee, *A. florea*, was considered an ideal species to act as a control. Two colonies were observed regularly to determine influence of environmental conditions. Brood-nest temperature (T_b) in winter (January) of *A. dorsata* (N=3, n=3) was measured by inserting a thermometer between the curtain formation bees and the brood over 24 h at 2-h intervals. Another thermometer was hung next to colonies of *A. dorsata* and *A. florea*.

Observation of migratory behaviour 1995–1998

Established nesting sites were visited monthly, and the presence or absence of colonies and the number of colonies that arrived, and departure date from their old nesting sites were recorded.

Data analysis

We used non-parametric techniques; c^2 test, and Spearman correlation analysis that were considered as appropriate to examine the relationships between predator-parasites pressure, and environmental parameters with colony migration.

Results

Migration due to predator disturbance

All harvested colonies (N=12, n=15) in Mae Tung Ting and Mae Hong Son migrated after 3–7 days.

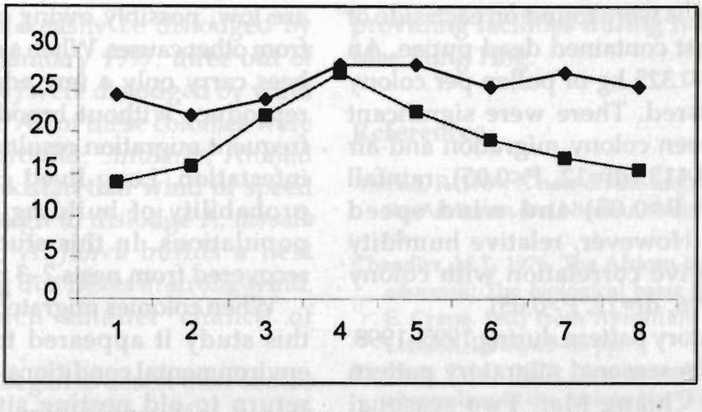

Fig. 1. Brood-nest temperature (T_b) of *A. dorsata* in winter (January)

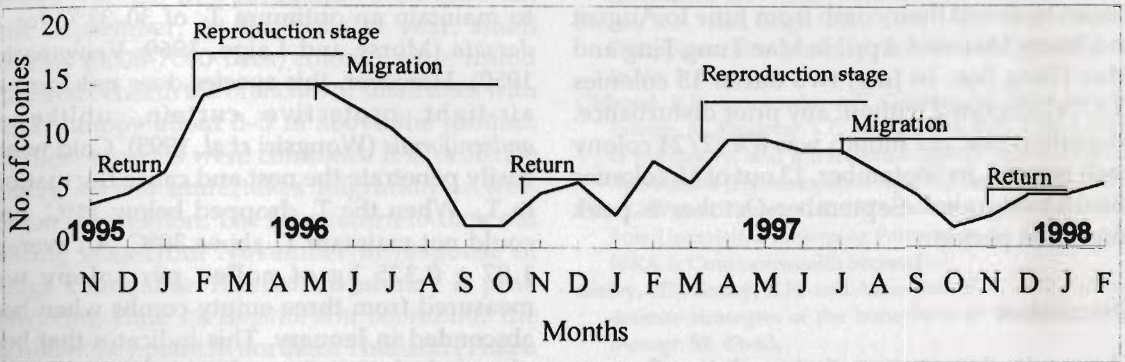

Fig. 2. Seasonal migratory pattern of *A. dorsata* in Chiang Mai, northern Thailand.

No colonies (N=13, n=15) migrated from control nesting sites. Eight out of 15 colonies (60 %) remained 6–9 months (mean=7.2 ± 1.24 months, N=15, n=15), and three out of 15 colonies (20.0 %) remained more than a year (14 months) in control nesting sites. There was a strong correlation between predator disturbance and colony migration (Spearman correlation r=1.00, df=12, P<0.05).

Migration due to parasites pressure

Four out of eight colonies (50 %) had parasite infestation. However, the infestation rate of parasites was negligible. All parasites (*Tropelaelaps claerae*) were collected from adult bees, and three parasites were collected from deserted combs. There was no significant correlation (r= -1.00, df=12, P>0.05) between colony migration and parasite infestation rate.

Colony migration due to environmental conditions

Figure 1 shows T_b of *A. dorsata* and ambient temperature (T_a) (N=3, n=3) in winter (January). The T_b ranged from 22–28°C ($T_{b\ diff}$ = 6°C) reaching a maximum at 1500 h. The T_a ranged from 14-27 °C($T_{a\ diff}$ = 13°C) also reaching a maximum at 1500 h. The greatest difference between T_a-T_b (7°C) occurred at 0900 h.

Temperature fluctuation strongly influenced colony migration in *A. dorsata*. During 2–13 January 1997, four out of 15 colonies (26.6%) migrated when the T_a ranged from 12–14°C. When deserted combs were checked, around 10-

15 sealed brood cells were found on each side of the comb and most contained dead pupae. An average of 1.07 ± 0.325 kg of pollen per colony (N=3) was measured. There were significant correlations between colony migration and air temperature ($r=0.413$, $df=12$, $P<0.05$), rainfall ($r=0.756$, $df=12$, $P<0.05$) and wind speed ($r=0.703$, $df=12$). However, relative humidity (RH) had a negative correlation with colony migration ($r=-0.996$, $df=12$, $P>0.05$).

Seasonal migratory pattern during 1995–1998. Figure 2 shows the seasonal migratory pattern (N=13, n=15) in Chiang Mai. Two seasonal migrations, with and without prior aborted swarming preparation, were observed. Bees began to desert their comb from June to August in Chiang Mai, and April in Mae Tung Ting and Mae Hong Son. In July, two out of 15 colonies (13.3%) migrated without any prior disturbance. Migration rate per month was 8% (2/24 colony each month). In September, 13 out of 15 colonies (86.6%) migrated. September-October is peak migration period.

Discussion

The results demonstrate that predators (human honey-hunters) are a significant causative factor in colony migration in *A. dorsata*. Hunters harvested not only honey-storage areas but the entire comb including brood. This is devastating for colony reproduction and survival. Mardan (1994), Morse and Laigo (1960), Seeley *et al.* (1982) and Wongsiri *et al.* (1996) reported similar results for *A. dorsata* in southeast Asia. Underwood (1990) and Valli and Summers (1988) reported similar results for *A. laboriosa* in Nepal. This type of migratory behaviour has also been observed in other honeybees: *A. mellifera scutellata* (Flecther, 1975; Otis and Taylor, 1978; Winston et al. 1979), *A. florea* (Seeley et al. 1982) and *A. andreniformis* (Wongsiri *et al.* 1995).

Our results suggest that parasites do not significantly impact on migration rates of colonies of *A. dorsata*. Parasite infestation rates are low, possibly owing to frequent migration from other causes. When a colony migrates, adult bees carry only a few adult mites that cannot reproduce without brood. As a consequence, frequent migration results in low levels of mite infestation. Long-lived colonies have a high probability of building up significant mite populations. In this study, mites were only recovered from nests 2–3 months old.

When colonies migrated from nesting sites in this study it appeared to be due to adverse environmental conditions. When *A. dorsata* bees return to old nesting sites in autumn, they immediately start to build comb and rear brood. As soon as brooding commences, it is essential to maintain an optimum T_b of 30–33°C for *A. dorsata* (Morse and Laigo, 1969; Viswanatha, 1950). However, this species does not form an air-tight protective curtain, unlike *A. andreniformis* (Wongsiri *et al.* 1995). Cold winds easily penetrate the nest and cause fluctuations in T_b. When the T_a dropped below 14°C, bees could not maintain T_b above 30°C. An average 1.07 ± 0.325 kg of pollen per colony was measured from three empty combs when bees absconded in January. This indicates that bees absconded in winter because of adverse environmental factors not scarcity of foraging resources. It can be concluded that *A. dorsata* starts to migrate when T_a falls to 12°C. This is confirmed by observations mabe by Ahmad (1985). Similar phenomena were observed in *A. laboriosa* (Underwood, 1990). In contrast *A. florea*, observed at the same time, did not abscond despite being directly exposed to wind and rain. The probable reason for this is that *A. florea* does not rear brood in winter, and also forms two to four protective air-tight curtains at the centre of the comb covering honey and pollen areas (Seeley *et al.* 1982; Wongsiri *et al.* 1995).

Strong wind can easily dislodge *A. dorsata* combs. Several colonies nesting on the southern side of buildings, water tanks and trees were directly exposed to strong solar radiation, presumably making the comb soft. As a result, these soft combs could easily be dislodged by strong wind. On 23 January 1997, three out of seven colonies (42.8 %) were dislodged by wind of speed 32-37 kmph. All of these colonies were 25-40 m above the ground. Similarly, Ahmad (1989) reported in Pakistan that wind of speed 8-21 kmph were enough to dislodge *A. dorsata* combs. In contrast, *A. florea* builds a nest encircling a small twig that flexes in strong wind. So, there is a much smaller chance of dislodgement.

A. dorsata colonies began to desert their combs from June-August in Chiang Mai which coincided with peak rainfall. The maximum rainfall (107-267 mm per month) occurred from June-September. At this time of year, small swarms (3000-7000 bees/colony) were found clustered beneath the branches of small trees with a thin canopy about 3-5 m above the ground. All these swarms were combless. It is probable that *A. dorsata* undertakes migration or wet-season hibernation. The bees return to their old nesting sites from November in response of forage abundance. November-January is peak flowering time of *Eupatorium odoratum*, the second honey plant in northern Thailand (Thapa and Wongsiri, 1997).

In conclusion, if colonies of *A. dorsata* are not disturbed by predators then adverse environmental factors and falling floral resources induce migration.

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Chapter 10

Apis florea in Saudi Arabia

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Apis florea is the better known of two recognised species of dwarf honeybee. Its main range is in hot regions of Pakistan, India, Sri Lanka, Myanmar, Thailand, Indochina and southern China (Otis, 1994). It also lives in several mid-western countries including Oman (Dutton and Simpson, 1977) and Iran (Tirgari, 1971). More recently *A. florea* has been reported from Sudan (Lord and Nagi, 1987) and Iraq (Claim, 1992). This is the first report of *A. florea* from Saudi Arabia.

In 1985, a colony of honeybees was reported from Riyadh to staff of the College of Agriculture of the King Saudi University. The person who reported it came to seek help in hiving the bees in a Langstroth hive, thinking it was an *A. mellifera* swarm. Upon seeing the colony it was realised that this was the first colony of *A. florea* known from Saudi Arabia. The colony nest measured about 15 cm x 15 cm and was attached to a frond of a palm tree. In 1986, many people called the Ministry of Agriculture and Water seeking help in hiving *A. florea* in swarm boxes in their gardens. By 1991, more than sixty colonies had been detected in many different areas of Riyadh. Moreover, recently *A. florea* bees were seen in Al-Gassem about 400 kilometres from Riyadh in the east of the country. The occurrence of *A. florea* in this area is not surprising because of the heavy movement between there and Riyadh.

1996 was different from other years for Riyadh as it had more rain than in the last 30 years, (about 100 mm) and was one of the best for beekeepers. This led to an increase in the number of *A. florea* with an average of 10 new swarm-reports per day. Most of the nesting sites were in gardens either in bushes and trees or between exterior window bars or in house walls. Comb size varied greatly depending on how long the bees had been established in a particular location. Combs were between 10 cm x 15 cm and 25 cm x 35 cm. They were full of brood and had less than 800 g of honey. Some of the larger colonies had up to ten queen cells; an indication that reproductive swarming was occurring.

The ability of *A. florea* to survive in Riyadh's harsh, hot climate is remarkable particularly as this species nests in the open on a single comb. This is especially true when one compares this species with imported *A. mellifera* colonies that with extensive care, sheltering, cooling and feeding, still experience a high degree of mortality.

Because of the high price of honey, most people who find *A. florea* colonies destroy them to harvest the honey. A few take the honey and then try to repair the rest of the comb but, unfortunately, bees do not return to nests that have been disturbed. The main concerns of beekeepers is robbing of *A. mellifera* colonies by *A. florea*, and the transference of *Varroa* mites, but not competition for limited nectar and pollen sources. Of five swarms examined in Riyadh in February 1997, two had *Varroa* mites on adult bees (brood not examined) indicating that *A. mellifera* had been robbed.

It is not known how *A. florea* entered Saudi Arabia. It is possible that it came from a neighboring country as, in addition to Oman and Iraq, it is also known to occur in Yemen and is suspected in Abu Dhabi (Whitcombe, 1984) and Qatar. If such is the case, this species has long been in Saudi Arabia, for it would have taken a long time to reach inland to Riyadh. On the other hand, its presence in Riyadh, located in the centre of Saudi Arabia, may mean that it entered the country by airplane in cargo.

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Chapter 11

Ecobiology of the Little Honeybee (*Apis florea*) in Semi-arid Subtropical Climates of India

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The little honeybee (*Apis florea*) is a wild bee and a natural pollinator of several important plants in its area of distribution in Asia and parts of Africa. However, its biology is poorly understood. This paper presents results of some ecobiological observations made on this honeybee.

Materials and Methods

Observations were recorded on artificially managed and wild colonies of the little honeybee (*A. florea*) at CCS Haryana Agricultural University, Hisar, India. Total volume of crop contents was measured in 100 bees by capturing returning bees, pressing their abdomen gently and collecting reguritated liquid with a microcapillary. Results were compared with bees kept hungry for two hours and then fed 50% sugar solution for two hours. Plants visited by this honeybee were recorded and on the basis of foraging modes, its use as a pollinator was determined (Sihag, 1988). Temperature optimas were determined by recording initiation and cessation of foraging activity in different seasons. Life cycle and build-up patterns were studied by making periodic observations of comb size. Months of drone production, queen-rearing and swarming were identified. Time of mating/drone

Increased food supply for all larvae after dequeening

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It is generally known, that worker bees construct emergency queen cells after a colony is dequeened. However, other events happening after dequeening are little known. The amount of food supplied for larvae in queen-right and queenless colonies was compared. Three colonies were divided into two parts. One part remained queen-right, and the other was queenless. Food was collected from comb cells with larvae 1, 2, 3 and 4 days old. Larval food was collected from 6530 cells. In queen-right colonies, 10 larvae 1, 2, 3, and 4 days old received on average 32.1, 62.1, 98.4 and 126.3 mg of food respectively. In queenless colonies, 10 larvae 1, 2, 3, and 4 days old received on average 43.9, 78.9, 108.7 and 144.0 mg of food respectively. All larvae of the same age received significantly more food in queenless than in queen-right colonies. In percentage, larvae 1, 2, 3 and 4 days old received in queenless colonies 137, 127, 111 and 114% of food supplied for larvae in queen-right colonies. In successive days, the relative amount of food supplied for larvae in queenless colonies decreased from 175% the first day after dequeening to 105% seven days later. The increased amount of larval food in queenless colonies was not the result of different ratios of the number of worker bees to the number of larvae in queen-right and queenless colonies.

flight was observed. During the course of the year, diseases, pests, predators and enemies were identified and times of their incidence recorded. Duration of nest occupation and possible cause of nest desertion were recorded.

Results and Discussion

Apis florea consumes about 10 µl of nectar (ave. = 9.82 ± 3.8 µl, n=100; range 4.5–13.0 µl) although bees fed artificially had up to 15 µl solution in their crop (ave. =14.7 ± 0.92 µl, n=100; range 12–15 µl). This shows that this bee can carry small nectar loads and seems to have low energy requirements. This is evident from the fact that it is most reliable as a pollinator of plants having small flowers as shown in Table 1. Such flowers are not visited by larger bees either because of their small size or because of the low energy reward they offer (Abrol and Sihag, 1997).

This bee starts foraging when ambient temperature surpasses 18°C and continues foraging until ambient temperature approaches 43°C. Maximum foraging activity is shown at 30–40°C. These ranges are higher than those shown by *A. mellifera* and *A. dorsata.* In subtropical climates, this bee remains at subsistence level during dearth periods. Colonies with small combs (ave. diameter = 4.5 cm) and little brood were seen during July–August. These colonies show gradual increase in comb size with the commencement of foraging on ground flora and subsequently on *Zizyphus jujube* followed by many other plants as shown in Table 1.

Colonies start producing drones in February. Four to six queen cells are produced per colony (Table 2). Swarming takes place in late February to March. All newly established colonies start build-up activities in early summer when ample bee forage is available especially from ornamental plants, eucalyptus, berseem, jamun and neem. Each colony acquires a comb size of 10–15 cm diameter and 500–1000 g of honey. Maximum comb size achieved in old colonies

Table 1. Important plants visited by *Apis florea* at Hisar

Plant		Flowering time	Source
Common name	Scientific name		
Plants mainly dependent on *A. florea*			
Ber	*Zizyphus jujube*	August–September	NP
Ber	*Zizyphus mauritiana*	September–November	NP
Coriander	*Coriandrum sativum*	February–March	NP
Cumin	*Cuminum cyminum*	February–March	NP
Fennel	*Foeniculum vulgare*	February–March	NP
Carrot	*Daucus carota*	March–April	NP
Phalsa	*Grevia asiatica*	April–May	NP
Jamun	*Syzygium cumini*	May	NP
Neem	*Azadirachta indica*	May	NP
Khajoor	*Phoenix sylvestris*	March–April	P
Grape	*Vitis vinifera*	March–April	NP
Major flora visited by *A. florea*			
Pigeonpea	*Cajanus cajan*	September–October	N
Rape seed and mustard	*Brassica* spp.	October–February	NP
Gram	*Cicer arietinum*	February–March	P
Berseem	*Trifolium alexandrinum*	April–May	NP
Eucalypts	*Eucalyptus* spp.	February–March	NP
Curcubits	*Curcubita* spp., *Cucumis* spp., *Luffa* spp.	April–November	N

Note: Other plants visited by *A. florea* have been listed by Sihag (1990); N = nectar, P = pollen, NP = nectar and pollen.

Table 2. Some attributes of *Apis florea* at Hisar

Attributes	Value
Nectar loading capacity	15 ml
Temperature preference/tolerance	18–43°C
Humidity preferences	15–95 %
Months of drone production	Feb.–March
Months of queen-rearing/swarming	Feb.–March
No. of queen cells produced per colony	4–6
Mating/drone flight time	1130 to 1430 h
Maximum comb size	15 cm (diameter)
Maximum honey storage	500–1000 g

Table 3. Diseases, pests, predators and enemies of *Apis florea* at Hisar

Enemies	Months of occurrence
Viral diseases	Absent
Bacterial disease	Absent
Fungal disease	Not detected
Protozoan disease	Not detected
Endoparasitic mite	Not detected
Ectoparasitic mite (*Euvarroa sinhai*)	Feb.–March
Wax moth (*Galleria mellonella*)	April–May
Predatory wasps	Not observed
Robber ants	Absent
Robber bees	Absent
Predatory birds	Not observed

was about 15–20 cm in diameter. In mid-May, pollen sources dry up and the strength of colonies starts declining.

At Hisar, *A. florea* does not show any viral, bacterial, fungal or protozoan diseases (Table 3). Endoparasitic mite was also not detected. However, about 40 per cent of the colonies were infested with the ectoparasitic mite, *Euvarroa sinhai*. All colonies in mid-to late May were found to be infested with the wax moth, *Galleria mellonella*. However, there were no robber bees, robber ants, predatory wasps and birds near *A. florea* colonies.

Local migrations were found to be caused by the availability of bee forage and the pest status of colonies. As long as there were no pests and bee forage was available, colonies tended to stay. Average stay at a site was 2.3 ± 1.4 months (n=100). All colonies deserted their original nesting sites by late May.

Use of non-conventional timber for making bee boxes

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Kerala is the leading state in India in honey production primarily because of large quantities of nectar available from extra-floral nectaries of rubber trees (*Hevea brasilensis*). Rubber plantations are raised primarily for latex. When trees are felled after 30–35 years, they become a valuable source of cheap wood. In order to reduce the pressure on traditionally used forest trees, rubber wood was tested for making bee boxes. Rubber wood was protected from insects and fungal attack by treating it with preservatives. Bee boxes were field tested in forestry and agroforestry plantations and results were encouraging.

Comparative performance of *Apis mellifera* in modern and mud hives under substropical conditions of Himachal Pradesh

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Indigenously developed low-cost mud hives (prepared using wheat straw and mud) having frames of Langstroth size were used. Performance of *Apis mellifera* colonies kept in such hives was compared with those in modern Langstroth hives during summer (March–June). Brood area, honey and pollen stores were 22.22, 1.24 and 11.66% more respectively, in such hives. These lives were also superior in thermoregulation as the inside mean temperature was 1–2°C lower. These hives can be successful in stationary beekeeping with *A. mellifera*.

Apis florea in semi-arid subtropical climates makes an excellent natural pollinator of many plants especially those that larger bees, owing to their high energetic demands, fail to visit. This bee survives the extreme summer as it has adapted to high temperatures and low humidity. It forages even at 43 °C when all other honeybee species either shun foraging or engage in water collection (Sihag, 1984, 1991). Like *A. dorsata* and *A. mellifera* in India (Sihag, 1991), *A. florea* is also free from honeybee diseases. Wax moth is the only common pest. The ectoparasitic mite, *Euvarroa sinhai*, is specific to this honeybee only and no other enemies of *A. mellifera* or *A. dorsata* were found (Sihag, 1991, 1998). Attack by wax moth is, however, so heavy that it causes absconding.

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Chapter 12

Ecobiology of the Giant Honeybee (*Apis dorsata*) in Semi-arid Subtropical Climates of India

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The giant honeybee (*Apis dorsata*) is a wild bee and a natural pollinator of several plants in its area of distribution in Asia. However, its biology is poorly understood. This paper presents results of some ecobiological observations made on this honeybee.

Materials and Methods

Observations were recorded on artificially managed and wild colonies of the giant honeybee (*A. dorsata*) at CCS Haryana Agricultural University, Hisar, India. Total volume of crop contents was measured in 100 bees by capturing field bees, keeping them hungry for two hours and then feeding them on 50% sugar solution for two hours. Afterwards their abdomens were gently pressed and regurgitated liquid was collected with a microcapillary. Plants visited by this honeybee were recorded, and on the basis of foraging modes, its use as a pollinator was determined (Sihag, 1988). Temperature optimas were determined by recording the initiation and cessation of foraging activity in different seasons. Life cycle and build-up patterns were studied by making periodic observations of comb size. Months of drone production, queen-rearing and swarming were identified. Time of mating/drone flight was observed. During the course of the year, diseases, pests, predators and enemies were

Amylase and esterase activity as markers in larvae of *Apis dorsata*

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Amylase and esterase activity were measured in the larval stage of *Apis dorsata* to ascertain the formation of ecoraces. *Apis dorsata* larvae were collected from migratory and permanent colonies in Assam. Amylase activity was measured with 3, 5-dinitrosalisylic acid (DNS) and esterase activity was determined using naphyl acetate as a substitute. Amylase activity was noted at pH 5.1–5.3. Three major isozymes were detected in PAGE in larvae of nomadic colonies. Zymograms of esterase also showed variations. Esterase activity of permanent colonies occurred at 0.091×10^{-3} mM against 0.086×10^{-3} mM for migratory colonies. The variations indicate the possibility of formation of an ecorace of *A. dorsata*.

identified and times of their incidence were recorded. Duration of nest occupation and possible causes of nest desertion were recorded.

Results and Discussion

Apis dorsata consumes about 35 µl of nectar (ave. = 35.5 ± 10.3 µl; range 24.0–52 µl). This bee, therefore, can carry large nectar loads and seems to have high energy requirements. This is evident from the fact that it is most reliable as a pollinator of plants with large flowers/inflorescences secreting plenty of nectar as shown in Table 1. Such flowers are handled effectively by this honeybee and are worth visiting because of the high energy reward they offer (Abrol and Sihag, 1997).

Table 1. Important plants visited by *Apis dorsata* at Hisar

Plant	Flowering time	Source
Sunflower (*Helianthus annuus*)	Nov.-Dec., Feb.-March, May-June	PN
Rape seed and mustard (*Brassica* sp.)	Oct.-Feb.	PN
Curcubits (*Citrullus* sp., *Cucumis* sp., *Curcubita* sp., *Luffa* sp.)	April-Nov.	N
Maize (*Zea mays*)	May-Oct.	P
Onion (*Allium cepa*)	March-April	PN
Eucalypts (*Eucalyptus* sp.)	Feb.-March	PN
Siris (*Albizia lebbeck*)	April-May	N
Pigeon pea (*Cajanus cajan*)	Sept.-Oct.	PN
Gram (*Cicer arietinum*)	Feb.-March	P
Shisham (*Dalbergia sissoo*)	April-May	PN
Berseem (*Trifolium alexandrinum*)	March-May	PN
Citrus (*Citrus* sp.)	March	PN
Tomato (*Lycopersicon esculentum*)	March-April	P
Brinjal (*Solanum melongena*)	March-April	P

Note: Other plants visited by *A. dorsata* are the same as listed by Sihag (1990). N=Nectar, P=Pollen, PN=Pollen and nectar.

This bee starts foraging when ambient temperature surpasses 16°C and continues foraging to around 40°C. Maximum foraging activity is shown at 25–35°C. These ranges are lower than *A. florea* but higher than those shown by *A. mellifera*. In subtropical climates, this bee usually emigrates during the dearth period (after May); only a few colonies remain. Colonies migrate to this region in late October/ early November with commencement of foraging on pigeon pea/toria, and stay until mid-May when the dearth period starts.

New colonies established in October/ November grow to over 1–1.5 m in length and 0.5 m in height during their stay at Hisar. Growth is facilitated by regular flora availability in the region. Colonies start producing drones in February, six to nine queen cells are produced per colony (Table 2). Swarming takes place in late February to March. Drone flight takes place at sunset. All newly established swarm colonies start build-up in early summer when ample bee forage is available especially from ornamental plants, eucalyptus, alfalfa, berseem and sunflower. Each colony acquires a comb size of 1 m in length and 0.5 m in height and 3–5 kg of honey. In mid-May, pollen sources dry up and the strength of colonies starts declining. Ambient temperature crosses 43°C and relative humidity falls below 20%. At this time, over 99 per cent of colonies emigrate to the foothills.

Table 2. Some attributes of *Apis dorsata* at Hisar

Attributes	Value
Nectar loading	35 µl (24-52 µl)
Temperature preferences	16–40°C
Humidity preferences	30–95%
Months of drone production	Feb.-March
Months of queen-rearing/swarming	Feb.-March
No. of queen cells produced per colony	6-9
Mating/drone flight	Dusk
Maximum comb size	l=1.5 m, h=0.5 m
Maximum honey storage	3-5 kg

At Hisar, *A. dorsata* does not show any viral, bacterial, fungal or protozoan diseases (Table 3). Endoparasitic mites were not detected. However, about 15 per cent of colonies were infested with the ectoparasitic mite, *Tropilaelaps clareae*. All colonies in late March were found to be infested with the wax moth, *Galleria mellonella*. However,

Table 3. Diseases, pests, predators and enemies of *A. dorsata* at Hisar

Enemies	Months of occurrence
Viral diseases	Absent
Bacterial diseases	Absent
Fungal diseases	Not detected
Protozoan disease	Not detected
Endoparasitic mite	Not detected
Ectoparasitic mite (*Tropilaelaps clarcaei*)	Feb.–May
Wax moth (*Galleria mellonella*)	March–May
Predatory wasps	Not observed
Robber ants	Absent
Robber bees	Absent
Predatory birds	Not observed

there were no robber bees, robber ants, predatory wasps and birds near *A. dorsata* colonies.

Local migrations were not found in this honeybee. However, desertion of old combs was caused by the non-availability of bee forage and by the pest status of colonies as well as by adverse ambient temperature and relative humidity. As long as there were no pests in the colonies and bee forage was available, colonies tended to stay. Average stay at a site for an established colony was about eight months and for a new swarm colony about 2.5 months. All colonies deserted original nesting sites by late May.

Apis dorsata in semi-arid subtropical climates makes an excellent natural pollinator of many plants especially those with large size flowers/ inflorescences that can meet the high energy demands of this bee (Abrol and Sihag, 1997). In thermal tolerance, this bee is between *A. mellifera* and *A. florea* (Sihag, 1984, 1991, 1998). *Tropilaelaps clareae* and *Galleria mellonella* are the only two pests and can be highly devastating to colonies causing desertion of combs (Sihag, 1982).

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Part 3
Recent Findings in Bee Diseases and Pest Control

Chapter 13

Thai Sac Brood Virus Situation in Thailand

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Thai Sac Brood Virus Disease (TSBVD) was first found in *Apis cerana* collected from Doi Pui, Chiang Mai province, Thailand, in 1976 (Areekul et al., 1979). It was confined to *A. cerana* colonies although there were a few *A. mellifera* colonies in the same apiary. TSBV was isolated from *A. cerana* larvae from Thailand and characterised to be different from sac brood viruses affecting *A. mellifera* by Bailey *et al.* (1982). The present situation in Thailand is reported here based on information from the Entomology and Zoology Division, Department of Agriculture, Bangkok, Thailand and observations of apiaries in central Thailand.

Morphological and Pathological Studies of TSBV

Attathom (1984) reported that TSBV is a spherical virus with diameter of 29 ± 1 nm. It is found to infect cytoplasm of fat cells of honeybee larvae. Electronmicroscopic observations of infected cells indicate that viral synthesis take place in electron dense areas randomly located in the cytoplasm. Newly synthesised virus particles are found to surround specific areas forming inclusions where subsequently virus multiplication occurs. Virus particles themselves demarcate the inclusion from the rest of the cytoplasm. The arrangement of virus particles are classified into five categories: short banded body row-to-row arrangement; long curved lines of virus particles arranged predominately in two rows; irregular arrangement of packed virus particles; crystalline lattice arrangement of packed virus particles; and, particles distributed singly at random.

Situation of TSBVD in Thailand

In 1976, TSBVD was found among colonies of *A. cerana* in mountainous areas of northern Thailand. There was no report of disease in the south of Thailand at that time. In 1990, there was an outbreak of TSBVD in Chumporn province in the south of Thailand (Jarungjit *et al.*, 1990). Beekeepers lost about 90 per cent of their colonies. Examinations confirmed symptoms of TSBVD in Nakornsri Thammarat province but no colony loss occurred. It was noticed that the outbreak occurred after Typhoon Kay had caused severe flooding and destroyed most fruit plantations in Chumporn. This outbreak of TSBVD might have been caused by changes in the ecological system and colonies being weak from lack of food (pollen and nectar). At present, there is no report of the TSBVD in Thailand. A few colonies that have been infected by European Foul Brood are suspected of having 1–2 larvae infected by TSBV.

Treatment

There is no effective chemotherapeutic agent in preventing or controlling TSBVD. The virus does not survive long and the disease may disappear during honey-flow period. Since the disease usually occurs when the colony is in a stress situation good management and sanitation are the best ways for preventing it. In mild cases, management measures to restore colony strength are needed such as providing food, adding to the worker population, pulling out infected larvae and destroying them, caging the queen for 5–10 days, moving bees to a new apiary area and reducing humidity in the hive. In severe cases, infected combs and bees should be destroyed by burning them or the colony requeened.

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Chapter 14

Thai Sac Brood Virus Disease Control in Vietnam

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In 1974, there were in North Vietnam 75,000 *Apis cerana* colonies kept in movable-frame hives with an average honey yield of 10–15 kg per hive per year. Colonies were well crowded with bees normally densely clustering on 5–6 frames but some reaching 9–10 frames (Anh and Dang, 1984). In April of the same year, a sac brood epidemic broke out. It first occurred in colonies imported from China and placed at Bach Thao apiary, Hanoi. Within a short time, it quickly spread to northern provinces causing losses of tens of thousands of colonies (Mulder, 1989; U.T.D., 1983; Vien, 1984). In some localities over 90 per cent of colonies were lost, e.g., before the epidemic there were 4300 colonies in the Thai Binh beekeeping company, but only 96 colonies survived (Ngan, pers. comm.). In 1977, it was estimated that only 7000 colonies were left in the country. By 1988, this number had increased to 15,000 frame-hive colonies but colony quality was worse than before the epidemic: a colony consisted of 3–4 frames only. In 1989, the presence of Thai Sac Brood Virus (TSBV) was determined in *A. cerana* colonies by Vincent Mulder, and Brenda Ball from Rothamsted Experiment Station in England.

Unlike in Thailand, Nepal or India where four to five years after the epidemic surviving colonies began to develop normally and the disease became less harmful (Kshirsagar and Phadke, 1984; Verma, 1990), TSBVD still lasts year after year in northern and southern Vietnam and causes large losses in some localities.

Treatment

Antibiotics

Since TSBVD occurred, many antibiotics have been tried in the hope of finding a successful treatment. These have included kanamicin, furazolidon, sulphathiazon natri, erythromycin, tetracyclin, biomycin (Anh, 1984), streptomycin (Vien, 1984), $KMnO_4$ 0.1%, rivanol 1 %, neotesol, chloramphenicol and penicillin. They were fed with 50% sugar syrup or sprayed into comb cells. However, effectiveness was very low. Some beekeepers put furazolidon into a small tin jar covered with mosquito netting and also sprayed it on to infected combs. This method is effective only for strong, populous, and lightly infected colonies. For the less crowded ones, it does not work. Residue of antibiotics remains in combs and honey.

Manual methods

Some beekeepers stimulate infected colonies to abscond artificially, then catch them again and force them to build new comb. Others remove all brood comb and keep honeycomb. Some colonies recover but some do not and abscond. It is also time consuming.

Biotechnical methods

TSBVD can be controlled by biotechnical methods (Chinh, 1989) either by requeening an infected colony with a virgin queen or queen cell, or by caging the queen of an infected colony for 7–8 days. These two methods need to be combined with eliminating old combs in order to increase the density of bees on remaining combs. Feeding sugar syrup continuously for 3–4 days until honeycomb is sealed or moving colonies to new floral resources are also essential. These methods aim at creating a young-larvae-free period for 7–8 days, especially free from two-day-old larvae that are most sensitive to TSBV (Bailey, 1981). At this time, additional feedings are given to the colony, which is populous, so that cleaning behaviour is strengthened for picking up or eating all infected larvae. In this way, the causative agent can be reduced and even dry larval scales, if they remain, cannot spread the disease. Cells that are cleaned will be filled with nectar or sugar syrup by the bees. Seven to ten days later, the queen will start to lay eggs and the colony will recover. Results of a three-year experiment show that by carrying out these two biotechnical methods, more than 90 per cent of colonies recover (Tables 1 and 2).

Depending on climatic conditions, floral resources and the status of the apiary, the beekeeper has to decide whether to requeen or cage the laying queen. In favorable seasons when nectar and pollen sources are adequate, it is easy to rear a queen from a strong and disease-free colony. Replacing a laying queen of the infected colony with a queen cell is more efficient. When nectar and pollen are scarce and climatic conditions are not favorable, it is advisable to cage the queen because it will be difficult to rear a queen and the virgin queen will not have performed a mating flight successfully. However, when the caging method is used some colonies will become infected again so this is a temporary solution. When conditions improve, queens of re-infested colonies should be replaced.

Table 1. Effect of replacing laying queens with virgin queen or queen cells (Chinh, 1989)

Group	No. of colonies per group	No. of recovered colonies	Recovery rate (%)	Floral condition
November 1986				No nectar, sugar syrup feeding
Control	6	0	0.0	
Requeening	18	17	94.0	
April 1987				Honey-flow of longan flower
Control	6	3	50.0	
Requeening	22	20	90.9	
May 1988				Some nectar and pollen resources
Control	6	1	16.7	
Requeening	20	18	90.0	
Total				
Control	18	4	22.2	
Requeening	60	55	91.7	

Table 2. Effect of caging the queen for seven days (Chinh, 1989)

Group	No. of colonies per group	No. of recovered colonies	Recovery rate (%)	Floral condition
December 1988				Honey-flow
Control	6	3	50.0	
Queen Caging	15	14	93.3	
February 1989				Little flow, rainy weather and cold
Control	6	0	0.0	
Queen Caging	25	18	72.0	
Total				
Control	12	3	25.0	
Queen Caging	40	32	80.0	

Selection for Resistance to TSBVD

In 1983, the veterinary doctor Mai Anh co-operated with the Thai Binh Beekeeping

Table 3. Mean values of some parameters of closed population breeding programme for *Apis cerana* in Vietnam from 1990–1993. Values in parentheses show the range (Chinh and Lap, 1994)

	Mean (range)			
	1990	1991	1992	1993
Honey production	10.2	11.23	13.73	15.54
(kg/colony)	(5.4–16.8)	(6.1–20.8)	(6.6– 21.75)	(7.4–24.9)
Number of capped brood/day	406	425	382	403
	(218–713)	(154–1290)	(152–945)	(172–945)
TSBVD	23.1	11.8	4.8	2.3
(% infected colony)	(0–85.7)	(0–26.7)	(0–16.7)	(0–13.3)
Europe Foul Brood	45.4	41.9	18.0	17.2
(% infected colony)	(0–85.7)	(0–66.7)	(0–40.0)	(0–40.0)
Absconding rate (% colony)	4.2	3.8	3.5	3.3
Swarming rate (% colony)	10.5	10.4	10.2	3.1

Company to select the TSBVD-resistant colonies for queen-rearing in order to replace queens of infected colonies. It showed good effect in the first generation, but in the second and third generations disease resistance had decreased remarkably. A selection programme for high honey production with *A. cerana* was carried out from 1989 to 1993. The closed population breeding programme proposed by Page and Laidlaw (1982) was applied and preliminary results have been achieved. The rate of TSBVD infected colonies is low and has a tendency to reduce year after year from 23.1% to 2.3% (Table 3).

Conclusion

In general, in an apiary of 40 or more colonies, it is advisable to rear queens regularly (from strong and disease-free colonies) for replacing old queens and reducing egg-laying capacity of colonies infected with TSBVD. If requeening is routinely carried out, infection of TSBVD can be reduced remarkably. It has been concluded in regular beekeeping practice with *A. cerana* that all combs of a colony must be densely covered with bees. So when colonies are attacked by TSBVD and are weakened, it is always necessary to remove unoccupied combs. In cases where colonies are reduced to less than three combs, two colonies should be united into one. It is important to detect first signs of the disease (i.e., death of older larvae that turn into liquid sacs). At an early stage it is easy to treat colonies successfully and reduce losses of worker bees.

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Chapter 15

Study on Thai Sac Brood Virus Disease of *Apis cerana* in Nepal

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Incident of TSBV Disease

Beekeeping with *Apis cerana* is decreasing among beekeepers in Nepal because of the frequent incident of brood diseases, mainly Thai Sac Brood Virus Disease (TSBVD). It is the most prevalent *A. cerana* brood disease in Nepal, and between 1980 and 1984 killed more than 90 per cent of colonies. During 1980, it was observed spreading in eastern border areas; and during 1983, its spread along the western border created a crisis in Nepalese beekeeping causing almost total loss of colonies. This was the first historical evidence of this disease on such a scale. It is possible that it was introduced from India as it was first observed in northern parts there during 1976. The disease started to subside by 1984 and bees began to regain normal populations in the eastern border. At present, TSBVD still occurs in almost all parts of the country causing epidemics during some seasons and as a result *A. cerana* colonies are declining at a rate that threatens the survival of the species. In districts such as Chitwan, Bhojpur, Makawanpur, Jumla, Jajarkot, Tanahun, Dolakha, Sindhupalchowk, Kaverepalanchowk, Rolpa and Kathmandu its presence has been confirmed. The disease tends to be seen in early spring and early autumn when brood-rearing is at a peak, and also whenever colonies are weak.

Status of Disease at Different Locations

Mid-Western Region: Jumla District (high-hill region)

In Jumla, TSBV infection rate was mostly high in the following areas surveyed during 1996 and 1997. In Chaukidhunga, during field surveys in 1996, 50 per cent infection was observed in four colonies of the ICIMOD apiary. Colonies of local beekeepers were free of disease and strong. In the same location when resurveyed in 1997, hives were found almost empty. Only three weak colonies were present against 66 the year before. It was obvious that transmission of TSBVD was from nearby infested apiaries through robbing, infested forage bees and improper handling by beekeepers. In Patmara, TSBV infection was 100 per cent in the ICIMOD apiary during 1996. Although infection was high, colonies were not too weak. However in 1997, no colonies remained in the ICIMOD apiary. Beekeepers' colonies were also highly infected with TSBV and had low honey and pollen storage. In Chandan Nath during 1996, ICIMOD apiaries located at the Karnali Trade School (KTS) and at Dadakot were seriously affected by TSBVD with about 50 per cent brood-comb infection. During 1997 the KTS apiary lost all but two colonies and caught three new swarms. At the Dadakot apiary, all bees absconded leaving diseased brood behind and no hives were occupied. In Gidikhola, low (33 %) brood-comb infection was seen in the ICIMOD apiary during 1996. In 1997, only one of six colonies remained.

Western Region: Tanahun District (mid-hill region)

In Dhorfirdi, colonies were in good condition in newly established apiaries owing to good management practices by well-trained farmers supported by the government's Beekeeping Section. However, at the Akie Vocational Training and Community Development Project, colonies with newly introduced swarms looked after by women farmers showed low TSBV infection in 1996 but all had absconded in 1997 as a result of bad colony management.

Eastern Region: Bhojpur District (mid-hill region)

In Bhaisipankha, all colonies in log hives surveyed in 1996 showed 20 per cent infection. In 1997, they had been transferred to modern hives with newly swarmed colonies and were performing well with no disease. In Taksar, TSBV infection was lower in 1997 than in 1996 mainly because strong colonies were able to suppress the disease. The beekeepers of Bhojpur were skilled. Although TSBVD was seen in some colonies, colony losses were few. Mostly it was neglected colonies that were highly infected. In Pokhim, TSBV infection was mostly in log hives and modern hives because of poor management; colonies in wall hives were performing well without any brood disease.

Central Region: Dolakha District (high-hill region)

Beekeepers were well trained in handling beehives. Mostly modern and some wall hives were found. Only 15.7 per cent TSBV infections were recorded in 1996 and 4.7 per cent in 1997.

Sindhupalchowk District (high-hill region)

Beekeeping is not widespread here because of scarcity of bee flora. Only Chautara was surveyed. Farmers were found keeping bees in modern hives with very few TSBV infected colonies.

Kavrepalanchowk District (mid-hill region)

As there is sufficient bee flora and an abundance of cherry trees in the forest, colonies can be found in most locations. In some locations, wall hives were preferred to modern hives, and had no TSBV infection. In other locations with newly established apiaries, TSBVD causes continual loss of colonies.

Makawanpur District (mid-hill region)

Bee colonies are confined to pockets because of insufficient and scattered flora. Locations that were infected with TSBVD in 1996, were free of disease in 1997 owing to frequent absconding and swarming of colonies for better flora pasture. In nature, colonies become virus-free when there is a one-week gap in brood-rearing.

Chitwan District (Terai)

Beekeepers focus on commercial beekeeping with *A. mellifera* bees. Some beekeepers also keep *A. cerana* colonies. TSBV infection was seen in most modern hives. So absconding is common. Only one wall hive in Ratnanagar showed good colony development with no disease.

Kathmandu District (mid-hill region)

Nearly all private beekeepers have changed to *Á. mellifera* beekeeping although small farmers keep one or two *A. cerana* colonies by catching natural swarms. In the Royal apiary, there was little TSBV infection during spring 1996. However in autumn 1997, all colonies were in a broodless condition owing to scarcity of bee flora.

Lalitpur District (mid-hill region)

Both ICIMOD and government apiaries at Godavari were infected with TSBV in both weak and strong colonies: 20 per cent in 1996 and 30 per cent in 1997. TSBVD has become established in these old apiaries.

Bhaktapur District (mid-hill region).
No TSBV infections were seen at the KNSN *A. cerana* apiary at Patletar in 1996 and 1997. This is a newly established apiary with no nearby beekeeping areas.

Colony Losses in Surveyed Areas

Among the areas surveyed, TSBV infection rate was highest in Jumla. Within one year only (1996–1997), colony losses of ICIMOD apiaries at Patmara, Chaukidhunga and Dadakot were 100 per cent, at KTS 80 per cent and at Gidikhola 83.3 per cent. Owing to a lack of movable-frame hives, the condition of bees cannot be seen easily and seasonal management approaches are not applied. As a result, TSBVD is multiplying and spreading into healthy colonies. Unknowingly, farmers are spreading the virus through improper handling and the catching of diseased swarms. In Bhojpur District, colony losses were 33.3 per cent in Bhaishipankha, 14.2 per cent in Takshar, 26.3 per cent in Bhojpur and 18.7 per cent in Pokhim. In the Central Development Region, colony losses were 21.4 per cent in Dolakha, 30 per cent in Sindhupalchowk and 11 per cent in Kavrepalanchowk. Besides TSBVD, other factors such as European Foul Brood, lack of proper management, insecticidal spray and scarcity of bee flora are the main reasons for declining populations of *A. cerana* colonies.

Field Observations

- Unskilled beekeepers were the main source for virus transmission, as they were not taking hygienic measures while handling colonies.
- Colonies that are weak because of a lack of seasonal management, traditional methods of honey-harvesting and primary infection by other diseases such as European Foul Brood, are more prone to virus attack and multiplication.
- Once TSBVD establishes in an apiary, it is difficult to remove it. Highly infected colonies are the main source for spreading the disease to healthy colonies. Such colonies should be destroyed or provided with better management at an early infection stage.
- Among hives, traditional wall hives seem to be most suitable for good colony development and lower TSBVD incidence.

Problems and Suggestions

As in many mountain countries, Nepal has placed emphasis on high-value crops: citrus throughout the mid-hills; apple in the inner Himalayan zone; and, vegetable-seed production in the hills and mountains including cash-crop farming. Beekeeping is a traditional household activity that, with little support of modern techniques, can improve the productivity of crops, fruits and vegetables through cross-pollination. Furthermore, it also helps in the preservation of the natural ecosystem through cross-pollination of forest plants. Hence, TSBVD management is essential. Most *A. cerana* beekeepers were found to be not thorough about modern management practices. As a result colony losses are high.

To solve the problem of TSBVD the following should be considered.

- Farmers should be convinced of the advantages of modern frames for proper seasonal management.
- Queens should be reared from disease-resistant colonies and supplied to beekeepers.
- Improvement of bees through selection and breeding should be carried out to prevent extinction of the species.
- As there is little expertise of bee diseases in many developing countries including Nepal, technology-sharing and transfer of knowledge through workshops, seminars and meetings of national and international groups should be organized.
- Suitable improved hives for better colony development that are less prone to TSBVD should be developed for the harsh and

changeable cold climate of northern parts close to the Himalayas. Desirable bee flora should be available; plantation should be encouraged.

- Exotic *A. mellifera* bees should be introduced only in tropical areas and should be strictly restricted from temperate regions for preventing disease transfer and risk of endangering indigenous bees.
- Before involving farmers in beekeeping, effective training, especially practical training, is necessary along with regular supervision and monitoring to establish good apiaries free of disease.

Chapter 16

Introduction to *Varroa* Disease

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Beekeeping is an important component of present strategies for sustainable agriculture and integrated rural development programmes. Bee diseases are one of the main problems for beekeepers. This is independent of the number of colonies kept and is world-wide. The outbreak of disease can destroy the beekeeping industry of a region if no method or treatment is available or if the disease is not managed properly. Usually disease in a colony is first detected by beekeepers on the basis inspecting for clinical symptoms. This is only possible with training and experience. Control methods and quarantine measures (in the case of infectious bee diseases) should follow this inspection. Clinical symptoms are in some cases not sufficient to clarify which disease actually threatens the colony. In order to clarify the specific disease, laboratory diagnosis has to follow inspection by the beekeeper.

In most cases, diseases such as infestation with the parasitic mites, *Varroa jacobsoni* or *Tropilaelaps clareae*, are first noticed by the beekeeper once infestation rates have already reached destructive levels. These mites are a problem only for the exotic hive bee, *A. mellifera*, since the original hosts, *A. cerana* and *A. dorsata*, have developed a balanced host-parasite interrelation

Parasitism and reproduction of *Varroa* in *Apis cerana japonica*

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The incidence of parasitic *Varroa* mite on *Apis cerana japonica* is very low or zero. A survey of nest debris from the floors of colonies in traditional hives (from different localities and separate from *A. mellifera*) showed that 50% (n = 20) of the colonies were weekly infested.

In *A. cerana japonica* colonies, female adult mites usually reproduce only in drone cells mainly because the sealed duration of worker cells is too short to allow full development of *Varroa* offspring. There might also be chemical factor(s) because *A. cerana japonica* worker pupae attracted less mites than *A. mellifera* worker pupae in a choice experiment in the laboratory, and 37% of *Varroa* that invaded worker cells either could not lay eggs or had delayed oviposition if it occurred.

Apis cerana japonica drone pupae seem not to be chemically resistant because an abnormally heavily parasitised queenless colony in late-phase drone production was observed. The parasitic incidence for adults was 5.3% for workers and 10% for drones; 38.4% of 700 drone cells were invaded by *Varroa*. It is likely that maximum of 5–7 female mites per drone could be produced. This reproduction rate is comparable to that for *A. mellifera* drones.

during evolution. The parasitic incidence of *V. jacobsoni* in *A. cerana* is known to be low and notable damage is not published. The main reasons for this are thought to be the limited reproduction of *Varroa* in *A. cerana* in seasonally occurring drone brood and defensive behaviour by the bees towards the mites. However, Yoshida *et al.* (1995) in Japan observed mite reproduction within worker cells in colonies of *A. cerana japonica,* and abnormally high parasitic incidence of drone cells in a worker-laying colony. These observations were made in natural colonies that were isolated from *A. mellifera.* Dying colonies with abnormally high parasitic incidence may serve as a source of dispersion of *Varroa* to other healthy colonies.

Status of Disease in *Apis mellifera* and *Apis cerana* in Asia

Varroa jacobsoni and *T. clareae* are no threat to beekeeping with *A. cerana.* However, in most Asian countries *A. mellifera* is endangered by *V. jacobsoni.* The mite externally parasitises adult bees, feeds on their haemolymph and reproduces on their brood. Favourable reproduction conditions stimulate mite population growth to the extent that colonies die from *Varroa* infestation (varroasis) within a few years if it is not controlled.

Commercial beekeepers are known to migrate *A. mellifera* colonies in order to explore different bee flora. This leads to an increased exchange of disease within bee species and colonies, and between geographic regions. There is a large variety of bee diseases present in Asia caused by viruses, bacteria, fungi, protozoa, parasitic mites and predators (Matheson, 1995). Some resulted in part from importation of exotic bees into Asia, which is not yet controlled by all governments.

A ranking of presently existing bee diseases is intended to identify the worst bee diseases to face beekeepers in Asia. *Varroa* mite is perceived by only a few respondents to a questionnaire handed out during the workshop as the most critical pest or disease. *Tropilaelaps clareae* is more destructive in Asia. Since chemical acaricides are used intensively by most commercial beekeepers in Asia, *Varroa* does not yet cause the problems seen in other countries. Statistical analysis of the questionnaire revealed that predatory birds are claimed to be the worst problem for beekeeping in Asia followed by wax moths, *Varroa,* European Foul Brood, *Tropilaelaps,* wasps and hornets, American Foul Brood, chalkbrood and sacbrood. Nosema disease and tracheal mites are only mentioned by 11.7% of the respondents. For *A. cerana,* Thai Sac Brood Virus Disease is mentioned as the worst problem followed by European Foul Brood.

Evaluation of Control Methods Currently Used in Asia

In many cases, beekeepers around the world are not able to identify bee diseases by clinical symptoms. Consequently, they are not familiar with potential negative impacts on their colonies. Moreover, lack of training means that some symptoms are misinterpreted to the extent that beekeepers treat colonies without identifying the causative organizm. For example, some beekeepers regularly treat colonies with acaricides but had never seen a *Varroa* mite on bees or even dead mites on the hive floor.

In Asia, the use of chemical control predominates; biotechnical and 'soft-chemical' methods are rarely used. *Varroa* is mainly controlled by chemical acaricides and since there is no regulation for the use of chemicals in bee colonies by any government in Asia, any available, marked or self-made products are used. Sulphur dust, Mavrik sticks, Klartan, Apistan, Bayvarol and Folbex represent some of the large variety of products. Sulphur dust is widely used and it is found to be at least partially successful, but its effectiveness still needs to be determined. Sulphur dust applied to the colony can lead to contamination of honey. Side-effects can create new problems. The use of acaricides may cause sublethal residues to accumulate in beeswax, and in the future form the basis for development of resistance by the mites to chemicals presently applied. In Vietnam, various biotechnical methods are used successfully by professional beekeepers to control *Varroa* and *Tropilaelaps*. *Varroa* is controlled by trapping and *Tropilaelaps* by creating a broodless period (Dung et al. 1997).

Potential Control Methods for the Future

Since chemical control methods have limitations, and are too expensive or sometimes not available for small-scale beekeepers, other control methods should be tested under local conditions. Requirements for such control methods are independence from outside resources; lack of residues in honey and wax; low costs; and practicality for beekeepers. A mixture of management, biotechnical and soft-chemical control methods are needed.

Preliminary data from applied research work in the Philippines using formic acid show success in controlling *V. jacobsoni* and *T. clareae* (Boecking and Sito, 1999). Short-time treatments with formic acid during the night revealed promising results and correspond well with data already published. Moreover, investigations showed that formic acid treatments against *V. jacobsoni* are highly effective against *T. clareae* too. Long (1998) successfully applied 15% formic acid combined with 3 ml of oil of marjoram under Vietnamese tropical climate conditions in a long-time treatment with average mite mortality of 97.98 ± 1.18%.

Also some data and practical experiences are available about the use of soft-chemical and biotechnical control methods against *Varroa*, but as of now no general recommendation can be given for use under the diverse and specific conditions of the many Asian countries. For this, research is required in order to apply integrated pest management systems that have been used successfully in one situation to the specific conditions of each Asian country.

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Chapter 17

Preliminary Data on Control of *Varroa jacobsoni* in the Philippines

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In the Philippines, spraying of DDT and other pesticides, heavy typhoons, the endemic mites *Varroa jacobsoni* and *Tropilaelaps clareae*, predatory birds, and lack of knowledge and training have hindered the establishment of a beekeeping industry (Cervancia, 1998). The ectoparasitic mites, *V. jacobsoni* and *T. clareae*, create difficulties in keeping *Apis mellifera*; the original hosts, *A. cerana* and *A. dorsata*, have developed a balanced host-parasite interrelation. *Varroa* mite is perceived as the most critical pest, but *T. clareae* is the more destructive. In most cases, bee diseases such as infestations with *V. jacobsoni* or *T. clareae* are first detected by the beekeeper when infestation rates have already reached destructive levels. Infested colonies show clinical symptoms of secondary infections and cause problems seen in other countries (Boecking, 1996). The impact on the growing bee industry is amplified because of lack of knowledge of control methods for most diseases.

A survey on currently existing *Varroa* control methods revealed that there is an urgent need to establish new methods, since the only available acaricide, Apistan, can only be obtained by a few beekeepers. Some beekeepers use botanicals such as leaves of neem (*Azadirachta indica*), alagaw (*Premnia odovata*), cogon (*Cylindrica emperata*) or

Biological control of *Varroa jacobsoni* in Pakistan

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The *Varroa* mite (*Varroa jacobsoni*) has long been associated with *Apis cerana* in Pakistan. However, its incidence has been negligible possibly because of natural enemies. With the introduction of *A. mellifera* in 1977, this mite became a serious pest of the newly introduced honeybee and destroyed a large number of colonies.

As a result of a survey, an anthocorid, a mirid, a reduvid and a pentatomid were found to prey on *Varroa*. Symptoms of a virus that infected this mite were also observed. However, a lack of equipment made it difficult to isolate this virus and release it on mites attacking *A. mellifera* colonies. Therefore, efforts were made to transfer the natural enemies (diseases) of this mite directly from *A. cerana* colonies to *A. mellifera* hives by keeping both honeybee species colonies side-by-side and by introducing *A. mellifera* sealed queen cells into *A. cerana* colonies in spring. Thereafter, the mite population declined to such an extent in 5–6 months that it was difficult to collect a sample of 20–30 mites in 3–5 hours. This mite, at present, is not a pest of considerable importance in Pakistan.

It seems that some natural enemies have kept the *Varroa* mite population under control in Pakistan. If potential natural enemies of the mite are isolated, evaluated, multiplied and released in *Varroa*-infested colonies of *A. mellifera* in climatically similar areas, some might prove useful.

lemon grass (*Andropogon citratus*) claiming to control mites during heavy infestation; however, their efficacy still needs to be tested (Boecking, 1996). The objective of this research is to protect the beekeeping industry from new problems that will arise from the presently used chemical control methods. Moreover, adaptation of methods originally established in other countries can only be done in the Philippines by research under local conditions.

Materials and Methods

Twenty *A. mellifera* colonies of the same size were randomly selected and grouped for replication. Initially, *Varroa* mites that fell naturally on to the bottom boards of infested hives were collected and counted over a period of 13 days at two-day intervals. Specially constructed inserts covered with a plastic screen were placed under each colony to prevent mites being cleaned out by bees. Treatments of freshly collected leaves from neem, alagaw, and cogon, and formic acid (60 %, 2 ml per comb carried on pasteboard plates), and Apistan (Fluvalinate strips) were applied twice over 23 days in February 1996. Plastic screens were fitted to the top of the frames to prevent bees from gnawing the pasteboard plates or leaves. The indigenous materials were applied following usual farmers' practice. Since formic acid should only be used below temperatures of 25°C and day temperatures reached 34°C, short-time interval treatments were tested twice during the night. Capped brood cells were opened after the second application to assess the impact of treatments. A final treatment of all colonies with Apistan was made to kill any remaining mites.

Results

The average number of dropping mites was 12 mites per day per colony (min.= 1.1 and max. = 58.2) indicating that some colonies were highly infested (Table 1). Of these dropping mites, 23.2% (n=3752) were still alive when collected.

The number of falling mites increased after the first application in colonies treated with Apistan (143.4 mites/day) and formic acid (71.8 mites/day). The results show that formic acid and Apistan affected the *Varroa* mite population. A slight increase of dropping mites can be seen after the first treatment with alagaw. Since the infestation level of experimental colonies was generally high this slight increase might range within normal variance. Therefore, indigenous materials, in the way they were applied, showed no impact on natural death rates of *Varroa*.

The final treatment of all colonies with Apistan showed the effectiveness of this acaricide. The total number of mites collected ranged from a minimum of 26 to a maximum of 2538. This experiment did not allow distinct evaluation of effectiveness of treatments used, however, the impact of formic acid is obvious. Moreover, short-time treatment of formic acid seems to be useful under local conditions in the Philippines since no queen losses or damage to brood were observed.

Large numbers of dead *T. clareae* mites were found only under colonies treated with formic acid indicating that Apistan and indigenous materials did not effect this mite. Analysing capped brood cells (n=760) in these colonies revealed that on average 12.3% of the *Varroa* mites were dead compared to 92.2% of the

Table 1. Average number of mites falling on to bottom boards before and after treatment (mites/day)

No. of colonies	3	3	3	6	2	3
Natural mite fall	6.6	24.1	22.2	11.3	14.7	2.7
Treatment	Cogon	Neem	Alagao	Formic acid	Apistan	Control
After first treatment	5.6	19.8	43.1	71.8	143.4	13.3
After second treatment	7.1	14.4	38.8	140.9	93.2	4.8
After Apistan treatment	111.7	135.0	242.7	91.1	89.7	64.4

Tropilaelaps mites. Only 3.2% of the *Varroa* mites were dead in Apistan-treated colonies, which corresponds to known natural death rates of mites in capped brood cells and shows that this chemical had no impact.

Discussion

Chemical treatments (acaricide) are used extensively in honeybee colonies to reduce damage caused by *Varroa* mite. As a consequence, sublethal residues can accumulate in beeswax and form the basis for development of resistance to these chemicals. Short-time treatments with formic acid during the night revealed promising results and correspond well with data already published (Garg *et al.*, 1984; Hoppe *et al.*, 1989). Moreover, the investigations showed that formic acid treatments against *V. jacobsoni* are also effective against *T. clareae*. Long (1998) applied 15% formic acid combined with 3 ml of oil of marjoram under Vietnamese tropical climate conditions in a long-time treatment with an average *Varroa* mite mortality of 97.98 ± 1.18 %.

These investigations using formic acid should be understood to be a first step. However, the results fit well with the demands of beekeepers in the Philippines: independence from outside resources; no residues in honey and wax; low cost; and practicality. Bee products must be of high quality without chemical residues, as a consequence any treatment must be applied during times without honey flow.

The number of mites falling from colonies treated with indigenous materials showed no differences to natural mite fall. Obviously either the indigenous material itself or the way it was applied had no impact on natural death rates of *Varroa*. Further investigations with different methods of application should follow.

Acknowledgement

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Reproduction of *Varroa jacobsoni* Introduced into an *Apis cerana japonica* Colony

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Damage to *Apis mellifera* by *Varroa* mites is a serious problem for beekeepers; however, *A. cerana* suffers hardly any damage. The lack of damage may be because the sealed duration of *A. cerana* worker cells is too short to allow full development of *Varroa* offspring (Sasaki *et al.*, 1995). Drone production is limited to April–June (Sasaki, 1989). Workers rapidly remove mites by allo-grooming and kill them with their mandibles (Peng *et al.*, 1987). The ability of *A. cerana* to recognise and identify foreign material is high (Peng *et al.*, 1987). *Varroa* is rarely found naturally in *A. cerana japonica* colonies suggesting high resistance. When *Varroa* was introduced into an *A. cerana* colony, a few eggs and female deutonymphs were observed (Rath and Drescher, 1990; Tewarson *et al.*, 1992). The behaviour of *A. cerana japonica* workers and the reproduction of *Varroa* in an *A. cerana japonica* colony were investigated by introducing newly emerged *A. mellifera* drones each with one parasitic mite into an observation hive with two or three combs of *A. cerana japonica*.

Materials and Methods

Wire net was used to separate combs and bottom board, which was covered with paper smeared with Vaseline. Mites that fell on the paper were counted. In the first experiment, 205 *Varroa* mites were introduced into an *A. cerana japonica* colony with worker cells over five days in May 1997. Nine days later, worker cells were opened and inspected for the presence of mother mites and offspring. In a second experiment, 543 *Varroa*

Hygienic grooming behaviour induced by parasitic *Varroa* mites in *Apis cerana japonica*

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The Japanese honeybee (*Apis cerana japonica*) (Acj) and the European honeybee (*Apis mellifera*) (Am) share the same habitat in Japan. *Varroa jacobsoni* (Vj), originally an ectoparasitic mite of *A. cerana*, now heavily infests Am colonies. Experiments were conducted to compare the hygienic grooming behaviour of Acj and Am in response to *Varroa* parasitism. A semiochemical compound from cuticular extract of *Varroa* was identified using GC-MS, GC-EAD and behavioural bioassays. This compound induced typical hygienic allo-grooming behaviour in Acj worker bees. Am worker bees showed no response to mite or mite extract.

Predatory behaviour of *Vespa velutina* and *Vespa mandarina* attacking honeybee colonies

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Predatory wasps are serious enemies of honeybees in Himachal Pradesh, India. Ten species of wasps were observed preying on *Apis cerana* and *A. mellifera* colonies; of these, *Vespa velutina* and *V. mandarina* were of primary concern. Maximum attack by *V. velutina* was during August; September and October were peak periods of *V. mandarina* attack. Peak hours of attack varied for both species. Studies of behavioural traits revealed that *A. cerana* was more resistant to attack than *A. mellifera*. Some control measures to check the menace of these wasps in apiaries are suggested.

mites were introduced into an *A. cerana japonica* colony with drone and worker cells over eight days in June 1997. In this series, the queen died and worker cells disappeared. Fifteen days later, only drone cells were opened. The same procedure was also used for an observation hive of *A. mellifera* with drone and worker cells where 189 *Varroa* mites were introduced over eight days in July 1997.

Results

Introduction of *Varroa* mites into *A. cerana japonica* worker cells

Fallen mites were observed soon after introduction. The total number of fallen mites was 167 (81.5 %) (Table 1). There were 113 (67.7%) undamaged mites and 54 (32.3%) damaged. Thirty-six (66.6%) of the damaged 54 mites had damage on the legs, 15 (27.8%) on the legs and shield, and 3 (5.6%) on the shield. The other 38 mites apparently remained in the colony.

On Day 9, the colony was inspected for the 38 unaccountable mites. 1203 *A. cerana japonica* workers and 68 (33.2 %) introduced *A. mellifera* drones were found. Sixteen of the 1203 workers were infested with mites, leaving 22 mites unaccounted for. Worker cells were investigated

Table 1. Number of fallen mites introduced with *Apis mellifera* drones into *Apis cerana japonica* observation hive

Day	No. of mites introduced with *A. mellifera* drones*	No. of fallen mites		
		Undamaged	Damaged	Total
1	30	14	9	23
2	40	14	8	22
3	35	10	8	18
4	60	17	3	20
5	40	11	6	17
6	–	7	3	10
7	–	2	4	6
8	–	6	1	7
9	–	32	12	44
Total	205	113	54	167 (81.5 %)

Note: * One *Varroa* mite per newly emerged drone.

on Day 10. Eight (3.4 %) of 238 worker cells were infested. Eight mother mites (3.9 % of introduced mites) were recovered from worker cells, and offspring were found in two worker cells (25 %) with pupae 14 days old (Table 2). The remaining unaccounted for 14 mites might have disappeared with introduced *A. mellifera* drones driven out of the hive.

Introduction of *Varroa* mites into *A. cerana japonica* drone cells

Fallen mites were observed soon after introduction. Total number of fallen mites was 268 (49.4 %) (Table 3). There were 198 (73.9 %) undamaged and 70 (26.1 %) damaged mites. Forty-seven (67.2 %) of the 70 damaged mites had damage on the legs, 19 (27.1 %) on the legs and shield, and four (5.7%) on the shield. The other 275 mites apparently remained in the colony.

On Day 15, the colony was inspected for remaining mites. 1668 *A. cerana japonica* workers, three *A. cerana japonica* drones and 279 (51.4 %) introduced *A. mellifera* drones were found. Twenty-three of the 1668 workers were infested with mites, leaving 252 mites still unaccounted for. On Day 16, drone cells were opened. Eighty-two (54.7 %) of the 150 drone cells were infested. 141 introduced mother mites (26 % of introduced mites) were still in drone cells, 66 (80.5 %) of

Table 2. Survival and reproduction of *Varroa* mites artificially introduced into worker cells of *Apis cerana japonica* colony (n = 238)

Age of worker pupa	Stage	Composition of mites								
		Egg	Proto-nymph		Deuto- nymph			New adult	Mother mite	Total
			male	female	male	female	male female			
13	Dark brown-eye pupa (dbe)	0	0	0	0	0	0	0	1	1
14	Dbe, lightly-pigmented thorax pupa	0	0	1	1	2	0	0	1	5
14	Dbe, lightly-pigmented thorax pupa	1	0	1	1	2	0	0	1	6
15	Dbe, medium-coloured thorax pupa	0	0	0	0	0	0	0	1	1
15	Dbe, medium-coloured thorax pupa	0	0	0	0	0	0	0	1	1
16	Dbe, dark thorax pupa	0	0	0	0	0	0	0	1	1
16	Dbe, dark thorax pupa	0	0	0	0	0	0	0	1	1
16	Dbe, dark thorax pupa	0	0	0	0	0	0	0	1	1

which were filled with offspring. Sixteen cells (19.5 %) contained mother mites only with no offspring. The pupal period from pink-eye to dark thorax was parasitised at a high rate. New adult mites were found at the stage of dark brown-eye pupa. Some were at an unknown stage, meaning that some infested pupae were not at an exact stage when they died (Table 4).

Introduction of *Varroa* mites into *A. mellifera* worker and drone cells

Fallen mites were observed soon after the introduction. The total number of fallen mites was 120 (63.5 %) (Table 5). There were 86 (71.1 %) undamaged and 34 (28.3 %) damaged mites. Twenty-seven (79.4 %) of the 34 damaged mites had damage on the legs, five (14.7 %) on the legs and shield, and two (5.9 %) on the shield.

On Day 15 after the introduction, the colony was inspected. 2301 *A. mellifera* workers and 83 drones were living in the colony, 81 of which were infested with mites. The mite total was 201 or 13 mites more than the total introduced. Possibly there were some mite survivors in cells although the observation hive had been treated with acaricide. Differentiation of introduced and survivor mites was impossible.

Table 3. Number of fallen mites introduced with *Apis mellifera* drones into *Apis cerana japonica* observation hive

Day	No. of mites introduced with *A. mellifera* drones*	No. of fallen mites		
		Undamaged	Damaged	Total
1	50	18	1	19
2	45	11	1	12
3	35	7	6	13
4	30	5	3	8
5	17	7	6	13
6	75	9	1	10
7	128	41	12	53
8	163	44	14	58
9	–	5	8	13
10	–	8	2	10
11	–	11	3	14
12	–	8	7	15
13	–	11	5	16
14	–	8	1	9
15	–	5	0	5
Total	543	198	70	268 (49.4 %)

Note: *One *Varroa* mite per newly emerged drone.

Discussion

The average rate of falling mites was 65.5 % for *A. cerana japonica* and 63.5 % for *A. mellifera* (Fig. 1). Peng *et al.* (1987) reported that 73.8 % of fallen mites in an *A. cerana* colony were damaged; Fries *et al.* (1996) reported 30 % in *A. cerana* and 12.5 % in *A. mellifera* colonies. Lodesani *et al.* (1996) noted that 26.1 % of dead mites in an *A. mellifera* colony were damaged. In these studies, the mite damage rate in *A. cerana* colonies was higher than in *A. mellifera* colonies. However, in this

Table 4. Survival and reproduction in drone cells of *Varroa* mites introduced into *Apis cerana japonica* colony (n = 150)

Stage	No. of cells examined	No. of infested cells (%)	Eggs	% of cells with new offsprings: Proto-nymph male	Proto-nymph female	Deuto-nymph male	Deuto-nymph female	New adult Male (a)	New adult female (a)	Mother mite(a)
Prepupa	9	6 (67)	0	0	0	0	0	0	0	100 (1.5)
Pink-eye pupa	7	6 (86)	83	83	83	0	33	0	0	100 (2.3)
Red brown-eye pupa	10	7 (70)	29	57	71	43	57	0	0	100 (2.0)
Dark brown-eye pupa (dbe)	16	12 (75)	67	33	58	67	67	8 (1.0)	8 (1.0)	100 (1.6)
Dbe, lightly-pigmented thorax puta	10	7 (70)	57	71	100	43	43	14 (1.0)	4 (3.0)	100 (2.4)
Dbe, medium-colored thorax pupa	67	27 (40)	30	0	41	70	89	30 (1.0)	5 (1.0)	100 (1.3)
Dbe, dark thorax pupa	22	8 (36)	50	0	0	50	75	25 (1.0)	38 (1.3)	100 (1.5)
Unknown stage	9	9 (100)	33	33	33	11	11	11 (2.0)	11 (2.0)	100 (2.3)

Note: (a) Average no. of mites per infested cell.

Table 5. Number of fallen mites introduced with *Apis mellifera* drones into *Apis mellifera* observation hive

Day	No. of mites introduced with *A. mellifera* drones*	No. of fallen mites: Undamaged	Damaged	Total
1	25	2	1	3
2	20	5	4	9
3	4	6	7	13
4	20	5	4	9
5	25	9	2	11
6	40	11	0	11
7	30	6	4	10
8	25	8	2	10
9		5	4	9
10		6	2	8
11		12	1	13
12		6	3	9
13		5	0	5
Total	189	86	34	120 (63.5 %)

Note: *One *Varroa* mite per newly-emerged drone.

experiment there was little difference (Fig. 2). This may be because the ability of *A. mellifera* to recognise foreign material was stimulated as many mites were introduced into the colony at one time. Tewarson *et al.* (1992) reported that 25 % of mites were recovered when mites collected from an *A. cerana japonica* colony were introduced into worker cells but there were no new female adults; 3 % of the grafted mites laid eggs. Yoshida *et al.* (1995) reported parasitism and reproduction of *Varroa* mite in *A. cerana japonica*. In a survey of absconding *A. cerana japonica* colonies, a 1.9 % parasitisation rate was counted in worker cells. In drone cells of a worker-laying colony, it was 38.4 %, 97 % of

Chemical control of *Vespa* spp. attacking *Apis* spp. in Pakistan

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The hornet (*Vespa* spp.) attacks *Apis* spp. during July–October in Pakistan. *Vespa velutina* caused heavy mortality of *A. mellifera* and *A. cerana* followed by *V. tropica* and *V. basalis*. *Apis cerana* copes with hornets better than *A. mellifera*. Earlier methods of hornet control are either expensive or have practical limitations. Poisoned baits using strychnine hydrochloride and zinc phosphide mixed with honey (1:20) were tested against hornets. Some 30–50 *velutina* adults, captured from *A. cerana* and *A. mellifera* apiaries, were fed on sugar solution, honey and minced meat. Before sunset, one drop of bait was poured on to the thorax of each hornet. Some 200–300 adults treated with poisoned baits were released at 9 sites in Islamabad/Rawalpindi. Hornet mortality was noted by daily counts of adults dead on ground under nests. After 3–4 days, nests were opened and remaining adult hornets/brood counted. Overall hornet mortality was 76.2–86.7% in treatment with strychnine hydrochloric, 71.6–80.3% with zinc phosphide and 0.9–2.2% in control. This technique seems to be useful provided the operation is extended over a long period. It can be practiced by beekeepers on a large scale.

Biological control of wax moth in Yunnan

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Wax moth (*Galleria mellonella* and *Achroia grisella*) cause serious damage to *Apis cerana* every year in Yunnan. Traditional insecticide treatment causes pollution of bee products and is not economical. After observing the life cycle of wax moth in apiaries in Mongzi county and Yaon county from 1995–96, two key periods (March and October) were found for treatment by cleaning the hive, exchanging old combs with new and melting old combs. Tests showed that wax moth harm could be reduced by 84% in this way.

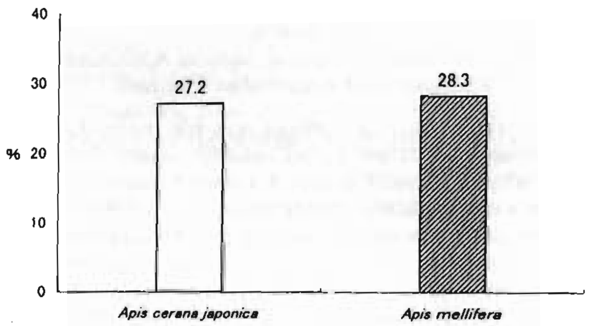

Fig. 1. Percentage of damaged mites in total mites fallen to bottom of *Apis cerana japonica* and *A. mellifera* colonies

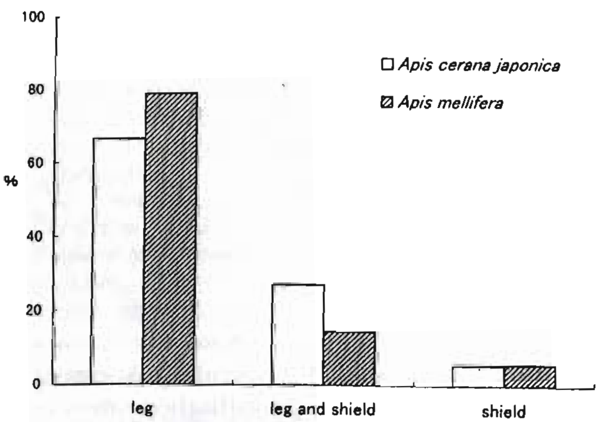

Fig. 2. Type of damaged to mites in *Apis cerana japonica* and *A. mellifera* colonies

which had offspring. In this experiment, the parasitisation rate of introduced mites in worker cells of *A. cerana japonica* was 3.9 % and offspring were found at a rate of 0.8 %. Eggs and nymphs were observed. On the other hand, new female adults were not seen, possibly because the timing was too early. It has been reported that the reproduction rate in worker cells is higher than in drone cells (Martin, 1995): drone cells of *A. cerana japonica* had 26 % parasitisation and 80.5 % had offspring. In this *A. cerana japonica* colony, the reproduction rate in drone cells was also higher than in worker cells.

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Chapter 19

Defence Behaviour of *Apis mellifera carnica* against *Varroa* and Inheritance of Defence Traits

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Beekeeping with *Apis mellifera* is now endangered world-wide by the mite, *Varroa jacobsoni*. *Varroa* can be controlled chemically but this has resulted in the contamination of hive products (Boeking and Ritter, 1994). Recently reported acaricide-resistant strains (Milani and Vedova, 1996) and limitations of chemical control have led scientists to explore the possibility of selecting *Varroa*-resistant strains. Some studies have indicated the natural defence mechanism in *A. mellifera* (Büchler *et al.*, 1992; Peng *et al.*, 1987; Ruttner and Hänel, 1992). Direct evidence regarding the defensive abilities of *A. mellifera camica* against *Varroa* in the form of video observations and infra-red photographs have been reported (Boeking, 1994; Thakur *et al.*, 1997). *Varroa*-defence is normally measured indirectly by per centages of damaged mites falling on to the bottom of hives (Bienefeld, 1996; Büchler, 1994) or the removal of artificially killed brood (Hoffman, 1996). Both methods are strongly affected by environmental influences. Colony-level selection may not be particularly efficient for *Varroa*-resistance breeding because of significant intracolonial variations. Thakur *et al.* (1997) found that *Varroa*-resistant traits, e.g, uncapping and removing, are performed at various levels within a colony. Some workers were found to be extremely active, whereas the majority were inactive. Boeking (1994) observed several bees repeatedly removing cell cappings. These results may be explained by the fact that colony composition has various patrilines with a different distribution of behavioural response thresholds for stimuli eliciting a task.

However, the different behaviour levels with respect to uncapping and removal of *Varroa*-infested cells may be caused by environmental effects. To quantify the inheritance of this *Varroa*-tolerance behaviour, these investigations were designed with the use of honeybee reproduction in particular. Moreover, breeding from workers may have advantages (Boeger, 1969) because it may provide the precision needed to detect genetic combinations that occur at low frequencies such as resistance to *Varroa* (Harris and Harbo, 1991).

Materials and Methods

Twenty-four hours before emergence, brood frames from six colonies with different per centages of damaged mites were separately placed in an incubator (34.5°C, 50–60% R.H.).

Workers (n = 50, 0–12 h old) from each colony were labelled with numbered plates on the thorax. Marked bees were maintained in a frame cage with a sliding panel of glass on one side and metal gauze on the opposite side. The cages, with four bee frames and one adjacent brood frame, were placed in a polystyrene mating box. An infra-red video camera was placed in front of the glass panel (Thakur *et al.*, 1996).

Marked workers were evaluated for selection of individuals that performed excellently during uncapping and removal of artificially mite-infested worker brood and responded to mite-infested dancers by nest-mate grooming. Mites were introduced in freshly capped worker brood (Rath and Drescher, 1990). Grooming behaviour and reactions of workers individually infested with mites was recorded continuously. Some excellently performing workers (n = 15) were maintained in a queenless and broodless nucleus containing young bees and sufficient provisions. Unmarked workers were replaced by a new batch of newly emerged workers at 5–8-day intervals (Harris and Harbo, 1988). Drone-rearing and drone-holding units were continuously supplied with pollen.

Queens (n = 5), reared from a homogenous stock of *A. mellifera carnica*, were instrumentally inseminated with mixed semen (3–4 μl) from drones (n = 8–12 each) reared from selected laying workers. Progeny from one cross was evaluated for genetic gain with regard to uncapping of artificially *Varroa*-infested brood, removal of uncapped cells and nest-mate grooming. The test population of the progeny (55 bees) was compared against the control (95 bees). The control consisted of bees taken from a well-established and homogeneous line from which the queens were reared.

Varroa-defence responses of marked bees in both the selection and progeny testing experiments were video-recorded continuously for seven days using an infra-red photography technique (Thakur *et al.*, 1996, 1997). Data were subjected to non-parametric analysis by using a Chi-square test (SAS Institute, 1988).

Results

With the control set at 100%, performances of bees supplying semen for the production of the next generation were 894% for uncapping, 333 % for removing and 54% for nest-mate grooming (Fig. 1). In total, 53.6% of the control and 10.9 % of the bees from Fl were not found to be involved in uncapping of 11 artificially *Varroa*-infested cells. Of the selected offspring, 25.4% were involved in the uncapping of more than five infested cells compared to only 6.3% of control bees. Uncapping of eight of the 11 infested cells was initiated by bees from the F1 generation (Fig. 2).

Behaviour concerning removal was also similar but less distinctive. The frequency of Fl bees involved in the process of removing was also higher in comparison to the control. With the control set at 100%, the performances of the offspring were calculated to be 290%, 239% and 157%. The uncapping process began between 4–5 days after infestation.

Discussion

Present studies show genetic improvement with regard to uncapping and removal of artificially *Varroa*-infested brood since a higher per centage of bees from Fl were found to be involved in comparison to the control (Fig. 3). Moreover, in 72.7% (8/11) of the infested cells, the uncapping process was started by bees from the Fl generation, which indicates that more of them were capable of detecting mites in the brood cells, possibly by perceiving signals, in comparison to bees from the control.

The fact that the uncapping of most of the *Varroa*-infested cells began between 4-5 days after infestation (Fig. 4) indicates that disturbance by the mite caused to the growing pupa resulted in the release of some cues or signals. These cues were possibly perceived by the uncappers and resulted in the initiation of opening. This is also supported by the fact that when freshly capped brood cells are infested and returned to a colony,

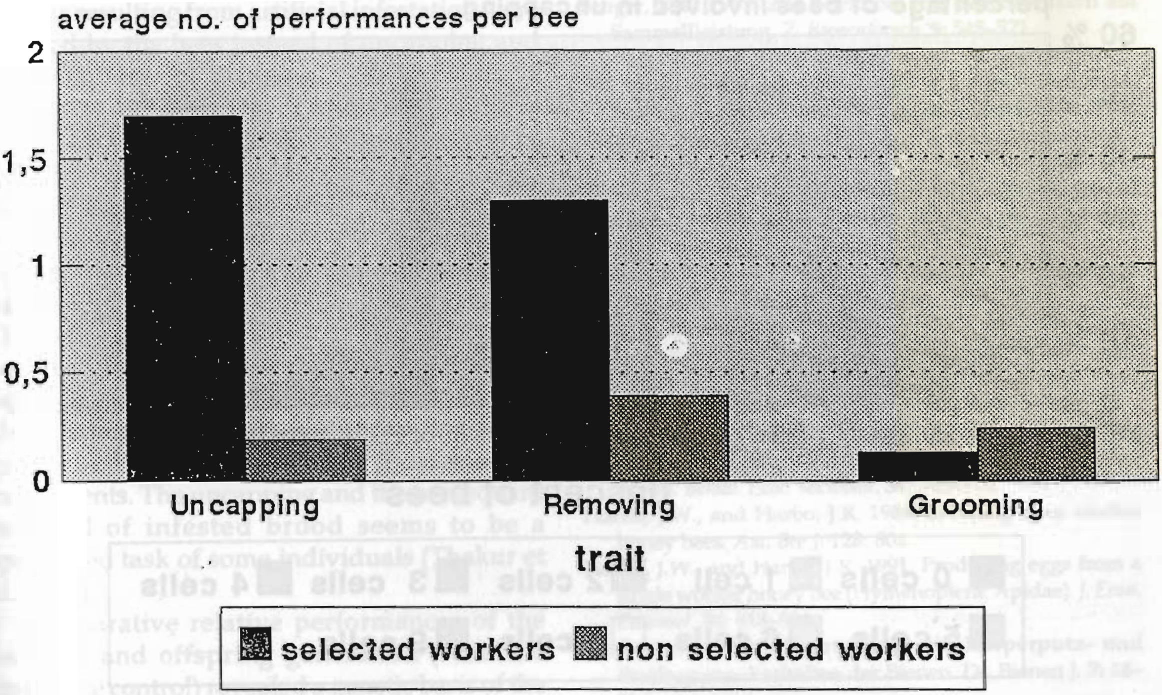

Fig. 1 Average performance of selected and non-selected workers

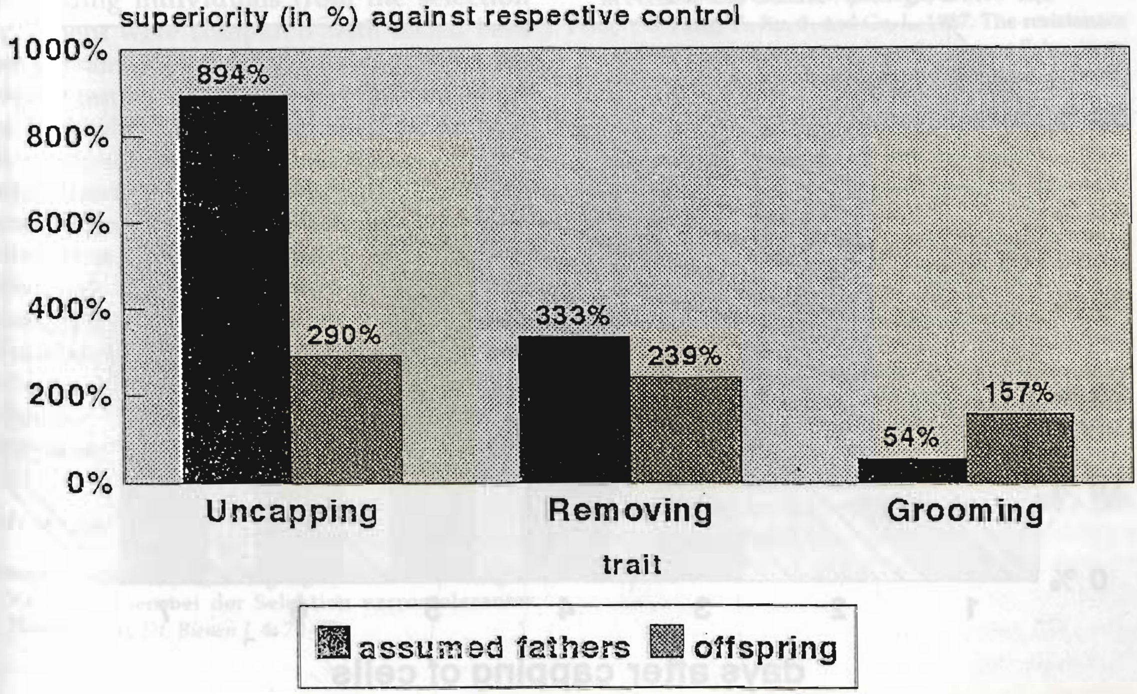

Fig. 2. Percentage superiority of assumed fathers and offsprings of assumed fathers

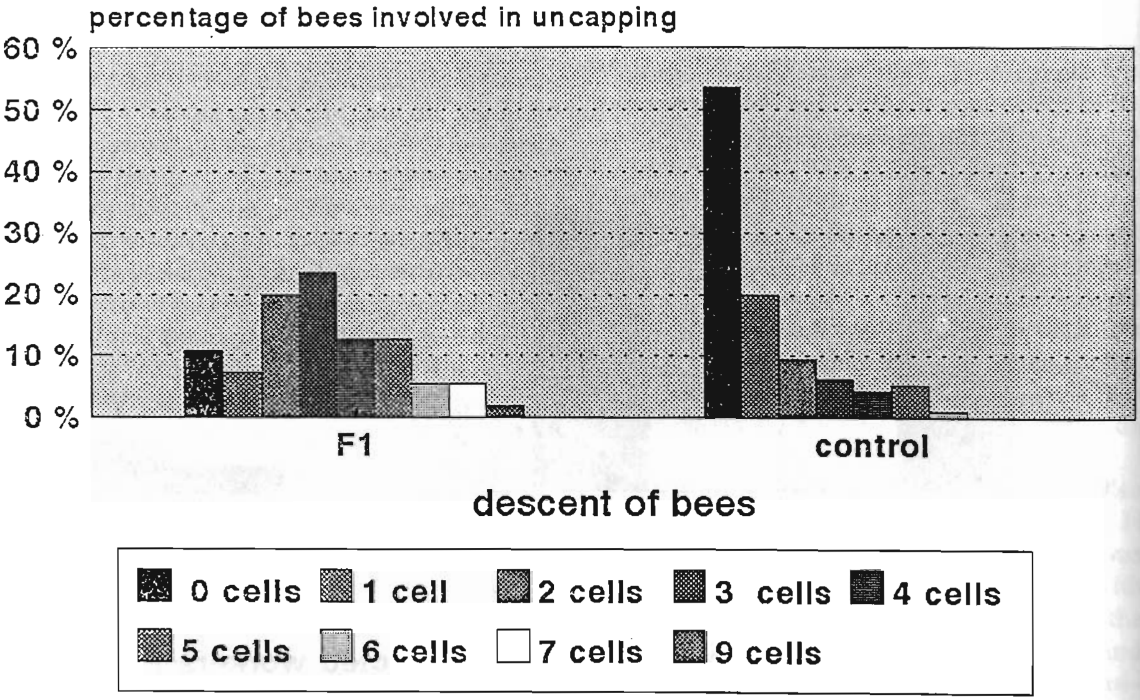

Fig. 3. Percentage of workers involved in uncapping

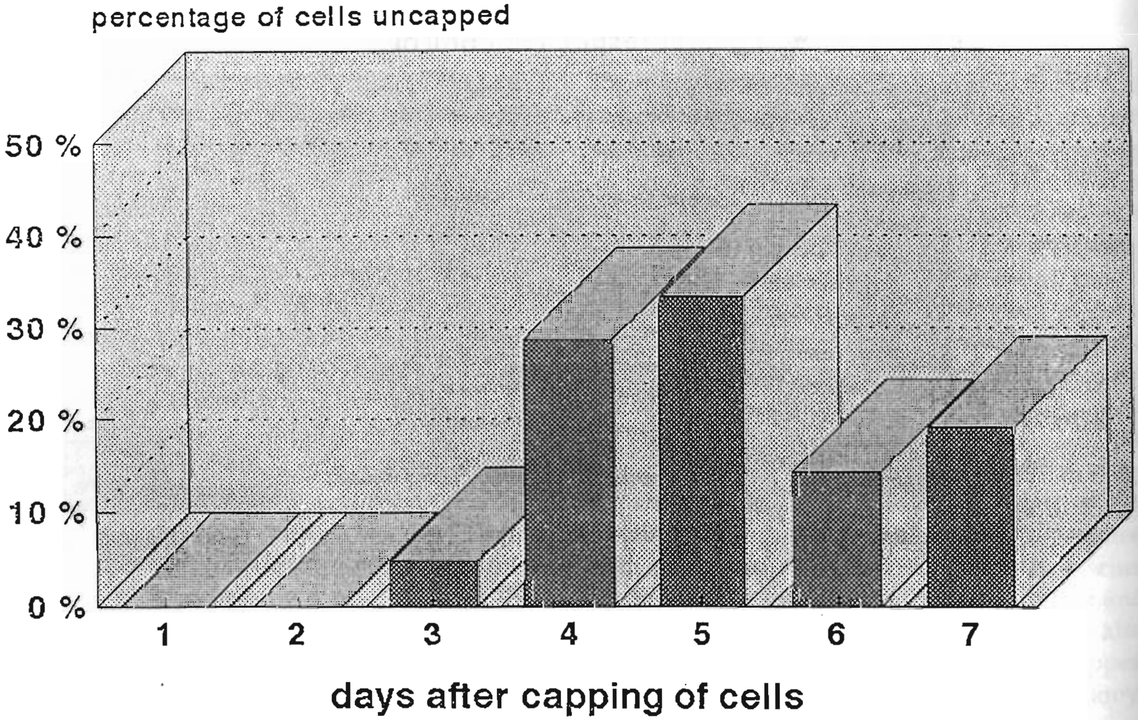

Fig. 4. Time of uncapping

the cuts resulting from artificial infestation were resealed by the bees instead of uncapping and removing larva at that stage. The initiation of uncapping between Day 4 and Day 5 may be caused by the rhythmic behavioural activity of mites searching for a feeding site on the pupal body (Donze and Guerin, 1994). The rise in these activities may cause the release of certain stimuli or cues by pre-pupae and pupae because of injuries or irritation as a result of feeding mites. These cues may be perceived by some specialists which in turn start uncapping. The possible preference of only a few bees to respond to the above stimuli and start the uncapping has a genetic basis as demonstrated by these selection experiments. The uncapping and the consequent removal of infested brood seems to be a specialised task of some individuals (Thakur et al., 1997).

Comparative relative performances of the parental and offspring generation (with the respective control) revealed a genetic basis of the traits for uncapping and removing. However, controls are not directly comparable because the outstanding individuals from the selection experiment were compared with tested bees from the same six lines. The control group in the progeny testing experiment were from a single line from where the mothers of all control and tested individuals came. These findings revealed partial transfer of superiority with respect to uncapping and removal behaviour to the next generation. This procedure of selecting individuals for *Varroa*-defence traits—making drone layers and using the resulting drones to inseminate the queens of selected stock—seems to be an efficient approach. It may help in inducing *Varroa*-tolerance/resistance in honeybees.

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Chapter 20

Study on Incidence of Parasites and Diseases of *Apis cerana* and *Apis mellifera* in Nepal

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In this study a preliminary attempt was made to investigate the occurrence of parasites and diseases of the honeybees, *Apis cerana* and *A. mellifera*, from different parts of Nepal.

Materials and Methods

Beekeeping areas within Nepal were visited to collect bee disease samples and to inspect colonies for the presence of parasites. Samples were collected from the following localities: Dhankuta, Bhojpur, Humla, Dadeldhura, Kavre, Chitwan, Rolpa, Lalitpur, Dolkha and Kathmandu. The combs were inspected for sealed and unsealed dead larvae displaced in unnatural positions in cells that had turned from white to yellow brown or dark brown. Dead larvae were taken from combs, crushed and air-dried. Bees crawling about in front of hives were killed with dilute ether and collected along with dead bees. Adult bees samples were kept in 70 % ethyl alcohol to enable diagnosis of tracheal mites. During the collection of brood, the presence of sacs within the body of larvae was noted for laboratory diagnosis. The presence of parasitic mites and wax moth were also noted.

Adult bee samples were diagnosed for nosema and amoeba diseases, and for the tracheal mite, *Acarapis woodi* (acarine disease). Brood samples were diagnosed for European Foul Brood (EFB), and Thai Sac Brood Virus (TSBV).

Results and Discussion

Results are shown in Tables 1 and 2.

None of the samples was infested with nosema or/and amoeba diseases. The absence of these diseases in *A. cerana* colonies may be because most *A. cerana* colonies are kept in log hives located in remote areas where cross-transmission of these diseases from *A. mellifera* is rare.

Adult honeybees of both species were diagnosed with *Acarapis woodi*. Among 16 colonies of *A. mellifera* from Kathmandu valley, 11 were infested. However, *A. woodi* was found in *A. cerana* only from Dadeldhura district from where the disease had been reported previously by Shrestha *et al.* (1993).

EFB disease was diagnosed in many localities. Secondary infection with *Streptococcus faecalis* was also found. During laboratory cultivation on bacteriological medium, heavily infected colonies produced small white opaque bacterial colonies within three days of incubation, and

Table 1. Field incidence and pathogens associated with honeybee colonies in Nepal

District	Hive type	Bee species	No. of colonies inspected	*Acarapis woodi*	EFB	TSBV
Dhankuta	Log hive	*A. cerana*	22	–	3	1
Bhojpur	Log hive	*A. cerana*	24	–	–	7
Humla	Log hive	*A. cerana*	54	–	4	2
Dadeldhura	Log hive	*A. cerana*	22	3	–	1
Kavre	Frame hive	*A. mellifera*	8	–	–	1
	Log hive	*A. cerana*	12	–	–	2
	Wall hive	*A. cerana*	2	–	–	–
Chitwan	Frame hive	*A. mellifera*	42	–	4	6
Rolpa	Log hive	*A. cerana*	68	–	6	5
Lalitpur	Frame hive	*A. cerana*	36	–	1	3
	Frame hive	*A. mellifera*	32	–	3	3
Dolkha	Log hive	*A. cerana*	26	–	2	2
	Frame hive	*A. cerana*	13	–	1	2
Kathmandu	Frame hive	*A. mellifera*	66	11	10	3
	Frame hive	*A. cerana*	28	–	5	5

Table 2. Presence of *Varroa jacobsoni*, *Tropilaelaps clareae* and wax moth

District	Hive type	Bee species	*Varroa jacobsoni*	*Tropilealaps clareae*	Wax moth
Dhankuta	Log hive	*A. cerana*	2	–	2
Bhojpur	Log hive	*A. cerana*	2	1	6
Humla	Log hive	*A. cerana*	2	–	5
Biratnagar	Frame hive	*A. cerana*	2	–	–
Chitwan	Frame hive	*A. mellifera*	12	4	–
Rolpa	Log hive	*A. cerana*	2	–	–
Godavari	Frame hive	*A. cerana*	2	–	–
Lalitpur	Frame hive	*A. mellifera*	16	2	–
Kathmandu	Frame hive	*A. mellifera*	36	–	–
	Frame hive	*A. cerana*	1	–	–

weakly infected colonies samples produced such bacterial colonies within five to eight days.

For the detection of Thai Sac Brood Virus, gel diffusion against antiserum (Bailey *et al.*, 1964) was used. The disease was diagnosed in many localities.

Only a general survey for the presence of parasitic mites, *Varroa* and *Tropilaelaps*, and wax moth was conducted.

Acknowledgements

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Chapter 21

Integrated Control Methods of Parasitic Mites on Honeybees

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Among 11 species of honeybee mites known in Korea (Woo and Lee, 1993), economic losses caused by *Varroa jacobsoni* and *Tropilaelaps clareae* have been enormous since their introduction. Even though Woyke (1987) and Cobey and Lawrence (1988) discussed control methods of *V. jacobsoni* and *T. clareae* other than acaricides, a questionnaire survey in 1993 by Woo *et al.* (1994) revealed that Korean beekeepers regard spraying acaricides as the only method of control (Table 1).

The problem is heavy dependence on acaricides resulting in residues in honey and mite-resistance as well as an increase in costs for beekeepers. This paper reports experiments performed to find the optimum number of treatments of acaricides and other methods to control bee mites, and discusses effective methods that can be used in an integrated way to control *V. jacobsoni* and *T. clareae* based on recent research (Woo, in press).

Chemical Control of *Varroa jacobsoni* and *Tropilaelaps clareae*

As shown in Tables 1 and 2, on average eleven treatments of various acaricides are given to control bee mites.

Table 1. Results of questionnaire survey on the number of acaricide treatments a year

Number of treatments (times)	Number of respondents	Ratios (%)
2	5	1
3–4	22	6
5–6	41	11
7–8	45	12
9–10	54	15
11–12	30	8
13–14	35	9
more than 15	140	38
Total	372	100

Table 2. Chemical control of bee mites

Acaricides	Major chemical component(s)
Micut, Mitac, Baam	Amitraz 20%
Apistan	Fluvalinate 10%
Apitol	Cymiazol (350 mg/2 g)
Bayvarol	Flumetrin
Folbex-VA	Bromopropylate (370 mg/ 1 strip)
Dacar	Unknown
Mavrik	Fluvalinate 5%
Formic acid	Formic acid
Perizin	Coumaphos 8g/1*l*
P2	Unknown
Apilife Var	Thymol, Eucalyptol, Menthol, and Camphor

Recent research (Woo, in press) reports that Apistan and Bayvarol give relatively and slightly better results than others for controlling *V. jacobsoni* (Tables 3 and 4), but all acaricides guarantee good results.

Table 3. Control effects of various acaricides on *Varroa jocobsoni*

Acaricide	No. of honeybee mites controlled (in total)	No. of honeybee mites survived	Infestation (%)	Control effect (%)
	97	389	4.86	19.96
Control	396	1197	9.96	24.86
	137	338	3.39	28.84
	984	36	7.29	96.47
Apistan	597	1	4.27	99.83
	163	3	1.38	98.19
	754	37	5.65	95.32
Bayvarol	980	155	7.09	86.34
	569	121	5.75	82.46
	94	57	1.51	62.25
Folvex-VA	169	56	2.25	75.11
	357	83	3.67	81.14

Table 4. Control effects of various acaricides on *Tropilaelaps clareae*

Acaricide	No. of honeybee mites controlled (in total)	No. of honeybee mites survived	Control effect (%)
	1,600	5,102	23.87
Control	1,813	6,566	21.63
	2,165	8,891	19.58
	4,599	312	93.59
Apistan	7,472	678	91.68
	7,537	783	90.58
	4,903	625	88.69
Bayvarol	3,102	436	87.67
	4,574	631	87.87
	7,436	688	91.53
Micut (X 1,000)	4,037	596	87.11
	6,108	824	88.11
	4,145	2,132	66.03
Perizin	2,698	1,001	72.93
	3,241	1,233	72.44

Investigation of seasonal infestation rates (Table 5) reveals that at most three treatments are required for control of *V. jacobsoni* and *T. clareae*.

Inspection of colonies should be made before chemical treatment. Acaricides can be applied before overwintering (September–October) and after overwintering (March–April). However, application can be made in June only just before population density reaches a peak, and avoided if density is low before and after overwintering. Also, Tables 3 and 4 indicate that most acaricides are effective for control. Thus, more than two acaricides should be used together and in turn, rather than sticking to one as this helps to slow down the development of resistance by mites to acaricides.

Survival of *Tropilaelaps clareae* during Winter

Infestation rates of *T. clareae* during overwintering is 19.2% although it varied in different areas. Investigation in the Cheju Islands (Woo, in press) shows that *T. clareae* can survive during winter when average temperatures are higher than 2°C (Table 6; Fig. 1). This observation indicates that if bee colonies are kept in places where temperature are below 2°C, spread of *T. clareae* can be effectively prevented.

Contrary to Woyke (1997), recent research (Woo, in press) also reveals that adult *T. clareae* can survive for 5–7 days without existence of a host.

Colony Management

In migratory beekeeping, *V. underwoodi* changes host from *A. cerana* to *A. mellifera*. Where migratory beekeeping is common, this fact should be noted to prevent wider spread of *V. underwoodi*. Also the maintenance of strong colonies is key to preventing the spread of bee mites and damage by them.

Table 5. Seasonal infestation rates of *V. jacobsoni*

	Seasonal Infestation Rates					
	April 1997		June 1997		October 1997	
	No/Comb	Rate(%)	No/Comb	Rate(%)	No/Comb	Rate(%)
Worker (uncapped)	3/50	6	36/100	36	247/680	36
Drone (uncapped)	25/100	25	63/90	70	-	-

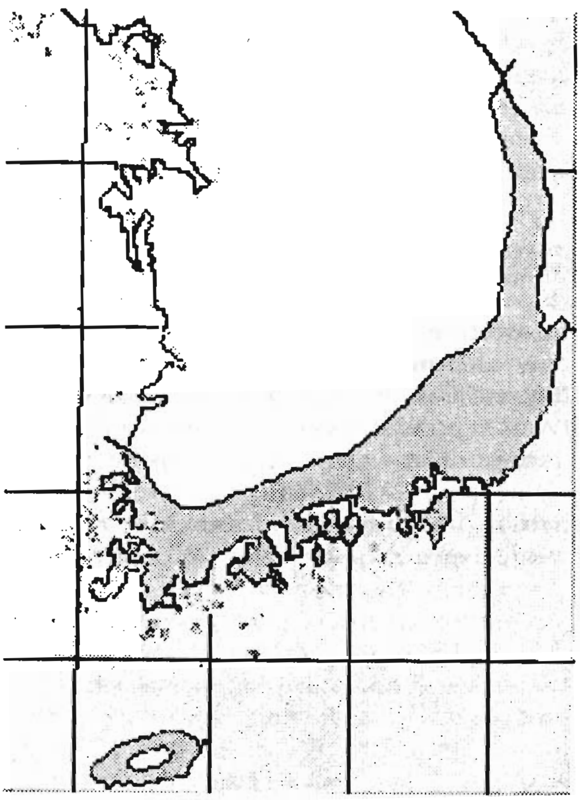

Fig. 1. Areas of Korea where *T. clareae* can survive during winter (Woo, in press).

Table 6. Infestation rates of *T. clareae* in overwintering bee colonies at different altitude

Locality	Altitude (m)	Brood area
Cheju city	100	Present
Bukcheju-Kun	100	Present
Seoguipo City	100	Present
Namcheju-Kun	200	Present
Bukcheju-Kun	400*	Absent
Sansemibong	600*	Absent

*The average temperature of marked areas are below 2°C. Temperatures of other areas fall in the range between 4–7°C in December, January and February.

Table 7. Development period of each stage of *T. clareae* in Korea

	Developmental period of each stage (hours)				
	Egg	larva	pre-nymph	deuto-nymph	Total
Worker	7.2 - 9.6	7.2 - 14.4	38.8 - 42	72 - 86.8	144

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Chapter 22

Integrated Defensive Strategy against Microbial Infection in Honeybee Colonies

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The atmosphere inside a honeybee colony is usually warm and humid with abundant food (honey and pollen) that provides ideal conditions for microorganizms. However, the actual intra-colonial environment is kept clean. We hypothesized that the inside of a honeybee colony, which is often called a 'super organizm', is analogous to inside the body of an ordinary insect. Honeybees seem to have evolved integrated defensive systems that exploit exogenous materials such as propolis, and endogenous substances such as antibacterial peptides and vaporous compounds of various origins.

Strategy 1: Individual Level

Antibacterial activities were induced in the hemolymph of individual honeybees injected with viable *E.coli* (Casteels *et al.*1989). We speculated that larvae and pupae have poorer inductive antibacterial activity than adults because they are nursed at the centre of the colony under aseptic conditions. However, antibacterial activities were induced in the hemolymph not only of adults but also of larvae and pupae (Fig. 1). No difference was found in the inductive ability among aging workers or

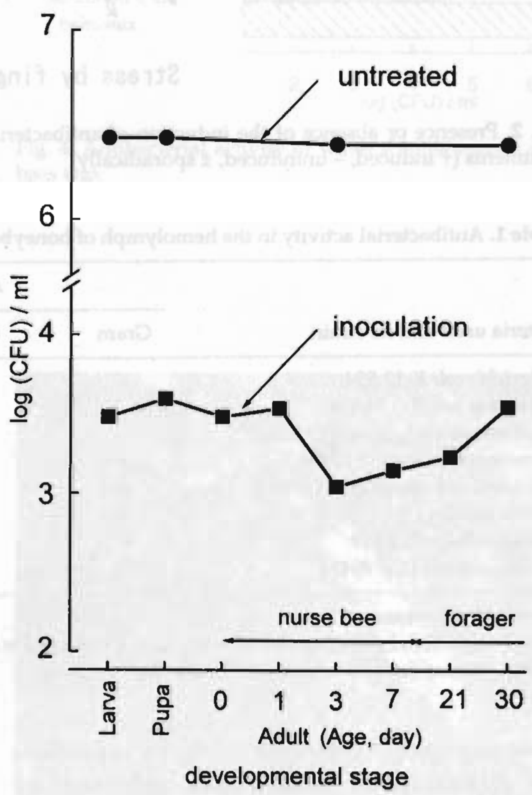

Fig. 1. Changes in antibacterial activity with the developmental stages and adult aging [inoculation: hemolymph (100 µl/20 bees) was diluted to 25%; untreated: not diluted]

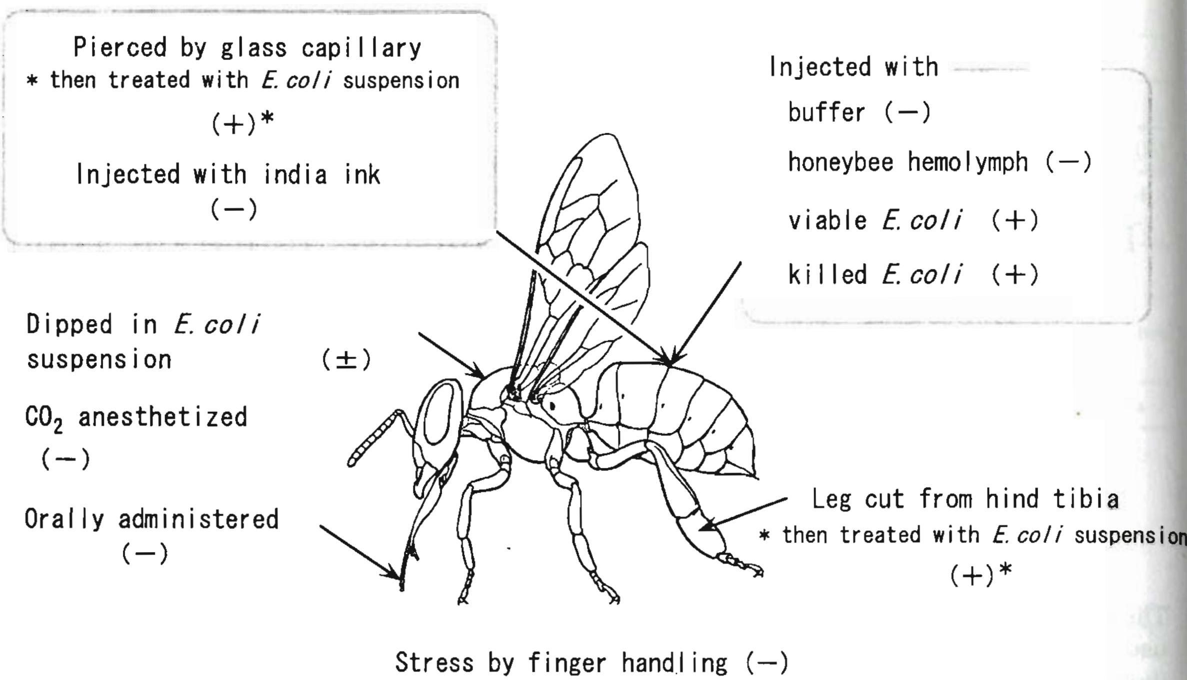

Fig. 2. Presence or absence of the induction of antibacterial activity in the hemolymph of honeybees received various treatments (+ induced, - uninduced, ± sporadically)

Table 1. Antibacterial activity in the hemolymph of honeybees injected with viable *E.coli* K-12

		A. mellifera		*A. cerana japonica*	
Bacteria used and its strain	Gram	untreated	inoculation	untreated	inoculation
Escherichia coli K-12 594	-	0.0	17.7	0.0	17.7
Escherichia coli IFO 12734	-	-	14.4	-	17.8
*Pseudomonas aeruginosa IFO 12689**	-	-	8.0	-	8.0
Micrococcus luteus IFO 12708	+	-	17.2	-	15.9
Staphylococcus aureus IFO 12732	+	-	17.6	-	14.0
Bacillus subtilis	+	0.0	9.8	0.0	-
Bacillus subtilis PCI 219	+	-	0.0	-	8.0
Bacillus larvae ATCC 9545T*	+	-	0.0	-	0.0

* Honeybee diseases.
Hemolymph (5.5µl / bee) of 100 µl was put in a cup (inside diameter 6 mm) and cultured at 30 °C for 24 h.
Inhibitory zone (mm) was measured with slide calipers.

those engaged in different work. To reproduce the situation of honeybees infected by microorganizms in natural conditions, no activity was induced by oral administration of *E. coli* but was occasionally induced by external application (Fig. 2). Antibacterial activity is not shown against *Bacillus larvae,* which is a pathogen of American Foul Brood (Table 1).

Strategy 2: Antimicrobial Measures

To make inside the colony aseptic, honeybees seemed to use antibacterial principles in beeswax. We speculated that antibacterial activity was not due to propolis because activity was found even in *Apis mellifera* colonies confined in a cage separate from their beeswax, and in *A. cerana* colonies that never use propolis (Fig. 3). However, antibacterial activity was found in water-soluble extract of virgin wax scales (Fig. 3) that had just been secreted from the abdomen and not yet mixed with saliva (Fig. 4). Development of stronger antibacterial activity with processing (Fig. 5) suggests that the active substance originates from saliva or exogenous propolis. Antibacterial activity of water-soluble extract from beeswax showed up against *Bacillus larvae*, which is a pathogen of American Foul Brood (Table 2). Also, water-soluble extract of cell

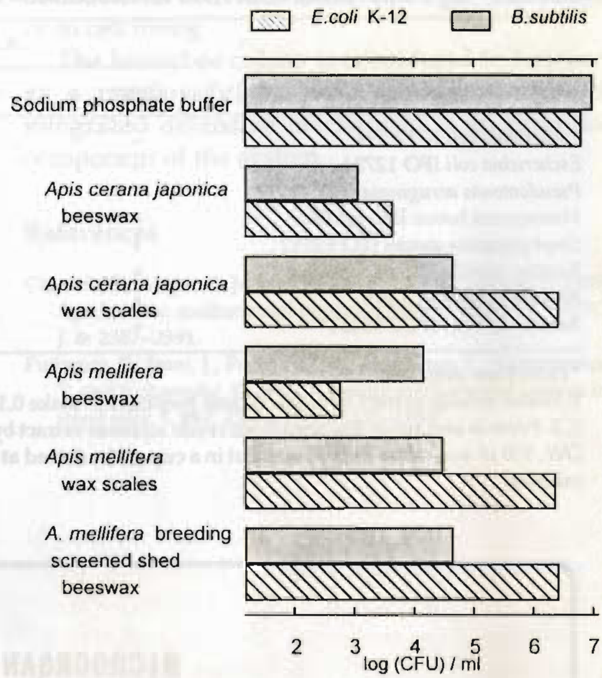

Fig. 4. Antibacterial activity of water soluble extract from bees wax

Fig. 3. Wax scales

Fig. 5. Beewax processed by honeybees

Table 2. Antibacterial activity in the water soluble extract of beeswax

	A. mellifera			*A. cerana japonica*	
Used bacteria and its strain	Gram	crude[1]	crude[1]	280[2]	490[3]
Escherichia coli K-12 594	–	8.0	9.4	0.0	0.0
Escherichia coli IFO 12734	–	–	8.7	0.0	0.0
Pseudomonas aeruginosa IFO 12689*	–	–	12.6	0.0	0.0
Micrococcus luteus IFO 12708	+	–	18.6	0.0	14.4
Staphylococcus aureus IFO 12732	+	–	20.6	0.0	0.0
Bacillus subtilis	+	9.2	10.5	–	–
Bacillus subtilis PCI 219	+	–	12.9	0.0	0.0
Bacillus larvae ATCC 9545T*	+	17.9	17.9	–	–

* Honeybee diseases.
1. Water soluble extract of beeswax was prepared to make 0.1 g / ml DW, 100μl was used.
2, 3. Peptide and sugar fractions from crude aqueous extract by gel filtration. Each fraction was prepared to make 0.01 g/ml DW, 100 μl was used. Extract was put in a cup and cultured at 30°C for 24 h. Inhibitory zone (mm) was measured with slide calipers.

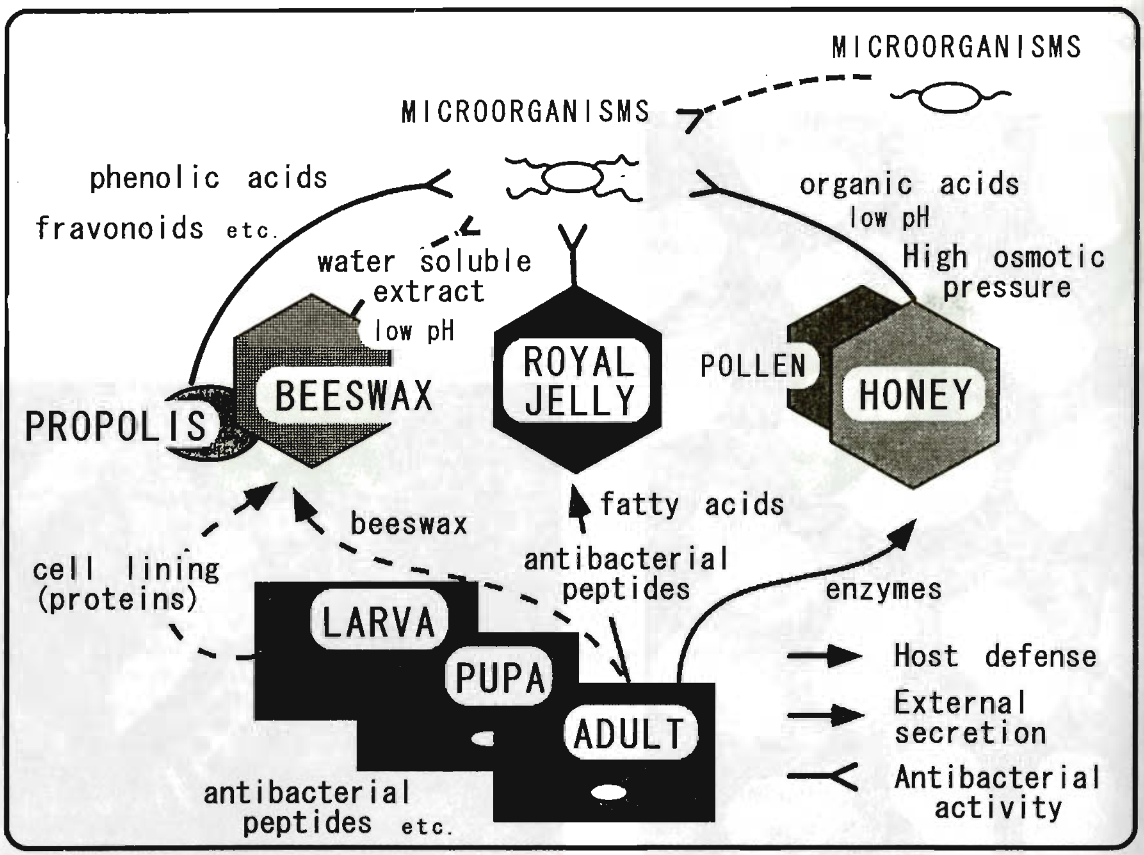

Fig. 6. Concept of integrated defensive strategy against microbial infection in the honeybee colony

lining also had antibacterial activity that might protect the pupae from exogenous infection.

Strategy 3. Integrated Defense to Microorganizms

Anti-microorganizmic measures in honeybee colonies are summarised in Fig. 6. As already mentioned, the larvae and pupae have similar host defense mechanisms to that of the adult. The external secretion of 'royalicin' (Fujiwara *et al.* 1990) could be analogous to internal phenomenon if the colony was regarded as an individual organizm. The same can be said for antibacterial activities found in virgin wax scales or in cell lining.

The honeybee colony is considered to function as a purposeful 'superorganizm', and the integrated defensive mechanism is an essential component of the system.

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Chapter 23

Activity of Oxytetracycline against *Bacillus larvae*

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American Foul Brood (AFB) is an important disease of larval European honeybees (*Apis mellifera*) caused by the bacterium, *Bacillus larvae*. Only the spore stage of *B. larvae* can initiate the disease. One-day-old larvae are highly susceptible, whereas two-day-old larvae are highly resistant (Chen *et al.*, 1997). In Taiwan, AFB was reported in 1967 (Yen and Chyn, 1971) and is still an important disease. Oxytetracycline (OTC) has been widely used for AFB control, and methods of use have been postulated by Delaplane and Lozano (1994). Considerable work has also been carried out on the stability of OTC in honey stored by bees (Lehnert and Shimanuki, 1981; Matsuka and Nakamura, 1990; Wilson, 1974) and the stability of OTC in diets fed to bees for disease control (Gilliam, 1975). However, less work has been aimed at the control efficiency of OTC, and how long OTC can prevent effects of AFB in field colonies. This paper surveyed the activity of OTC against *B. larvae in vitro* and in apiary colonies to formulate an AFB control strategy.

Materials and Methods

In vitro test

Three antibiotics, OTC, chlorotetracycline (CTC) and lincomycin, were tested for bacteriostatic and bactericidal activities against *B. larvae* spores (obtained from AFB scales) and vegetative cells (ATCC 9545) by broth dilution method. Each tube contained 4 x 10^6 cells (spores) per ml and were tested in BHIT broth at doses ranging from 0–400 μg per ml to determine the minimal inhibitory concentration (MIC) and minimal bactericidal concentration (MBC).

Control efficiency in field colonies

Eight healthy hives with no history of AFB each of nine frames and approximately the same strength were selected. Four were fed 1 kg of sugar syrup containing 50 mg of OTC, and four were fed 125 mg of OTC. To determine the control efficiency, 90 one-day-old larvae were marked and inoculated with 21 spores, 442 spores or water only. Each colony was inoculated on Day -14, -2, 0, 3, 7, and 10. When treated larvae reached capping stage, all adult bees were removed and capped frames were placed in an incubator at 37°C and 70% R.H. Nine days later, treated bees were examined for signs of AFB.

Therapeutic effects on diseased colonies

Twenty-one diseased hives with either light (AFB signs <50) or heavy infection (AFB signs >500) were selected. Adult bees only were kept, all frames were discarded and replaced by disease-free combs. OTC medication was carried out on Day 5 after frame replacement. Doses were 50 mg per colony or 125 mg per colony. Colonies

Table 1. Minimal inhibitory concentration (MIC) and minimal bactericidal concentrations (MBC) of three antibiotics to vegetative cells and spores of *Bacillus larvae*

Antibiotics	Vegetative cells		Spores	
	MIC	MBC	MIC	MBC
Oxytetracycline	0.016 μg/ml	0.125 μg/ml	0.125 μg/ml	>8.0 μg/ml
Chlorotetracycline	0.008 μg/ml	0.250 μg/ml	0.004 μg/ml	>8.0 μg/ml
Lincomycin	0.063 unit/ml	0.063 unit/ml	0.016 unit/ml	1.0 unit/ml

were surveyed weekly for AFB reoccurrence over 15 weeks.

Results and Discussion

In vitro test

The antimicrobial activity of OTC, CTC, and lincomycin is shown in Table 1. All these antibiotics may have good potential for controlling AFB in hives; however, OTC is the only approved medication in the USA and some other countries.

Control efficiency of OTC in field colonies

Although Delaplane and Lozaho (1994) postulated a control method—200 mg of OTC per colony repeated three times 4–5 days apart—this dose is probably too high for one-storey hives used in Taiwanese apiaries. In a preliminary study (Chen *et al.*, 1997), the pathogenicity of *B. larvae* to one-day-old larvae is 21 spores (LD_{50}) and 442 spores (LD_{95}). Treatment groups fed 125 mg of OTC showed good prevention of AFB with 0 % infection from Day (-2) to Day 7 of spore inoculation. Even at Day 10, treatment groups showed only 0.8 % infection. There were lower preventive effects in treatment groups fed 50 mg of OTC. They showed 0.8 % infection at Day 7 of inoculation.

Recovery of diseased colony

OTC has no sporicide effect, so all frames of diseased colonies should be discarded, if colonies are to be kept. By this method, treatment groups with light infection recovered without any drugs (Table 2). In groups with heavy infection, a dose of 125 mg OTC per colony was required to prevent reoccurrence of AFB.

Table 2. Date of AFB reoccurrence of infected colonies after comb replacement and OTC syrup treatment

Hive no.	Treatment[1]	AFB class before treatment[2]	Date of AFB reoccurrence (weeks)
P_{1-4}	125 mg OTC + R	**	n[3]
$O_{5-6,9}$	50 mg OTC + R	**	n
O_{7-8}	50 mg OTC + R	**	9
C_{1-3}	R	**	3
C_4	R	**	N
O_{1-4}	50 mg OTC + R	*	n
C_{5-8}	R	*	n
C_{9-12}	N	–	N

Notes: (1) R = all combs replaced by disease-free combs; 125 mg OTC = fed 125 mg of OTC five days after R; 50 mg OTC = fed 50 mg of OTC five days after R; N = no treatment (control). (2) * = AFB signs < 50; ** = AFB signs > 500; – = AFB free. (3) n = no AFB reoccurrence.

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Chapter 24

Accelerated Degradation of Carbaryl by Acclimated Bacterial Isolates from *Apis cerana* Bees

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Pesticide metabolism in microorganisms results in formation of toxic and/or non-toxic products (Kearney *et al.*, 1963). Stenerson (1965) first speculated upon the role of bacteria-influenced metabolism of DDT in resistant mosquitoes. Sharma and Nath (1996) showed adaptation to carbaryl of bacterial isolates from *Apis cerana* bees. Treatment of bees with these modified isolates resulted in decontamination of bees and enhanced tolerance to carbaryl. This paper reports carbaryl degradation by acclimated bacterial isolates in different media and discusses the effects of supplemented carbon sources on degradation rates.

Materials and Methods

Bacterial strains (*Citrobacter* sp., *Enterobacter aerogenes* and an unidentified bacterium) active in degrading carbaryl were the isolates of *Apis cerana* bees obtained by the enrichment and adaptation technique used Sharma and Nath (1996). The stock solution of carbaryl was prepared in dimethyl sulphoxide followed by filter sterilisation. These bacteria were made adaptive to carbaryl by transferring them every week from a medium containing a lower concentration of carbaryl to a similarly prepared medium containing a higher concentration of carbaryl. Every transfer to the higher concentration was made when more than 2000 colonies per ml of suspension were observed. The process was continued until 600 ppm were obtained.

Estimation of carbaryl and l-naphthol

Estimation of carbaryl was as used by Benson and Finocchiaro (1965); l-naphthol, an initial degradation product of carbaryl, was estimated by the same technique but without alkali hydrolysis of the samples.

Reagents and growth media

Growth and carbaryl degradation experiments were carried out in nutrient broth and basal salts medium. Experiments were also conducted with and without exogenous-added carbon sources in basal salts medium to see their effect on carbaryl degradation. The constituents of nutrient broth were peptone 5 g l^{-1}, NaCl 5 g l^{-1}, beef extract 3 g l^{-1} and distilled water 11 g l^{-1}. The basal salts medium contained L K_2HPO_4 $3H_20$ 5.8 g l^{-1}, KH_2PO_4 (anhydrous) 4.5 g l^{-1}, $(NK_4)_2So4$ (anhydrous) 2.0 g l^{-1}, $MgCl_2$ $6H_20$ 0.16 g l^{-1}, $CaCl_2$

$2H_20$ 0.02 g l^{-1}, Na_2MoO_4 $2H_20$ 0.002 g l^{-1}, $FeSO_4$ H_2O 0.001 g l^{-1}, $MnCl_2$ $4H_20$ 0.001 g l^{-1} and distilled water 11 g l^{-1} (Niemeela and Vaatanem, 1982). To study the effect of exogenous-added carbon sources on growth and carbaryl degradation, the basal salts medium was supplemented with glucose (0.2 g l^{-1}) and yeast extract (0.2 g l^{-1}) alone and in combination.

Inoculum

The isolates (24–28-h-old bacterial culture) were inoculated into nutrient broth and basal salts medium independently. Bacterial-cell suspension (0.5 ml) of 0.5 O.D. at 600 nm was routinely added to each flask containing 50 ml of medium to give a final concentration of about 1.5×10^5 cells ml^{-1}.

Carbaryl degradation and growth of bacteria

Carbaryl was added to the flasks containing 50 ml of media-inoculated bacterial isolates to reach a final concentration of 1 mM for determining growth and carbaryl degradation capacities of isolates. Each treatment was replicated three times. In every experiment there were controls for carbaryl degradation (i.e., medium containing only carbaryl but no bacterial cells) and for growth (i.e., medium containing only bacteria but no carbaryl). There was no degradation of carbaryl nor production of material from cells that interfered with the assay. Carbaryl enrichment cultures were incubated at 30°C under stationary conditions. Samples were drawn at 0–1, 24, 48, 72, 96 and 120 h of incubation for estimating loss of carbaryl and naphthol formation. Samples from these aliquots were also used for determining bacterial-cell population by measurement of cell survival by serial dilution and plating. The two media, nutrient broth and basal salts medium, were compared for degradation of carbaryl per unit biomass by various bacterial isolates by using t tests at 1 and 5% levels of significance. The effect of exogenous-added carbon sources on carbaryl degradation and growth of isolates was determined by comparing the basal salts medium with and without supplemented glucose and yeast extract. The data (mg μg^{-1} dry wt) were analysed statistically using CRD at 5% level of significance. Biomass was computed on the basis of the formula: 10^9 bacterial population = 380 µg biomass dry wt.

Results and Discussion

Degradation of carbaryl in culture media

All the bacterial species (*Citrobacter* sp., *Enterobacter aerogenes* and unidentified sp.) have the ability to grow and degrade carbaryl in nutrient broth and basal salts medium. Maximum growth and degradation of carbaryl were observed in nutrient broth compared to basal salts medium. All organisms exhibited about 25% carbaryl degradation at log phase (24–36 h). Maximum degradation (more than 80%) was during stationary phase of growth in nutrient broth and about 32–48% carbaryl degradation was during 72–96 h in basal salts medium. The carbaryl recovery in the absence of organisms at 1 mM concentration was about 95% in 120 h.

Quantitatively the breakdown of carbaryl per unit of biomass was more in basal salts medium compared to nutrient broth. When comparing these two media statistically, the value of 't' was

Table 1. Comparative degradation of carbaryl (mg/µg dry weight) by bacterial spp. in nutrient broth (N.B.) and basal salts medium (B.S.M.)

Time (h)	Carbaryl (mg/µg dry weight)					
	Citrobacter sp.		*Enterobacter aerogenes*		Unidentified sp.	
	N.B.	B.S.M.	N.B.	B.S.M.	N.B.	B.S.M.
24	0.034	0.438	0.063	3.509	0.082	7.895
48	0.019	0.132	0.025	1.716	0.022	3.289
72	0.025	0.111	0.039	1.786	0.026	1.316
96	0.026	0.150	0.039	1.933	0.028	1.404
120	0.027	0.204	0.041	1.907	0.029	1.624
't'	3.16*		6.41**		2.48*	

* Significance at 5% level
** Significance at 1% level

significant at 5% in all bacterial species, and in *Enterobacter aerogenes* it was significant at 1% (Tables 1 and 2). The degradation was greatest in the cultures of *Enterobacter aerogenes* and unidentified sp. compared to culture of *Citrobacter* sp. in basal salts medium. This difference in degradation of carbaryl could be because l-naphthol formed in basal salts medium with carbaryl as the sole source of both carbon and nitrogen concomitant with faster carbaryl degradation. In nutrient broth, because of preferential utilisation of available energy sources, conversion of 1-naphthol to other metabolites did not take place. Liu and Bollag (1971) demonstrated that the influence of changed growth conditions on microbes, heavy

Table 2. Efficacy of bacterial isolates to degrade carbaryl (mg μg^{-1} weight) in nutrient broth and basal salts medium

Time (h)	Carbaryl (mg μg^{-1} dry weight)					
	Nutrient broth			Basal salts medium		
	Citrobacter sp.	*Enterobacter*	Unidentified	*Citrobacter*	*Enterobacter*	Unidentified
024	0.034	0.063	0.082	0.438	3.509	7.895
048	0.019	0.025	0.022	0.132	1.716	3.289
072	0.025	0.039	0.026	0.111	1.786	1.316
096	0.026	0.039	0.028	0.150	1.933	1.404
120	0.027	0.041	0.029	0.204	1.907	1.624
F(CD)	2.76(0.055)				5.46(2.062)*	

* Significance at 5% level

Table 3: Effect of exogenously added carbon sources on degradation of carbaryl (mg/μg dry weight) by carbaryl enrichment cultures in basal salts medium (BSM).

Bacterial sp.	Time (h)	Carbaryl (mg μg^{-1} dry weight)			
		BSM	BSM	BSM	BSM
			+glucose (g)	+yeast extract(y)	+(g+y)
	24	3.51	7.39	2.81	0.50
	48	1.72	0.22	1.49	0.10
Enterobacter	72	1.79	0.11	0.70	0.06
aerogenes	96	1.94	0.09	0.59	0.06
	120	1.91	0.07	0.64	0.06
F(C.D)		1.91 (1.80)			
	24	0.44	0.50	2.01	0.16
	48	0.13	0.10	0.10	0.08
Citrobacter spp.	72	0.11	0.10	0.07	0.09
	96	0.15	0.10	0.08	0.11
	120	0.20	0.14	0.08	0.14
F		0.81			
	24	7.89	4.31	0.76	1.0
	48	3.29	1.63	0.27	0.66
Unidentified sp.	72	1.32	0.20	0.28	0.60
	96	1.40	0.15	0.31	0.64
	120	1.26	0.16	0.31	0.67
F (C.D.)		4.40 (1.78)*			

*Significance at 5% level

inoculum or a different nutrient media promoted the formation of specific metabolites.

Recoveries of carbaryl and naphthol were better in nutrient broth than in basal salts medium, i.e., 82-94% at the end of 120 h of incubation. Reduction in recovery per centage (6-18%) in basal salts medium may be a result of opening of the aromatic ring of naphthol. Soil isolates have been reported to open the aromatic ring (Rajagopal *et al.*, 1983). It is possible that in nutrient broth other sources of carbon are available and microorganisms require limited metabolism of carbaryl for their needs, i.e., simple hydrolysis of the ester bond.

Effect of exogenously added carbon sources on degradation of carbaryl. The rate of total carbaryl degradation was lower in minimal media inoculated with all enrichment cultures, except in the presence of media containing glucose and yeast extract alone or in combination. In this case, there was an increase in growth compared to minimal media. Breakdown of carbaryl was significant with the unidentified species in basal salts media with and without glucose and yeast extract, while in other bacterial enrichment cultures the degradation was almost the same in these media (Table 3). The lower rate of carbaryl degradation compared to growth in the presence of additional carbon sources probably resulted from preferential utilisation of easily available sources of carbon and energy.

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Part 4

Innovations in Apiary Management

Chapter 25

Management of *Apis mellifera* in Semi-arid Subtropical Climates of India

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Success of beekeeping in a region depends upon three key factors: ambient climatic conditions; available bee forage; and, incidence of diseases, pests, predators and enemies (Eckert and Shaw, 1960; Eisikowitch and Masad, 1980; Lensky and Golan, 1966). Semi-arid tropics present a different set of environmental conditions and resources to temperate climates (Furgala, 1975), and therefore, require entirely different management practices (Sihag, 1990a, 1990b, 1991; Smith, 1953, 1960). This paper presents the life-cycle pattern and diseases, pests, predators and enemies of *A. mellifera* under prevailing climatic and floral conditions of subtropical India.

Seasonal Climatic Conditions

Seasonal temperature and relative humidity prevailing at Hisar in northwest India are presented in Table 1. Throughout northern India, distinct summer and winter exist. The dearth period comes in summer and is accompanied by high temperature and low humidity (in some parts).

Floral Conditions

Prevailing floral conditions are given in Table 2. However, there is variation in floral availability from place to place. Bee forage availability starts with flowering of pigeon pea in September–October. Major honey plants are rape seed, mustard, sunflower, eucalyptus, pigeon pea and litchi (in restricted areas). Other plants support beekeeping during different months.

General Ecobiology of *Apis mellifera*

Apis mellifera in subtropical northern India starts build-up activity with the commencement of flowering on toria (*Brassica campestris* var. Toria) in October. Weak colonies show build-up and strong colonies store honey. Drones are produced from December to March depending on earlier build-up. Accordingly, queens are reared. This coincides with winter in the region. Therefore, management practices related to winter are required, along with rearing of new queens and division of colonies. The post-winter months again witness weak colonies showing build-up and strong colonies storing honey. Honey storage continues with availability of bee forage. From mid-May onward the dearth period commences when temperatures are high with low relative humidity. Management practices related to these conditions are required during this period (Sihag, 1990a). In July, the rains start and humidity is high. During the post-rainy period both

Table 1. Seasonal pattern of temperature and humidity at Hisar

Season*	Duration of season	Temperature fluctuations (°C)		Relative day humidity (only during daytime min-max range)%
		Max.	Min.	
Early summer	Early March to early May	25–40	15–24	30–45
Mid-summer	Early May to early/mid-June	40–44	18–28	28–40
Late summer	Mid June to I/II week of July	40–47	25–30	25–30
Early monsoon	Mid-July to mid-August	30–36	24–27	75–95
Late monsoon	Mid-August to mid-September	30–35	22–25	55–85
Early autumn	Mid-September to mid-October	30–35	15–25	50–70
Late autumn	Mid-October to mid-/late November	24–33	12–18	45–60
Winter	December to February	21–28	1–12	45–55

Note: *Defined by Sihag (1983).

Table 2. Floral calender of major bee plants in northern plains of India

Bee plant	Months of flowering
Pigeon pea (*Cajanus cajan*)	September–October
Rape seed and mustard (*Brassica* sp.)	October–February
Eucalyptus (*Eucalyptus* sp.)	February–March
Berseem (*Trifolium alexandrinum*)	March–mid-May
Shisham (*Dalbergia sissoo*)	April
Sunflower (*Helianthus annuus*)	April–May, October–November
Maize (*Zea mays*)	May–July
Curcubits	May–October
Citrus (*Citrus* sp.)	March
Litchi (*Litchi chinensis*)	March

Table 3. Seasonal incidence of major pests, predators and enemies of *Apis mellifera* in northern India

Enemy species	Months of incidence
Ectoparasitic mite (*Tropilaelaps clareae*)	September–May/June
Wax moth (*Galleria mellonella*)	June–November
Predatory wasp (*Vespa orientalis*)	June–July
Predatory bird (*Merops orientalis*)	June–July
Robber ants	July–August
Robber bees (*Apis dorsata*)	June–July

humidity and temperatures are high. Bee forage during these months is scarce. Therefore, colonies either need artificial feeding or may be moved to other places. These conditions stretch to mid-September when pigeon pea begins to flower and colonies start build-up or honey storage.

Diseases, Pests, Predators and Enemies

Apis mellifera has no viral and bacterial diseases in India. However, other enemies such as ectoparasitic mite, wax moth, predatory wasps and birds, robber ants and robber bees are prevalent. Their monthly incidence is reported in Table 3. Along with seasonal management practices, management of these enemies is also required as suggested by Sihag (1990b, 1991).

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Chapter 26

Rearing Carnica Bee for High Production in China

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Spring Management

An important characteristic of Carnica bees is that the colony collects pollen in early spring and begins to rear brood. So development of the population is fast. This means that they are good at making full use of spring honey-flow resulting in high honey yields. Therefore, colony management is vital for high production of bees in spring.

Shortening beeway

Shortening the beeway is a important measure as it enhances population density in a brood-rearing colony, stimulates the queen to lay more eggs, and increases and maintains hive temperature. Combs of a strong colony should be used to replace combs of a weak colony in order to balance colonies within the apiary. At the same time, mite infestations should be controlled completely. A feed should be given when sterlising the hive, and workers allowed to make a cleaning flight. Then, the hive should be kept warm by covering it with a quilt.

Feeding pollen

Pollen that is to be fed to the colony should be completely sterilised so as not to spread disease. Experiments have shown that composition of amino acids in sterilised pollen is the same as in non-sterilised pollen. Feeding the colony with this pollen will cause no harm to developing brood or bees.

Providing water

With weather being cold in early spring, brood-rearing needs water. A water-feeder should be placed at the entrance of the hive so that bees do not have to fly outside to collect it. Water should be kept clean and supplied continuously.

Adding combs

In normal climatic conditions, combs should be added to the hive every seven days for the first three times. When new bees emerge and the weather becomes warmer, the intervals between adding combs should diminish. According to the quantity of eggs laid by the queen and the climatic conditions, supers should be added to a hive of ten frames as the colony reaches its peak population.

Adding eke

When adding eke, five or six pieces of good new comb should be left in the hive for the queen to lay eggs, and four or five pieces of poor old comb and sealed brood should be placed into eke. If the colony has two queens, one should be removed to another hive to build a new colony. Generally, only a single queen is used.

Management in honey-flow periods

Building combs

At the beginning of honey-flow, the colony has abundant nectar and pollen, the queen is actively laying eggs, there are many combs of sealed brood and new bees are emerging, so the colony suffers from congestion. At this time, workers increase rapidly. Foundation comb should be added to the hive every three days as this will stimulate workers to make new comb for the queen to lay eggs, and will effectively reduce swarming. The workers from new combs are strong and healthy; they are good forage collectors and keep the colony strong all year round. A colony can build five or six pieces of new comb every year; poor and old comb should be replaced at this time.

Strengthening production

In honey-flow periods, nectar and pollen resources are most abundant. Workers should be feeding the brood. When the colony develops to its peak and to prevent swarming, two pupate combs of emerging cells should be drawn out of every strong colony and placed in an empty hive. Ten combs can be used to build a new production colony. At the same time, frames can be added to old colonies according to need in order to increase production and reduce swarming tendency.

Temperature control

In summer, hot weather affects the ability of the queen to lay eggs and workers to collect forage, so reducing the temperature in the hive is important. Hives can be placed where there is little heat radiation such as under the shade of tree or in a cool shed. Water can be sprinkled on to the lid of the hive or the hive itself covered with wet towelling. This also provides water for the bees.

Fall and Winter Management of Colony

Carnica bees originated in the Alpine area of Europe, so these bees are well adapted to a climate of long harsh winters and hot summers. In autumn, as nectar and pollen are scarce, the quantity of eggs laid by the queen and the rate of brood-rearing are rapidly cut down. Generally, a small colony can well adapt to winter.

The following measures should be adopted.

- A new queen can be reared in autumn because she will be highly active at laying eggs and take only a short time to lay five or six pieces of brood comb. This can ensure a colony with suitable bees and brood well adapt for winter.
- When the quantity of queen-laid eggs is low, the queen should be stopped from laying more eggs in order to prevent workers foraging and using up too much energy as this will shorten their lives and make the colony weak in early spring. Brood-rearing should also be stopped at this time. Workers of new emergence should be prevented from collecting forage and rearing brood so that they are strong for early spring when colony development is speeding up.

As Carnica bees are tolerant to cold, this should be borne in mind when packing the hive for winter. The size of colony should determine the amount of cloth covering the hive in order to ensure proper ventilation and humidity so that bees are safe.

Chapter 27

Effect of Colony Strength and Stimulant Sugar-feeding on *Apis mellifera*

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Brood-rearing in honeybee colonies starts in September in Hisar and Kurukshetra districts. At this stage, pollen sources such as *Zizyphus mauritiana, Tridex* spp., etc. are available. However, availability of nectar is poor. With the idea that providing artificial sugar syrup may stimulate brood-rearing and affect subsequent development, the present studies were conducted.

Materials and Methods

Thirty-two *Apis mellifera* colonies with bee strengths of four, five, six and seven frames each were selected in September in both Hisar and Kurukshetra districts. Colony parameters—unsealed brood, sealed brood, pollen and honey stores—were the same for each bee-strength group of eight colonies. Queens in all 32 colonies were of the same age. Normal colony management practices were followed. Fifty per cent sugar syrup was prepared and fed to four colonies of each bee-strength group. The other four colonies of same strength each were not fed (control). Two feedings were given: the first in the third week of September and the second 20 days later. Each feeding consisted of 400 g of sugar for four-frame colonies, 500g for five-frame colonies, 600 g for six-frame colonies and 700 g for seven-frame colonies. Bee strength (frames), unsealed and sealed (worker and drone) brood (cm^2), pollen (cm^2) and honey stores (g) were recorded at intervals of 21 days from September 1995 to February 1996. Initiation and cessation of bee activity was recorded on three continuous sunny days in a month and then an average taken.

Results and Discussion

Observations on colony build-up and stores in colonies fed with sugar and control colonies are presented in Table 1. Results reveal that feeding sugar syrup increased egg-laying and subsequent colony development at both locations. Sheesley and Poduska (1988) noticed that colonies that received drivert sugar plus 1% pollen started laying on the day the supplement was given, whereas control queens started when natural pollen became available eight days later.

Data recorded in the second week of October, 21 days after feeding sugar syrup, show that at Hisar total brood-rearing in colonies fed with sugar syrup increased over the control by 277.50

Table 1: Colony build up and stores in *A. mellifera* with different strengths, with and without sugar feeding at two locations in India

Starting strength (no. of frames)		Bee strength (no. of frames) SF	Bee strength (no. of frames) UF	Strength increase due to sugar feeding (%)	Total brood cm² SF	Total brood cm² UF	Total brood increase due to sugar feeding (%)	Pollen stores (cm²) SF	Pollen stores (cm²) UF	Pollen increase due to sugar feeding	Honey stores (g) SF	Honey stores (g) UF	Honey increase due to sugar feeding (%)
Sept.,95 (Starting)													
4	L_1	–	–	–	1272.50	1270.00	–	98.75	101.25	–	200.00	197.50	–
	L_2	–	–	–	1275.00	1269.75	–	101.25	102.50	–	200.00	193.75	–
5	L_1	–	–	–	1580.00	1591.25	–	172.50	173.75	–	257.50	255.00	–
	L_2	–	–	–	1582.50	1591.25	–	173.75	173.75	–	255.0	255.0	–
6	L_1	–	–	–	1898.75	1898.75	–	166.25	150.00	–	307.50	312.50	–
	L_2	–	–	–	1896.25	1897.50	–	151.25	151.25	–	307.50	306.25	–
7	L_1	–	–	–	2192.50	2193.75	–	172.50	175.00	–	332.50	335.00	–
	L_2	–	–	–	2191.25	2195.00	–	173.75	176.25	–	337.50	337.50	–
Oct., 95													
4	L_1	4.88	4.38	12.50	3401.25	2856.25	42.38	263.75	217.50	52.28	572.50	409.25	79.04
	L_2	4.49	4.25	6.00	2897.50	2620.00	20.75	142.50	117.50	26.11	493.75	393.75	43.65
5	L_1	5.70	5.55	3.00	4770.00	4428.75	23.58	320.00	242.50	45.94	773.75	612.50	60.29
	L_2	5.50	5.25	5.00	3400.00	2845.00	36.06	202.50	178.75	13.67	733.75	648.75	33.33
6	L_1	6.65	6.38	4.50	6025.00	5408.75	32.45	345.00	295.00	10.85	815.00	618.75	67.04
	L_2	6.50	6.25	4.16	4800.00	4445.00	18.88	278.75	187.50	60.33	775.00	593.75	58.16
7	L_1	8.08	7.38	10.00	6386.25	5901.25	22.28	376.25	312.50	39.58	228.50	618.75	64.47
	L_2	7.55	7.25	4.29	6145.00	5238.75	41.47	310.00	263.75	28.77	881.25	776.25	31.11
CD (P±. 05)			(0.15)			(109.75)			(13.67)			(32.52)	
Feb., 96													
4	L_1	15.75	14.12	40.75	5312.50	5093.75	16.40	981.25	917.50	87.50	7962.50	7062.50	405.31
	L_2	16.13	15.13	25.00	7463.75	6621.25	63.75	3090.00	2957.50	166.49	5568.75	5068.75	168.24
5	L_1	19.44	17.38	41.20	5651.25	5367.50	20.36	982.50	925.00	37.19	9641.25	8050.00	587.31
	L_2	19.88	18.06	36.40	8147.50	7756.25	27.42	3110.00	2897.50	122.31	6573.75	5620.00	374.02
6	L_1	19.38	18.50	14.67	6032.50	5701.25	17.45	1040.00	948.75	–6.94	12225.00	11212.50	387.61
	L_2	20.38	18.38	33.34	8171.25	8031.25	7.67	2895.00	2957.50	–41.32	7337.50	6025.00	418.83
7	L_1	23.19	21.38	25.86	6572.50	6156.25	19.14	1008.00	981.25	24.28	13475.00	11437.50	638.45
	L_2	23.31	21.79	21.72	8285.00	7881.25	19.04	3017.50	2770.00	167.27	9700.00	8331.25	1405.55
CD (P± 0.05)			(0.23)			(95.14)			(63.23)			(235.78)	

L_1 - Kurukshetra L_2 - Hisar SF - Sugarfed colonies UF - Unfed/control colonies

cm² (21 %) for four-frame colonies, 555.00 cm² (36 %) for five-frame colonies, 355.00 cm² (19 %) for six-frame colonies, 906.25 cm² (41 %) for seven-frame colonies and at Kurukshetra by 545.00 cm² (42 %) for four-frame colonies, 341.25 cm² (24 %) for five-frame colonies, 616.25 cm² (32 %) for six-frame colonies and 485.00 cm² (22 %) for seven-frame colonies. Bee strength at Hisar was up by 0.24 (6 %), 0.25 (5 %), 0.25 (4 %), 0.30 (4 %), and at Kurukshetra by 0.50 (12.5 %), 0.15 (3 %), 0.27 (4.5 %), 0.70 (10 %). Likewise pollen and honey stores were greater in sugar-fed colonies. Increases were at a time when the major bee flora, *Brassica* spp., becomes available allowing strengthened colonies to exploit these sources of pollen and nectar fully. As a result, colonies fed with sugar syrup had significantly higher strengths, brood-rearing, and pollen and honey stores at the end of experiment in February when *Brassica* spp. are no longer available.

At the end of the experiment in February at Hisar total brood of sugar-fed colonies had increased over the control by 842.50 cm^2 (64 %) for four-frame colonies, 391.25 cm^2 (27 %) for five-frame colonies, 140.00 cm^2 (8 %) for six-frame colonies, and 403.75 cm^2 (19 %) for seven-frame colonies. Pollen stores were increased by 133.00 cm^2 (166 %), 213.00 cm^2 (122 %), -62 cm^2 (-41 %) and 247.50 cm^2 (167 %). Honey stores were increased by 500.00 g (168 %), 953.75 g (374 %), 1312.50 g (419 %) and 1368.75 g (1406 %). Bee strength was up by 1.00 frame (25 %), 1.82 frames (36 %), 2.00 frames (33%) and 1.52 frames (22 %). At Kurukshetra sugar-fed colonies increased by 1.63 frames (41 %), 2.06 frames (41 %), 0.88 frame (15 %) and 1.81 frames (26 %). Total brood increased by 218.75 cm^2 (16 %), 283.75 cm^2 (20 %), 331.25 cm^2 (17 %) and 416.25 cm^2 (19 %). Pollen stores were up by 63.75 cm^2 (87.5 %), 57.50 cm^2 (37 %), 91.25 cm^2 (-7 %) and 26.75 cm^2 (24 %). Honey production was up by 900.00 g (405 %), 1591.25 g (587 %), 1012.50 g (388 %) and 2037.50 g (638 %). Increased brood-rearing due to sugar-feeding has been reported by Forster (1968) in New Zealand, Musa *et al.* (1988) in Sudan and Singh *et al.* (1992) in India. Likewise increased bee strength and brood have been reported by Crane (1950), Peng *et al.* (1984) and Standifer *et al.* (1970). Free (1965), Free and Spencer-Booth (1961), Goodwin *et al.* (1991) and Herbert and Shimanuki (1979) observed greater pollen stores in sugar-fed colonies. Increased honey production in sugar-fed colonies has been reported by Forster (1968), Musa *et al.* (1988) and Zmarlicki and Marcinkowski (1979). However Zherebkin and Martynov (1977) found that sugar-feeding does not have any effect on honey production.

Effect of sugar-feeding on drone brood

Data on drone brood are presented in Table 2. Results show that at Hisar drone brood appeared earlier in the sugar-fed five-frame, six-frame and seven-frame strength colonies. At Kurukshetra early appearance of drone brood was not observed. However, drone brood area in sugar-fed colonies was higher than in unfed colonies at both locations. Drone brood area in colonies

Table 2: Drone brood in *A. mellifera* colonies with 4, 5, 6 and 7 frames strength, with and without sugar feeding at Kurukshetra and Hisar in India

Month (week)	Location	Drone brood (cm^2) in colonies with							
		4-frame strength		5-frame strength		6-frame strength		7-frame strength	
		SF	UF	SF	UF	SF	UF	SF	UF
Nov.,95 (1st week)	L_1	0.00	0.00	16.25	0.00	162.50	67.50	162.50	132.50
	L_2	0.00	0.00	0.00	0.00	52.00	3.75	61.25	4.00
Nov.,95 (Last week)	L_1	31.25	28.75	168.75	142.50	235.00	226.25	231.25	226.25
	L_2	0.00	0.00	67.50	12.50	250.00	237.50	307.50	221.25
Mid-Dec.,95	L_1	222.50	197.50	477.50	405.00	632.00	605.00	935.00	871.25
	L_2	125.00	77.50	190.00	151.25	547.25	455.50	675.00	578.75
Jan.,96 (last week)	L_1	361.25	325.00	498.75	493.75	846.25	793.75	940.00	886.25
	L_2	365.00	306.25	576.25	345.00	621.25	425.00	1051.25	255.00
Jan.,96 (Last week)	L_1	251.25	245.00	287.50	280.00	271.25	245.00	288.75	263.75
	L_2	617.50	562.50	880.00	810.00	1485.00	830.00	1162.00	1017.50
Feb.,96 (3rd week)	L_1	121.25	98.75	155.00	146.25	171.25	142.50	196.25	175.00
	L_2	251.50	188.75	760.00	212.00	232.50	240.00	235.00	216.25

L_1 - Kurukshetra L_2 - Hisar SF - Sugar fed colonies UF - Unfed /control colonies

Table 3: Start and Cessation of activity in *A. mellifera* colonies with different strengths with and without sugar feeding at two locations in India.

Month	Time of start of bee activity in colonies with (hours)															
	4-frame strength				5-frame strength				6-frame strength				7-frame strength			
	L_1		L_2		L_1		L_2		L_1		L_2		L_1		L_2	
	SF	UF	SF	UF	SF	UF	SF	UF	SF	UF	SF	UF	SF	UF	SF	UF
Activity Start																
Sept.,95	7.20	7.18	7.18	7.15	7.16	7.20	7.20	7.24	7.24	7.18	7.18	7.21	7.24	7.25	7.24	7.28
Oct.,95	7.15	7.21	7.15	7.18	7.20	7.15	7.20	7.24	7.18	7.16	7.18	7.20	7.25	7.18	7.25	7.17
Nov.,95	8.35	8.32	8.25	8.30	8.30	8.28	8.30	8.34	8.34	8.32	8.38	8.26	8.16	8.20	8.15	8.25
Dec.,95	9.35	9.40	9.41	9.35	9.35	9.41	9.36	9.46	9.20	9.36	9.36	9.48	9.35	9.36	9.39	9.45
Jan.,96	10.20	10.16	10.21	10.18	10.25	10.15	10.31	10.36	10.16	10.27	10.28	10.22	10.30	10.18	10.21	10.30
Feb.,96	9.45	9.41	9.42	9.46	9.40	9.35	9.35	9.44	9.38	9.45	9.40	9.38	9.47	9.50	9.45	9.41
Activity cessation																
Sept.,95	6.15	6.10	6.10	6.14	6.18	6.12	6.12	6.15	6.10	6.10	6.14	6.18	6.15	6.16	6.15	6.18
Oct.,95	6.05	6.00	6.04	6.04	6.04	6.08	6.01	6.08	6.05	6.05	6.00	6.01	6.01	6.04	6.05	6.05
Nov.,95	5.35	5.40	5.40	5.36	5.40	5.42	5.38	5.40	5.35	5.35	5.40	5.40	5.35	5.40	5.40	5.35
Dec.,95	5.26	5.20	5.20	5.22	5.25	5.26	5.21	5.26	5.24	5.21	5.18	5.24	5.22	5.24	5.25	5.21
Jan.,96	5.06	5.00	5.00	5.08	5.05	4.58	5.00	5.00	5.08	5.06	5.05	5.08	5.00	5.08	5.00	5.02
Feb.,96	5.20	5.20	5.25	5.21	5.25	5.30	5.18	5.24	5.28	5.20	5.21	5.27	5.22	5.27	5.10	5.25

L_1 – Kurukshetra L_2 – Hisar SF – Sugarfed colonies UF – Unfed/control colonies

at Kurukshetra was greater than in colonies at Hisar until mid-December; in January and February the situation was reversed. This pattern may be because at Kurukshetra *Brassica campestris* var. Toria becomes available earlier than Hisar and the area under cultivation is greater; after mid-December bee flora *B. juncea* remains plentiful at Hisar but not at Kurukshetra. Singh et al. (1992) in Punjab, India, concluded that drone brood area increased significantly with increase in colony size.

Effect of sugar-feeding on initiation and cessation of activity

Data on initiation and cessation of bee activity is presented in Table 3. Results reveal that initiation and cessation of bee activity occurred almost at the same time in sugar-fed and unfed colonies at both locations. Initiation of activity ranged from 7:15 h to 10:31 h in sugar-fed colonies and 7:15 h to 10:36 h in control colonies. Cessation of activity at Hisar ranged from 17:00 h to 18:15 h in sugar-fed and 17:08 h to 18:18 h in unfed colonies, and at Kurukshetra from 17:00 h to 18:18 h in sugar-fed and 17:00 h to 18:15 h in unfed colonies. Variation in initiation and cessation of bee activity may be attributed to ambient temperature. Abady (1975), Oh and Choi (1986) and Singh (1962) stated that bee foraging is temperature dependent.

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Chapter 28

Non-stinging Honeybees Induced by Gamma Radiation

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Honeybees are useful domestic animals that produce honey and royal jelly. They are also the major natural pollinators of many important crops. Artificial pollination of crops is time-consuming and calls for great skill. When an apple-grower in Japan was asked, 'Why don't you use honeybees for pollination?', he replied, 'Honeybees sting us. I can endure the occasional sting myself, but what if my grandchildren and the children of my area should be attacked by them? Terrible!' Honeybees are highly protective of themselves and their hives, so will sting enemies if they feel threatened. Consequently, many farmers refuse to keep and make use of them.

This study succeeded in breeding non-stinging honeybees by inducing mutations with gamma-ray irradiation (Photo 1). These bees cannot sting their keepers, whom are now confident about handling and using this new type of honeybee.

Apiculture in Japan

Two species of honeybee live in Japan. One is the native Japanese honeybee (*Apis cerana*), the other is a European honeybee (*A. mellifera*). *Apis mellifera* is the main commercial species. At present, about 7000 beekeepers care for about 24,000 colonies. Honeybees are the principal insect pollinators for 80 per cent of cultivated crops, but regrettably have not been bred in large enough numbers to meet increasing demand. This is because of the potentially massive stinging capability of honeybee colonies, each consisting of from 20,000 to 60,000 workers. Farmers consider it difficult to keep honeybees.

Stinging is an instinctive reaction of the honeybee, protecting the swarm and ensuring its survival. It is impossible to remove this instinct, but it is possible to disable the stinging mechanism. The process involved in changes in heredity and form or characteristic is known as mutation. The Laboratory of Apiculture at the National Institute of Animal Industry, and the National Institute of Radiation Breeding have worked together to breed non-stinging honeybees by causing mutation using gamma-ray irradiation.

Stingers of Honeybees

Most bees have an ovipositor for egg-laying. The stinger of honeybees evolved from the ovipositor although it no longer has that function, now being exclusively used for protective purposes. Normally the stinger is stored in a small chamber at the end of the honeybee's abdomen and, when the need arises, is turned over and extruded. The stinger is a tube composed of two types of stings: one stylet and two lancets. Each sting has barbs at its end so that it cannot be removed once it penetrates the skin of the bee's enemy. The stylet plays the role of a prop against which the two lancets move alternately, first one and then the other, forcing deeper through the skin of the enemy. The stinging action is, in other words, made by the alternate movement of the two lancets rather than the pushing power of the abdomen. The base of the stinger is thick and spherical, and contains the poison to be injected into the enemy's body. In this bulb are two valves fixed to the lancets, and as the lancets slide by turns, the valves move backwards and forwards supplying poison to the stinger simultaneously. In the case of honeybees, the insertion of the stinger by the alternate movements of the lancets and the injection of poison take place at the same time. Because of the barbs, the stinger fixed in the enemy's skin does not come out and finally tears entirely from the honeybee's body taking with it the bulb of poison. The honeybee is badly injured by this process and soon dies.

In the non-stinging honeybees that were bred, the stylet and lancets are separated from each other. Because of this, the lancets cannot make the mutual sliding action and cannot perform their stinging function. The valves for sending poison are also away from the bulb and so cannot send poison to the stinger.

Breeding Non-stinging Honeybees

To induce mutation artificially it is necessary to consider the level of gamma radiation dosage, the method of irradiation, the developmental stage of the honeybee and a number of other factors. Two effective methods of inducing mutation were discovered.

In the first, an acute irradiation of gamma ray of 20 to 50 gray (Gy) was given to queens that had already completed copulation and had sperm in their spermatheca. Non-stinging honeybee workers were produced in some colonies but the mutation rate was low: 0.5–1.0 per cent. This non-stinging characteristic also appeared in the swarm following the prime swarm and in subsequent generations, indicating heritability. However, observation of the characteristic phenotype suggests that the mutation is caused not just by the work of a single gene. A line of non-stinging honeybees can probably be established if crossing and selection are repeated using these genetic resources as a basis.

The second method was acute irradiation of 30-Gy gamma ray of honeybees at the developmental stages where they metamorphose from mature larvae into pupae (eight to ten days after oviposition). In this case, almost all (97 per cent) of the honeybees subjected to gamma rays turned into non-stinging honeybees. Using this method, artificial colonies of non-stinging honeybees were made, although they were not permanent. When nectar-producing plants were placed in the chamber (kept at a stable temperature and humidity and in a long-day condition) with the colony for studying flight activities, flower-visiting and other behavioural aspects, no difference between these bees and normal honeybees was observed. This indicates that the non-stinging honeybees will probably be of practical use.

Line Selection of Non-stinging Honeybees

It is impossible to distinguish by appearance the non-stinging honeybees generated by irradiation of queens from those created by irradiation to individuals at the developmental stage. The latter may, however, show defects that occur in the generation process. However, if there is heritability, it will bring a higher experimental efficiency to selection and breeding of non-stinging honeybees. Non-stinging queens were created by the latter technique and found to lay eggs normally.

Use of Mutant Bees

Care should be taken when releasing mutants into nature in order to take into account the possible consequences of outflows or escapes of mutation-related genes and disturbance to the ecosystem by mutants. However, in the case of the European honeybee in Japan, these problems will be of less importance for the following reasons.

- European honeybees are an exotic species and need a beekeeper's care to establish themselves in the environmental conditions of Japan. This is due to such local factors as natural enemies, parasites and climate. Because of this, there are virtually no natural colonies of these honeybees in Japan. Therefore, no problem will arise with cross-breeding of mutant European bees and wild species.
- In a honeybee colony, only the queen and her drones can pass on their genetic inheritance to the next generation. Worker bees are not involved. The escape of genetic variations can be avoided by controlling queens and drones. As queens and drones are much larger than worker bees, they can be easily controlled by adjusting the size of the entrance of the hive. The colonies made in this study consisted only of worker bees.

Fig. 1. Non-stinging honeybees on a hand

Conclusion

Honeybees either sting their keepers or induce the fear of being stung. They are useful farm animals but cannot be tamed like horses, cattle or sheep. If non-stinging honeybees (Fig. 1) can be used for practical purposes, farmers will be more likely to keep and manage honeybee colonies. It will also be possible for people other than farmers or expert beekeepers to install a beehive in their garden and enjoy honey production several times a year. It is hoped that honeybees will be as widely farmed as other livestock.

Chapter 29

Effects of Liquid Protein Diets on Honeybee Colonies

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Liquid protein diets have been avoided because honey from colonies fed with these diets is usually contaminated with additives other than sugars. Since harvesting honey is usually the major purpose of beekeeping, investigation into liquid protein diets has been neglected. However, in modern beekeeping, particularly in Japan, an increasing proportion of colonies is being hired for pollination, especially in glasshouses. These colonies do not produce honey and suffer from lack of protein sources. The present study developed a liquid protein diet for colonies under such conditions.

Diet Concentration

Bees in small cages (3 cm × 5 cm × 8 cm, 20 bees/cage) were fed yeast extract (YE) of different concentrations in a 50% sucrose solution. Higher concentrations caused higher mortality. There were no significant differences among groups fed 0–2.0% of YE. When the diets in choice experiments were placed in a colony as well as with caged bees, consumption of the diet was the same for the control as for YE concentrations under 2.0%.

Protein Sources

Consumption of eight types of soluble protein material (2.0 % in 50 % sucrose solution) was tested on bees in small cages. Peptone and yeast extract had highest consumption. Combining peptone and yeast extract in different ratios (2 % in total), the highest consumption was found in 2 % of peptone only. However, the combination of 1.5 % peptone and 0.5 % yeast extract was the most frequently chosen by bees in multi-choice tests.

Effect on Colonies in the Glasshouse

In order to test the liquid diet in practice, 2 % YE diet was fed to colonies in strawberry glasshouses. Colonies fed with the YE diet maintained egg-laying by queens and brood production during the period of pollen shortage whereas control colonies suffered decreased numbers of larvae due to cannibalism caused by malnutrition. Similarly, the 2 % protein diets (peptone or yeast extract) stimulated egg-laying and brood production of colonies confined inside a flight cage. The number of eggs laid and sealed brood production were 13–21% and 58–70% higher in 2% protein diets.

Effects on Growing Colonies

In the spring season, the combined liquid diet (peptone 1.5% and yeast extract 0.5%: P+YL) and 2% YE were tested in outside colonies. Egg-laying and brood production were stimulated by the diets. Total sealed brood production in colonies fed P+YE was 28% greater than the control. The YE colonies showed a similar but lower effect on the stimulation of brood production.

Conclusion

In liquid form, concentration of protein source is best at 2% in 50% sugar syrup. Among protein source, peptone and yeast extract are preferred by honeybees. Peptone is almost pure protein whereas yeast extract contains vitamins and minerals that are nutritionally important. The combined diet of peptone and yeast extract (1.5% and 0.5%) was more effective than the diet with yeast extract alone. The recommended liquid protein diets are easy to prepare and feed. Practically, colonies hired for pollination or purposes other than honey harvesting can be fed this type of diet to prevent bees suffering from malnutrition.

Chapter 30

Management of Swarming in *Apis cerana*

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Often the Asiatic honeybee, *Apis cerana* is maligned as a difficult to manage honeybee, who is highly prone to absconding during dearth periods and swarms excessively during food abundance and or honeyflow periods. Our investigations have revealed that swarming mostly dependent on environmental conditions rather than on genetic make up of this honeybee and it is important to find a management system suitable for beekeepers under conditions of high swarming and under the beekeeping conditions for *Apis cerana* in tropical Asia (Kevan (ed.) 1995).

Punchihewa (1994) recommended a system of colony division where the colony is divided in to two or three daughter colonies with the advent of mature queen cells while retaining the previous seasons new queen in the production colony. As long as the laying queen is a young queen from the previous season, further retention of the swarming impulse was overcome in this method. However, sometimes under practical beekeeping situations the beekeepers tend to retain much older queens in their production colonies and therefore then this method does not work too satisfactorily. Because of this immediate replacement of the existing laying queen with a young (newly mated and laying) queen had to be devised.

The diagrams explain the summary of the mechanism. Fig. 1 explains the situation soon after division (please see Punchihewa, 1994 for details). As shown in Fig. 2 one of the newly mated young laying queen is interchanged with the mother queen in the large production colony which is the main crux of the whole exercise. Therefore, during the honeyflow the production colony will be headed by a very young laying queen, which can effectively suppress the further development of the swarming impulse. This

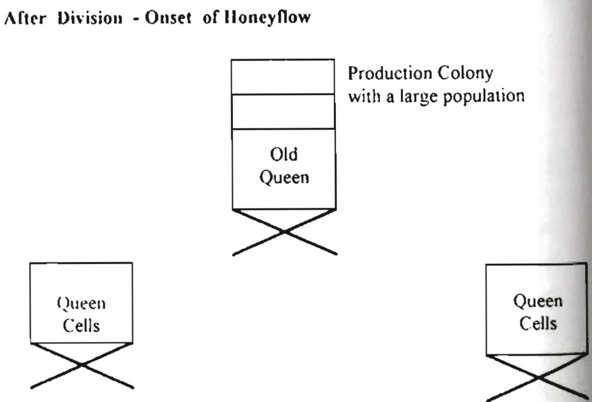

Fig. 1. Soon after division. Combs with mature queen cells are used in making small splits or divisions. Ideally a split will have 2 or 3 combs with about 2500 worker bees.

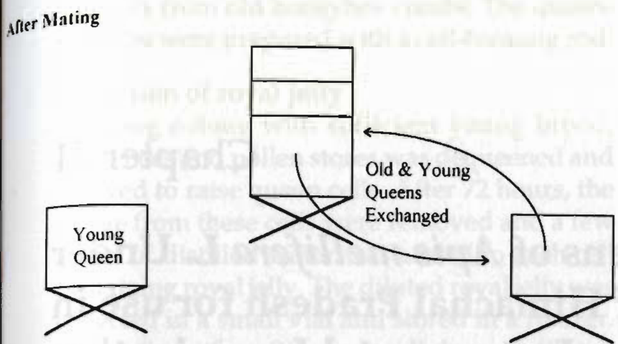

Fig. 2. Soon after young queen started laying, usually about 7-10 days after dividing, one of the young laying queens is exchanged with her mother in the production colony. The use of queen excluder and proper smoking greatly facilitate the whole operation, which can be done in a few minutes.

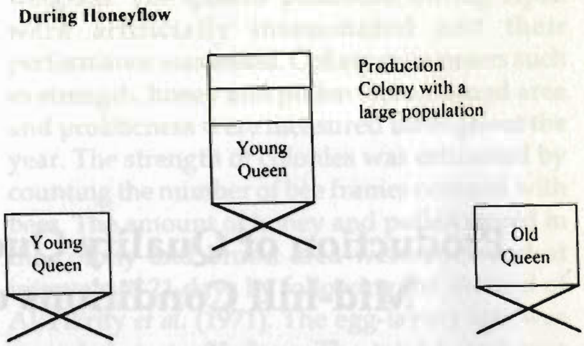

Fig. 3. Therefore during the honeyflow the production colony is now headed by a young laying queen. This young queen can very effectively suppress further building of queen cells and consequent swarming.

method can easily overcome the requirement for re-queening, which has effectively overcome the problem of swarming; such as in countries with well developed honey production industry, almost exclusively with *Apis mellifera*.

The exchange of queens can be done very effectively with the use of smoke. Even though *Apis cerana* queen are highly prone to "queen-balling" or "queen-pecking" the proper use of smoke can completely suppress this behaviour and queens were readily accepted in the recipient colony. The use of queen excluders comes very useful here. In actual practice, a queen excluder is placed above the brood box to smoke the bees so that queen would be retained with a thinned-out population of bees, often on a comb or sometimes on the excluder itself, if the smoking was too much. The queen in the first colony to be smoked could be retained on the comb by the use of a simple queen holding cage embedded on the comb, until the next colony is prepared in the same manner. The use of queen excluder and queen holding cages will greatly facilitate the whole operation to be done in a few minutes without any helpers. The queen exchange (Fig. 2) can take place between 7 to 10 days after dividing. If properly matured (well ripened) queen cells were used in making smaller splits (Fig. 1), the queen would emerge in about a day or two and will mate within the next 3 to 4 days. The detection of the proper maturity of queen cells can easily be determined by the use of "Mirror Box" as explained in Punchihewa (1994). Therefore the whole operation will take only about a week. At the time of queen exchange, while looking for the old queen in the large colony, now thinned out from bees by smoking; it is advantageous to remove any developing queen cells that can be there. Therefore, now *Apis cerana* beekeepers need not worry about "excessive swarming" but can concentrate on honey extraction (Fig. 3).

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Chapter 31

Production of Quality Queens of *Apis mellifera* L. Under Mid-hill Conditions of Himachal Pradesh for use in Instrumental Insemination

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The first step in honeybee stock improvement entails the rearing of queens from desirable, selected stock. Superior stocks cannot be produced until desirable traits are produced in offspring brought about by systematic mating of selected individuals. Many characteristics of the honeybee are open to improvement. This approach towards stock improvement can be carried out if appropriate timings or seasons of queen production are known in a particular area. It requires standardisation of queen-rearing methods when multiplying colonies or replacing old and ineffective queens. Secondly, it is important to consider quality attributes like queen-weight when proposing queen production. Hoopinginner and Farrar (1959) and Woyke (1967, 1971) worked out a significant positive correlation between queen-weight and number of ovarioles, and suggested that queen-weight at emergence might be a useful index for selecting quality queens. Similarly Huang and Zhi (1985) reported a significant and positive correlation between queen-weight at emergence and number of eggs laid. Further Avetisyan *et al.* (1967) worked out a positive correlation between queen-cell volume and queen-weight as a parameter for culturing cells and selecting virgin queens. Jhajj *et al.* (1992) studied queen-weight and queen-cell volume of *Apis mellifera* raised during different seasons and they designated March and November as best periods of queen-rearing both for replacement of old queens and multiplication of stock. Other parameters such as acceptance and emergence of queens are also vital for queen-rearing success. These quality attributes have benefits in successful insemination. The present studies were aimed at working out the best period for quality-queen production under local conditions at Nauni and then using such queens for artificial insemination.

Materials and Methods

The studies were conducted in the apiary of the Department of Entomology and Apiculture, Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan located at 1125 m. Standard method of queen-rearing involving grafting of appropriate-aged larvae was followed. Queen cups were made by obtaining beeswax from old honeybee combs. The queen-cell cups were prepared with a cell-forming rod.

Collection of royal jelly

A strong colony with sufficient young brood, nurse bees and pollen stores was dequeened and allowed to raise queen cells. After 72 hours, the larvae from these cells were removed and a few drops of distilled water was added to each cell containing royal jelly. The diluted royal jelly was collected in a small vial and stored in a freezer. At the time of grafting, a small drop of diluted royal jelly was placed with a dropper at the bottom of the cell cup to facilitate priming of cell base. Immediately after priming, a 12-hour-old larva was grafted over the drop of royal jelly.

Collection of larvae of desired age

A brood frame from the centre of the breeder colony was removed and replaced with a frame containing empty worker cells. This comb was examined daily for the presence of eggs. Cells with eggs were marked for each particular date. Marked egg combs were introduced into a colony with sufficient nurse bees, pollen and sealed brood for development of the larvae. The incubator colony was regularly provided with 40% sugar syrup. After removing the first batch of eggs from the breeder colony, another empty comb was inserted in its place and this sequence was repeated to obtain a regular supply of eggs.

Grafting of larvae

A colony with sufficient nurse bees, sealed and emerging bees, pollen and honey stores was selected as a cell-breeder colony for rearing queens from grafted larvae. The colony was dequeened and the young brood, if any, was removed. Such a colony was liberally provided with enough provisions throughout the course of experimentation, starting from one day prior to the introduction of larvae. The percentage acceptance, sealing of accepted larvae and emergence of queens was recorded. Ripe cells were removed from the frames and placed in an incubator maintained at 33 ±1°C for emergence. Immediately after emergence 20 queens were weighed. The queens produced during April were artificially inseminated and their performance was tested. Colony parameters such as strength, honey and pollen stores, brood area and prolificness were measured throughout the year. The strength of colonies was estimated by counting the number of bee frames covered with bees. The amount of honey and pollen stored in the colony and brood area were recorded at intervals of 21 days by following the method of Al-Tikrity *et al.* (1971). The egg-laying rate was recorded every 21 days. The total brood area measured was multiplied by a factor of 3.9, which was the number of cells in 1 cm^2 of brood comb. The total number of brood cells was divided by 21 to obtain the daily rate of egg-laying by a queen (Sharma, 1958).

Artificial insemination

The queens were inseminated with 2 µl of semen. To assess the success of insemination, after two days the last abdominal segment of each queen was detached by grasping its ventral part with fine forceps and the spermatheca removed. The trachea from the surface of the spermatheca was placed in a dish containing 0.1 ml of 0.9% NaCl. The spermatheca was pierced with a fine needle to liberate sperm and the empty spermatheca was removed after thorough washing. The sperm were dispersed by drawing and expelling the fluid with a dropper. The number of sperm was counted with a haemocytometer.

Results and Discussion

In order to find out the most appropriate period of larval grafting for quality-queen production, 20 larvae aged 12–24-hours were grafted every month from February until October under environmental conditions prevailing at Nauni. Data revealed that during the first year, acceptance of the larvae varied in the range 28.83–95.0%. Different steps in queen-rearing such as percentage acceptance of larval grafts, percentage sealing of grafted larvae, percentage

Table 1: Effect of one day storage of semen under different storage temperatures on the number of spermatozoa entering the spermathecae of *Apis mellifera* L. queens

Semen stored at different Temperature (°C)	Quantity injected (microlitre)	No. of spermatozoa in spermathecae (in millions)
10	2	0.29
15	2	1.13
0	2	0.83
Room temperature (26–32)	2	0.51
CD 0.05		0.08

emergence of queens and quality of queens depends upon seasonal variations. The success of queen-rearing with reference to the above parameters was found to be significantly greater during March, April and May (both years of experimentation). However, these criteria were not significantly different in June and October. Weight of newly emerged queens varied from 156.7 to 221.7 mg/queen during first year and from 167.7 to 205.0 mg/queen during the second year. During the first year, heavier queens were reared in March and April when the weight of queens was 218.0 and 221.7 mg respectively. Similarly during the second year, significantly heavier queens were reared during March to May when the weight ranged from 205 to 192 gm/ queen. Lightest queens were reared in August during both year (average weight 156.7 mg and 167.7 mg). Queen-weight is considered to be largely determined by genetic makeup (Abdellatif, 1967). However, in the present study queens reared from the same stock differed in weight indicating that factors other than genetic makeup also play a significant role in determining queen-weight.

The variability in the weight of queens during different months can be attributed to climatic conditions, incoming nectar and pollen stores, and bee population in the colonies. This is evident from the fact that heavier queens were produced during the period of main nectar flow in both the years; whereas lightest queens were produced during dearth periods, i.e., June and September. The lower weight of queens can also be attributed to prevailing low temperature in October and high temperature in June. Cale (1983) reported that lightweight queens were produced under unfavourable conditions such as low temperatures, lack of incoming food and insufficient population of bees. The prevalent climatic conditions, availability of bee flora, number of nurse bees and state of colony are major factors contributing towards the development of quality queens (Taranov, 1959). With the approach of spring, bees are able to maintain high brood temperature (Zhdanova, 1967). This factor coupled with sufficient inflow of pollen and nectar might be contributing to the production of heavier queens (Abdellatif, 1967; Taranov, 1959). Better colony conditions with regards to nectar, pollen stores, brood area, foraging efficiency and prolificness during main nectar flow were observed between end of February to mid-May. These factors might have contributed to the production and better performance of queens reared during these months.

The experiment conducted at Nauni revealed that queens can be reared efficiently in the months of March to May. These months are the nectar-flow period and can be designated as breeding period under local conditions. The loss of a queen during autumn can be made good by rearing new queens in September and October and colonies can be given a new prolific queen in order to face effectively the coming winter season. However, March to May is the best period for breeding for replacement of old queens and multiplication of stock. The insemination of quality-queens produced during April was successful since spermatheca contained 0.29 to 1.13 million sperm/queen. However, lower-weight queens were more difficult to inseminate and spermatheceae of such queens did not show the presence of sperm.

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Chapter 32

Effect of Hive Design on Internal Hive Temperature: A New Application of Temperature Data Loggers

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Introduction

Apis cerana like other *Apis* species thermoregulates to keep its thoracic temperature between 30 and 36°C (Underwood 1991). In order for brood to develop properly, honeybees maintain high temperatures (30–36°C) in the centre of the cluster where the brood nest is located (see reviews by Seeley 1985, Winston 1987, Roubik 1989, Crane 1990 and Graham 1992). Thermoregulation by bee colonies (Simpson 1961, Kronenberg and Heller 1982 and Heinrich 1985) has a high energetic cost, so insulation provided by beehives can have a strong influence on the rate of food consumption, work allocation of workers and ultimately colony survival. Hence, microclimatic suitability of hives for local bees is important in designing appropriate beehives.

In the current study, the thermal qualities and performance of bee colonies in different hives have been tested in conjunction with trials to ascertain the suitability of the hives from the point of view of local farmers in two sites: Jumla, a remote part of mid-Western Nepal (2500–3100 m); and Godavari in the Kathmandu Valley (1500 m). Jumla is a stronghold of traditional beekeeping with log hives. It is isolated from motorable roads by 5-days walk and hence nails and other hive-making materials are not affordable to local people. Godavari, on the other hand, lying only 15 km outside Kathmandu, is relatively developed with availability of ready-made 'modern' beekeeping equipment, and nails and machine-cut wood.

Methods

Temperature and bee performance data were collected in demonstration apiaries in Karnali Technical School, Jumla, and ICIMOD testing and demonstration site Godavari from May 1996 - March 1998 inclusive, and will be ongoing until November 1998. Hive types were tested as follows: traditional log hive, modified log top-bar hive, straw hive, Newton hive, and the 'Jumla' hive (a square cross-section log top-bar hive). The latter was tested in Jumla only, being particularly suited to the Jumla situation.

Maximum-minimum temperatures and details of the colony performance were recorded, but results will be presented in later publications. In each hive type, internal hive temperature of occupied and empty hives was compared by placing ONSET 'Stowaway' temperature-data loggers inside hives. The data-loggers were set to record at 30-min intervals 24 hours a day over periods of several months. Distance of the loggers from the hive clusters was difficult to control, but as long as the hive cavity was not completely full of bees they were placed at the side of the hive not directly adjacent to a cluster. This was to avoid the loggers measuring the temperature of the bee cluster, which should not vary between hive types.

Hive types were assumed to vary in their response to ambient temperature and solar warming at different times of day, so time-slots were set for analysis of hive temperatures. Mean temperatures were calculated over four-hour periods as follows: 0600–1000, 1000–1400, 1400–1800, 1800–2200, 2200–0200, 0200–0600 h. One-way ANOVAs were conducted for each time slot to determine whether the differences between mean hive temperatures in different hive types and between mean hive temperatures and ambient were significant or not. Duncan's test was used to determine which means were significantly different from one another.

Examples of data for periods when occupied hives of all the different types were available with sufficient levels of replication were chosen as follows: in Jumla between 18 and 31 May 1996 in the warmest time of year, and in Godavari between 18 August and 30 September 1997 in the late monsoon. In Jumla, colony deaths and absconding due to Thai Sac Brood Virus Disease (TSBV) and European Foul Brood (EFB) disrupted data collection in 1996 and 1997. In Godavari in 1996, insufficient replication caused insignificant results. Hence, to give meaningful results, data has been selected in Jumla before colonies died and in Godavari after logger replication was sufficient.

Results

Between empty hives, in both Jumla and Godavari, differences in internal hive temperature were not significant. In occupied hives however, differences were significant in some cases but not others. Mean temperatures over the sampling periods chosen for each hive type and for ambient temperature in each time slot are shown in Fig. 1 for Jumla and Fig. 2 for Godavari.

In Jumla, the straw hive was warmest most of the time, followed by log top-bar, log and Newton. The Jumla hive was warmest at night but cool in the morning. The significance of the differences, listed pair-wise between hive types at different time slots in Jumla is shown in Table 1.

Due to low night temperatures in this high altitude area, all the hives were significantly warmer than ambient overnight (1800–0600), and all, except the straw hive, equilibrated with ambient once the sun came up. The straw hive

Table 1. Comparison of different hive types (occupied by bees) at different times of day (time slots) in Jumla over the period from 18 May to 31 May 1996.

	Newton vs LTB	Newton vs log	Newton vs Straw	Newton vs Jumla	Newton vs Outside	LTB vs Log	LTB vs Straw	LTB vs Jumla	LTB vs Outside	Log vs Straw	Log vs Jumla	Log vs Outside	Straw vs Jumla	Straw vs Outside	Jumla vs Outside
06 to 10	Y	N	Y	N	N	Y	Y	Y	N	Y	N	N	Y	Y	N
10 to 14	N	N	Y	Y	N	N	N	Y	N	Y	N	Y	Y	N	Y
14 to 18	N	N	Y	N	N	N	Y	N	N	Y	N	N	Y	Y	N
18 to 22	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	N	Y	Y
22 to 2	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y
2 to 6	Y	N	Y	Y	Y	Y	N	N	Y	Y	Y	Y	N	Y	Y

(Y indicates that the difference is significant and N indicates that the difference is insignificant. LTB means Log top-bar hive and Outside means outside ambient temperature.)

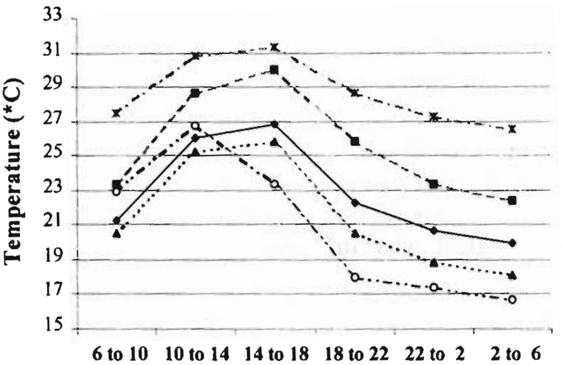

Fig. 1. Mean Temperature by hive type and time slot for Godavari from 16 Aug 1997 to 30 Sep 1997

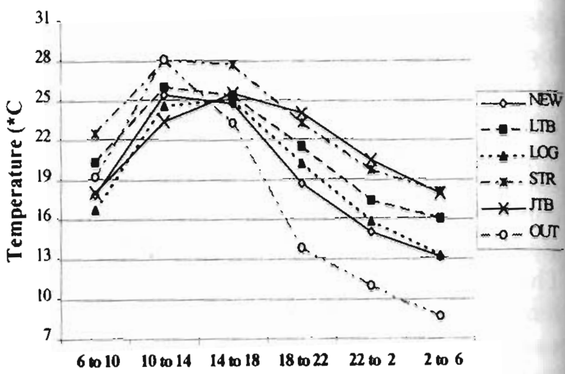

Fig. 2. Mean Temperature by hive type and time slot for Jumla from 18 May 1996 to 31 May 1996

was significantly warmer than ambient at all times, except when it converged with ambient around midday. The Jumla hive was significantly cooler than ambient in the midday period whereas the Newton hive and log top-bar hive were not significantly different from ambient during daytime (0600–1800). The log hive was significantly colder than ambient in the morning (0600–1000). The straw hive was significantly warmer than the Newton and log hives in all time slots, and than the Jumla hive in the day (0600–1800). However, it was not significantly different than the Jumla top-bar hive overnight (1800–0600). It was significantly warmer than the log top-bar hive between 1400 and 1800 hours, at 2200–0200 hours, and again around dawn (0200–0600) but not at other times. The Jumla hive was significantly warmer than the Newton hive, except in early morning and late afternoon, and was significantly warmer than the log overnight. The Newton hive was significantly colder than all others overnight (1800–0600) with the exception of the log hive. This did not differ significantly from the Newton hive except between 1800 and 2200 when the log hive was colder. The log top-bar hive was significantly warmer than the Newton (1800–1000), Jumla (0600–1400) and the log (0200–1000), but was significantly cooler than the Jumla hive at night (1800–0200). In late afternoon (1400–1800) and around dawn (0200–0600) there was no significant difference between the log top-bar and Jumla hives. The log hive was not significantly different from either the Jumla and Newton hives in the day (0600–1800) or the log top-bar hive between 1000 and 0200 hours. It was significantly colder than the log top-bar hive from 0200–1000 hours.

In Godavari, a similar pattern emerged: all pair-wise differences were significant except between log top-bar and ambient (outside) at 0600–1000 hours, when hive temperature almost equilibrated to ambient due to overnight cooling. The straw hive was significantly warmer than all others and ambient in all time slots. The log top-bar hive was next warmest, then the Newton and lastly the traditional log. Log and Newton hives were cooler than ambient outside temperature in the morning and between 1000 and 1400 hours. For the remainder of the time slots and hive types, hive internal temperature exceeded ambient temperature.

Discussion

Since only small subsets of the data are being used here, cautious interpretation is necessary. Later ICIMOD publications will present all the data (including colony performance data) collected during the year in the two sites and confirm whether these sample data sets are representative of the general situation. The insignificant differences between different hive types when empty is attributable to the shading effect of the hives upon the loggers and the lack of warming from inside. The assumption that the thermal properties of hives can be determined by measuring temperature of empty hives was incorrect when only small sample data sets were used. To perform better controls in the future, heating devices with a fixed temperature of 35°C (to mimic the heat generated in the centre of the bee cluster) need to be placed inside hives without bees. Loggers would then be placed at a fixed distance (e.g., 20 cm) from the device and the same comparisons made.

Straw hives provide better insulation than hives made of wood, even when the wooden walls are 5–6 cm thick. This probably has a positive effect in winter but may cause overheating in the summer at lower altitudes. Although the straw walls are probably most important in providing insulation, hive volume is also much smaller in the straw hive than the Jumla and log hives. Hives with larger volumes (especially traditional logs) show generally lower temperatures than those with smaller volumes (Newton, straw and log top-bar). In both Jumla and Godavari, the log top-bar hive was significantly warmer than the traditional log (the hive design from which it is adapted). This difference is probably due to the decrease in internal hive volume by around one third that occurs when the hive is adapted. The smaller hive cavity warms up more quickly in response to the temperature of the bee cluster. The higher temperature of the Newton hive at night in comparison to the log in Godavari is also probably attributable to this volume consideration. In Jumla where cooling from outside is more extreme, the thin wooden Newton hive cooled more quickly than the log in the afternoon/evening despite the smaller volume. The two hive temperatures then converged around dawn but once the sun came up the Newton hive responded more rapidly to solar heating. Although rapid temperature increase due to solar heating in the morning may be positive, since bees may emerge more quickly to forage, rapid cooling when the sun goes down renders Newton hives inappropriate in mountain conditions (2600 m) especially in winter. The thick-walled wooden Jumla hive holds the heat well overnight. Although it responds slowly to solar heating, this may protect against overheating in summer and perhaps also against too much solar warming in winter. It is questionable whether too much heat in winter may have a negative effect by causing higher consumption of honey by bees that would otherwise remain alive but dormant. Winter honey stores may be finished too quickly and the bees starve later. In future analyses, the hive volume and size of the cluster will also be taken into account.

Although this paper has looked specifically at the thermal properties of different types of hive, selection of a hive for use in beekeeping extension programmes must depend more on the preferences of the local farmers and the availability of materials and tools to make hives than on this one factor. Hence although straw hives are on average warmer than Jumla log top-bar hives, the latter has been accepted by the Jumla farmers while the former has not. The straw hive is disliked because of susceptibility to pest attack (especially pine martens and ants) and its tendency to hold moisture; also traditional threshing techniques break the straw into small pieces, and the press for making the hives is expensive and cannot be made in the village. Similarly, the Newton hive is not accepted by Jumla farmers because of its poor insulating properties, the need for exact measurements and the lack of availability of machine-cut wood and nails. This clearly demonstrates that appropriate technology needs to grow from the resources and technologies already in use, using participation of the local people in order to succeed.

Acknowledgements

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Chapter 33

Temperature Measurements of Different Types of Beehives in Nepal

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It is important for bees to have beehives that are insulated against cold as well as heat. Badly insulated hives cause stress that result in disease, winter losses and absconding of bees. A well-insulated beehive supports the best environmental conditions for a bee colony and reduces stress, lowers food consumption and susceptibility to disease, and results in strong colonies.

Method

The temperature inside occupied hives and the air temperature outside the hives were measured in two locations (Jumla, northwest Nepal (2600 m) and Kathmandu (1500 m)). In Jumla, straw hives, Newton B hives, log hives and modified log hives (top-bar hives) were compared (Fig. 1). Temperature readings were taken inside the hive at the top and bottom every hour over 24 hours from five of each type (Fig. 2). In Kathmandu, temperatures at the top and bottom of the hive and inside the brood nest were recorded in straw hives and Newton B hives (Fig. 3). The measurements were made with an electronic system (calibrated feeler with ± 0.1°C accuracy).

Fig. 1. Test apiary in Jumla

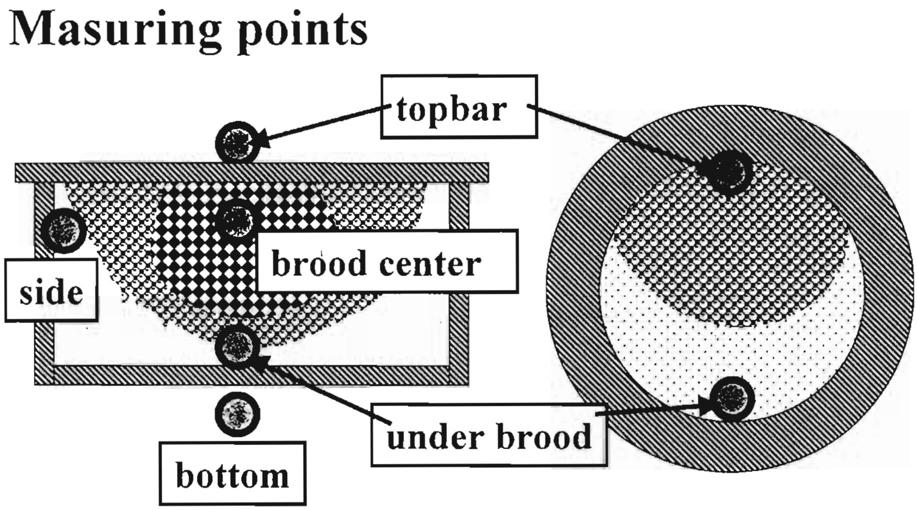

Fig. 2. Test apiary in Kathmandu (electronic measurement system is placed in the centre).

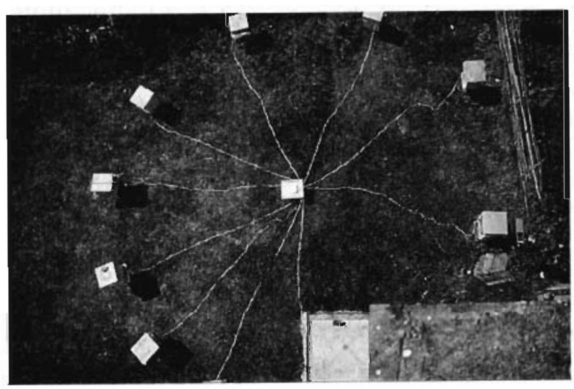

Fig. 3. Computing points inside the hive.

Results

In both Jumla and Kathmandu, the best insulation was provided by straw hives and the worst by Newton B hives (Figs. 4, 5 and 6). Even in the warm climate of Kathmandu large differences were found between outside temperatures and inside temperatures in straw hives and Newton B hives. The insulation of log hives and modified log hives is not as good as straw hives.

Discussion

A straw hive is the most insulated, and therefore the most comfortable, hive for bees. Work carried out by Partap et al. (1997) in Kathmandu showed that colonies in straw hives performed better than those in wooden hives. Therefore well-insulated hives increase the productivity of an apiary. The results also show that decreasing outside temperatures result in immediate heating activities by the bees. This may be one of the main reasons for stress within the colony.

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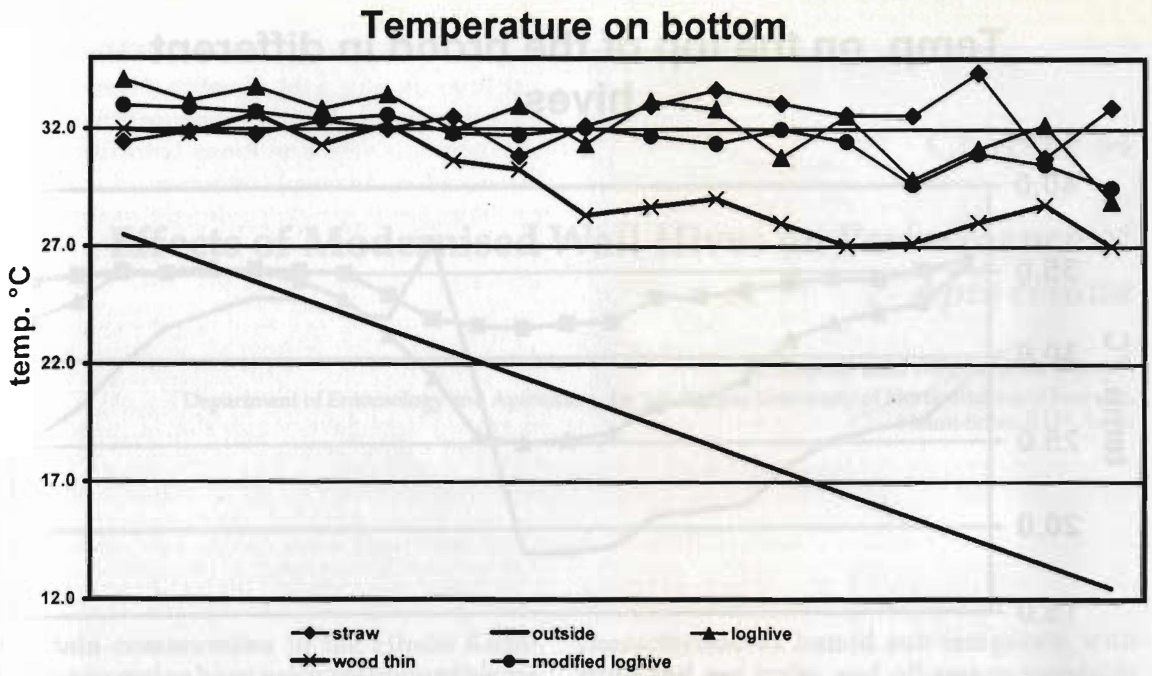

Fig. 4. Results for the measurements in Jumla

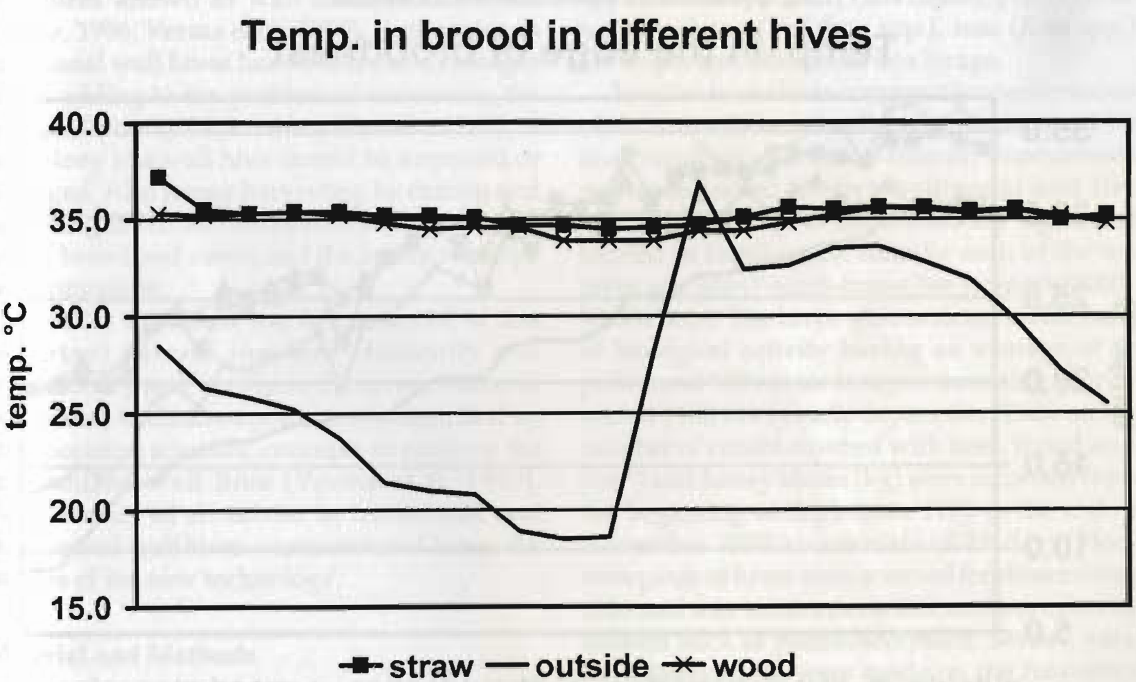

Fig. 5a. Results of temperature measurement in the brood nest in different types of beehives

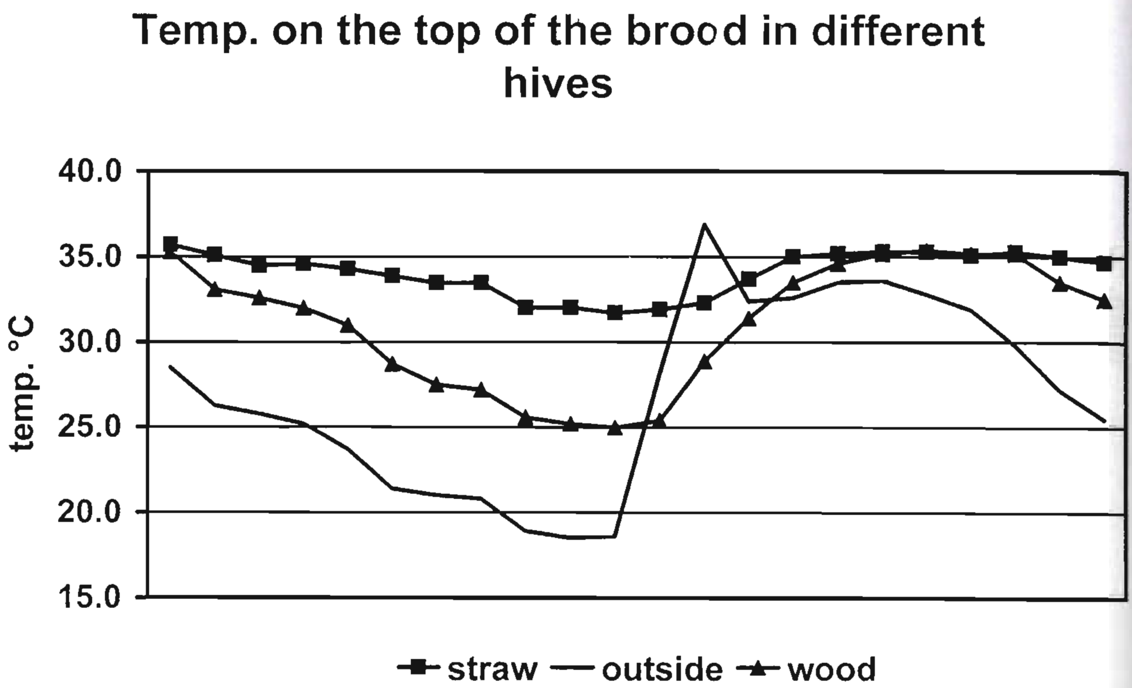

Fig. 5. Results of the measurements in Kathmandu

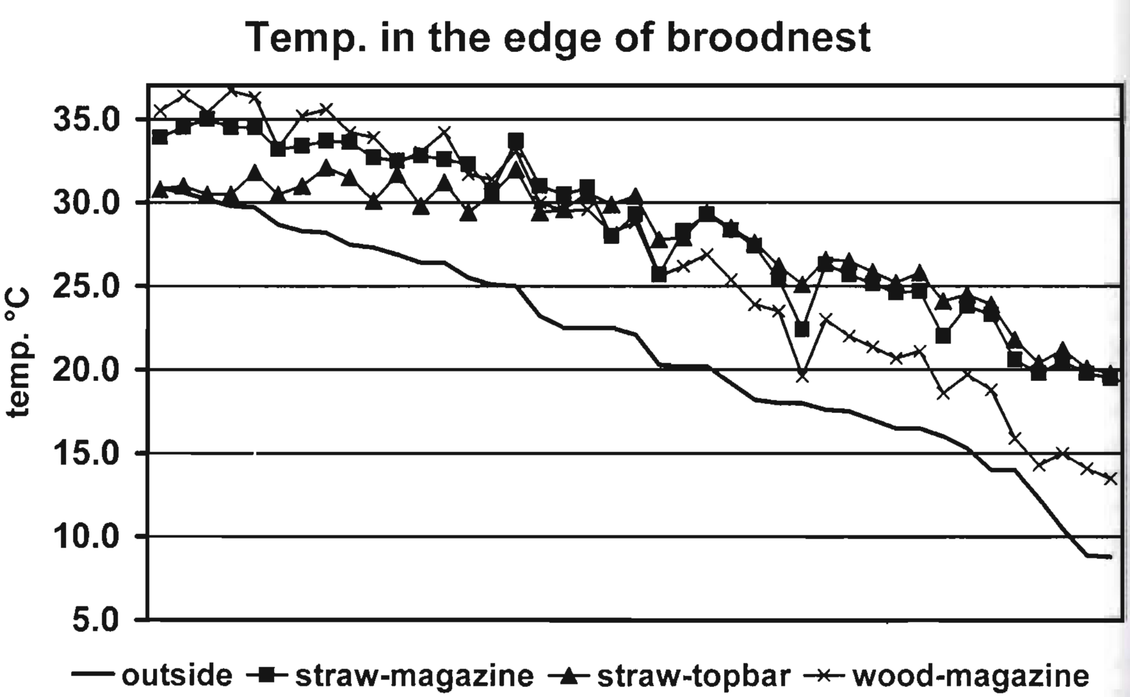

Fig. 6. Correlation between decreasing outside temperature and the temperature on the edge of the brood nest (Kathmandu).

Chapter 34

Effects of Modernised Wall Hives on Performance of *Apis cerana*

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Mountain communities in the Hindu Kush-Himalayan region have a rich tradition of hiving the Asian honeybee, *Apis cerana*, in indigenous structures known as wall hives (Kumar and Kumar, 1996; Verma *et al.*, 1999). Beekeeping in traditional wall hives has certain disadvantages and is adding to the problem of conserving the genetic diversity of *A. cerana* (Kumar, 1997). A bee colony in a wall hive cannot be inspected or managed. Also honey harvesting by cutting and squeezing the comb causes heavy bee mortality, loss of brood and comb, and the honey is unripe and unhygienic.

In order to exploit the full potential of this important natural resource efficiently and economically and to help in the conservation of the species, traditional practice was modified by incorporating scientific concepts to produce the modernised wall hive (Verma *et al.* 1999). Performance of *A. cerana* in traditional and modernised wall hives was monitored to test the success of the new technology.

Material and Methods

Studies were carried out in the mid-hills of Himachal Pradesh at 1500 m. This area is characterised as humid sub-temperate with stone and nut fruits, and off-season vegetable cultivation and seed production. *Plectranthus* spp., *Berberis* spp., tun (*Tuna ciliata*), paja (*Prunus padum*), clover (*Trifolium* spp.), rose (*Rosa* spp.) are important additional bee forage.

In order to evaluate comparative performance of *A. cerana* bees in wall hives modernised by inserting movable comb-frames, experiments were conducted on five traditional and five modernised hives of approximately equal size located in farmhouses. Initially each of the ten hives was at 6–7 comb-frame bee strength (8000–10,000 bees). The hives were selected on the basis of biological activity having an average of 60 pollen and 130 nectar foragers incoming every 5 min at 1100 hrs in early September. Data on the number of combs covered with bees, brood area (cm^2) and honey stores (kg) were recorded from the beginning of September 1995 to the end of November 1997 at intervals of 15 days. Floor sweepings of hives were scanned for determining mite and wax moth infestation, and intrusion by robbers such as pseudoscorpions, beetles, ants, etc. Observations were made on the frequency of absconding, swarm emission, artificial sugar-

Table 1. Comparative performance of *Apis cerana* during 1995–97

Parameter	Traditional hive*				Modernised hive^				Remarks
	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	
Number of combs	8	1	3	5	8	5	6	8	
Strength (no. of bee frames)	6.5	1	2.5	4	5	3.5	5	7	
Brood area (cm²)	–	–	–	–	800	200	1200	2100	*Could not be evaluated
Honey stores (kg)	–	–	–	–	1.5	0.75	4.5	6	*Could not be assessed
Incidence of wax moth	low	low	medium	low	nil	low	nil	nil	–
Robbers and scavengers	high	high	high	high	nil	low	nil	low	^treated after detection
Mite infestation	low	low	medium	medium	nil	low	low	nil	^managed
Absconding frequency	nil	high	nil	high	nil	nil	nil	nil	^averted by management
Swarm emission	0.5	nil	nil	1.5	nil	nil	nil	nil	^colony divided
Artificial feeding	–	–	–	–	1	1	nil	nil	*not practised
No. of honey harvests	1	nil	nil	0.6	0.25	nil	nil	1.4	^during modernisation
Honey harvested (kg)	3	nil	nil	2.5	2.5	nil	nil	3.8	^subsequent increase in harvest

feeding, number of honey harvests and amount of honey harvested.

Results and Discussion

Results of biological and economic performance parameters are presented in Table 1. The data reveal that initially during autumn bee strength in traditional hives was on an average 6.5 comb-frames whereas it was five comb-frames in the modernised hives. This can be explained by the fact that hives were modernised at the beginning of the first autumn. During this operation the combs were cut from the point of their attachment in the wall cavity, surplus honey was extracted, and combs with brood were mounted on to movable frames. The moveable frames were then introduced into the wall cavity and the bees allowed to settle on them. Numerous young and forager bees were lost and brood suffered chilling. The bees took some time to recover from the shock and to adapt to their overhauled habitat. Subsequently it was observed that bees in modernised hives gradually built up in strength to reached 7 comb-frames by summer.

The traditional method of harvesting honey by cutting and squeezing combs towards the end of autumn reduced bee strength in traditional wall hives to a single comb. There was loss of comb, brood and bees. Surviving bees in a queen-right situation rebuilt their hive. Build-up in strength was slow and rose to only four combs at the end of summer. Furthermore, after the autumn honey harvest and during the winter dearth, bees demonstrated a high tendency to abscond and desert traditional hives. This was probably because no sugar-feeding was provided to help bees during this period. In contrast to this, the regular monitoring and management of bees that is possible in modernised wall hives averted or controlled absconding. There was also faster spring build-up, swarming was averted and two out of five colonies were divided. This management was not possible in traditional wall hives where an average of 1.5 swarms were emitted.

The modernised wall hives allowed checking of the colony for disease (sac brood, nosema), pests (wax moth), parasites and robbers (pseudoscorpions, beetles, ants). Appropriate remedial measures could be provided. No such cleanliness and medication was possible in traditional wall hives triggering the tendency of bees to abscond. Economics improved as there was a higher number of honey harvests in summer from a modernised hive (1.4) compared to a traditional hive (0.6). The lower number of honey harvests during autumn for modernised hives (0.25) was because honey had been extracted during the operation of modernisation. It was observed that subsequently not only did the number of honey harvests increase in modernised hives but also the honey yield (3.8 kg compared to 2.5 kg for traditional hives). This was because modernised hives provided facilities for efficient and hygienic honey extraction without causing any loss to the bee colony.

Acknowledgements

Grateful thanks are due to the Head, Department of Entomology and Apiculture, for facilities and to the farmers for allowing work on the wall hives in their farmhouses.

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Chapter 35

Size of Traditional Beehives

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The size of a beehive is important for the good development of the bees inside it. In order to find out the appropriate hive size for unselected native bees in Nepal, traditional beehives from different places were measured.

Method

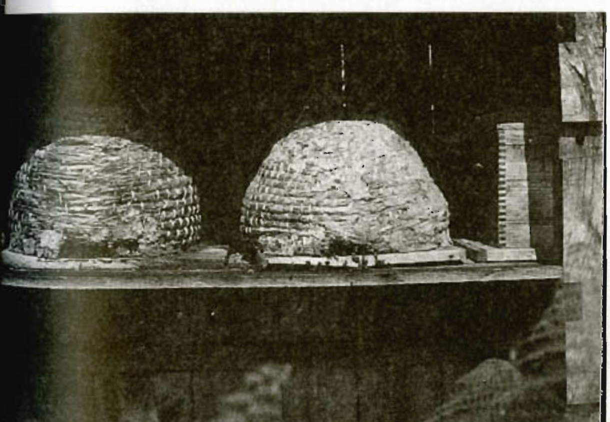
The size of traditional Nepalese log hives and wall hives for *Apis cerana* were measured (Figs 1 and 2). For comparison, traditional hives for *Apis mellifera* were also measured in Europe (Figs 3-5) and North Africa (Figs 6 and 7). The volume for all hives was calculated in litres. Location, bee species and number of hives measured were also recorded.

Results and Discussion

The results are shown in Table 1.

The volume of traditional beehives is more or less the same for *A. cerana* and *A. mellifera*. Only the basket log hive in Morocco (*A. m. intermissa*) is significantly smaller than the others. Today such traditional hives are much too small for selected *A. m. carnica*. This bee needs hives with a volume of more than 100 l. It is only a question of effective selection: in time, *A. cerana* might also need the same large-sized hive as *A. mellifera* today.

Figs 1 and 2. Typical log hive and wall hive in Nepal



Figs 3 to 5. Traditional log hives in Austria, Europe
Kaerntner Bauernkasten (Fig. 3)
Rauchfangstock (chimney hive; Fig. 4)
Strohkorb (traditional straw hive; Fig. 5)

Figs 6 and 7. Traditional hives in Morocco, North Africa: Ferula log hive (top) and basket log hive (bottom).

Table 1. Volume of hive types from *Apis cerana* and *Apis mellifera*

Area	Hive type	Bee species	No. of hives measured	Volume (l)
Nepal	Wooden log hives	*A. cerana*	120	38.8 ± 14.2
Nepal	Wall hives	*A. cerana*	19	38.7 ± 9.1
Austria	Diff. types (straw, log, etc.)	*A.m. carnica*	21	29.0 ± 12.3
Morocco	Log hives (Ferula)	*A.m. intermissa*	6	30.7 ± 6.7
Morocco	Log hives (basket)	*A.m. intermissa*	10	20.2 ± 4.1

Part 5
Bee Products and Marketing

Chapter 36

Physical and Chemical Properties of Nepalese Honey

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There is a long tradition of beekeeping and harvesting honey in Nepal where several species of honeybee are found. Honey is harvested and marketed mainly from *Apis cerana, A. dorsata, A. laboriosa* and *A. mellifera.* It can be divided into two broad types in terms of the method of harvesting: squeezed and extracted. *A. dorsata* and *A. laboriosa* are wild honeybee species. They only produce squeezed honey. *A. cerana* is managed in log hives in many parts of the country although it is also kept in modern movable-frame hives; so, honey from *A. cerana* can be either squeezed or extracted. *A. mellifera* is popular only with commercial beekeepers and its honey is entirely extracted. Although *A. florea* bees do live in Nepal, their honey is not available in the market.

Since honey is produced by different bee species during different seasons with different floral compositions, and harvesting techniques and post-harvesting handling differ, the quality of honey varies accordingly. However, honey produced on-farm is always of good quality with special floral composition.

Beekeeping Development and Environment Conservation Organization (BEEDECO) is an NGO involved in strengthening beekeeping in Nepal. Among its activities the organization carries out honey-quality testing and laboratory analysis for rural farmers. The organization also carries out research on Nepalese honey quality with support from the International Foundation of Science, Sweden and the Netherlands Development Organization, Nepal.

Methodology

Four hundred honey samples were analyzed in the laboratory using a simple low-tech method. Samples were collected from bee species as follows.

Apis cerana (beekeepers)	300
Apis cerana (directly from hive)	60
Apis mellifera	30
Apis dorsata	10
Total	**400**

Analyses were as follows.

- Moisture content: by hand refractometer (EU/Apimondia Honey Commission, 1995).
- Reducing sugar and apparent sucrose: titration method Codex Alimentarious Commission, 1989.
- HMF (Hydroxymethyl Furfural) extraction with ethylacetate and colour measurement with resorcinol (White *et al.*, 1988).
- Peroxide accumulation (glucose oxidase): screening with peroxide test strips (Kerkvliet, 1994).

- pH and electrical conductivity: measurement in 20% (m/m) solution (Kerkvliet, 1992).
- Diastase: Codex Alimentarius Commission (1989).
- Products (Kerkvliet *et al.*, 1995); (b) pollen analysis (Louveaux *et al.*, 1978).

Results

Moisture content

Moisture content was in the range 13.4–27.5% (Table 1). The lowest moisture content recorded was from *A. cerana* honey collected directly from modern hives. The moisture content of *A. dorsata* honey was highest with an average of 23.2%.

Table 1: Physico-chemical properties of Nepalese honey

Parameter	Source	Average	Range
Moisture content (%)	*A. cerana*	19.44 ± 2.33	13.40 - 26.00
	A. mellifera	18.75 ± 1.03	17.00 - 20.00
	A. dorsata	23.20 ± 2.44	19.70 - 27.50
Reducing sugar (%)	*A. cerana*	68.21 ± 4.57	58.10 - 80.30
	A. mellifera	74.93 ± 3.74	64.42 - 74.93
	A. dorsata	65.69 ± 3.30	61.33 - 71.23
Sucrose (%)	*A. cerana*	4.00 ± 2.51	0.69 - 13.00
	A. mellifera	2.00 ± 1.80	0.55 - 8.39
	A. dorsata	2.23 ± 1.20	0.69 - 4.64
HMF (mg/kg)	*A. cerana, A. mellifera and A. dorsata*	<10	<10 - 40
Peroxide accumulation (µg/g/hr at 20°C)	*A. cerana*	10	0 - 25
	A. mellifera	25	10 - 50
	A. dorsata	10	0 - 25
pH	*A. cerana*	4.5	3.35 - 5.85
	A. mellifera	4.11	3.65 - 4.39
	A. dorsata	4.72	4.20 - 5.25
Electrical conductivityu m/cm	*A. cerana*	701.11	200 - 1010
	A. mellifera	303.00	130 - 690
	A. dorsata	1062.50	930 - 1190
Diastase (number)	*A. cerana*		≤ 5 - 22
	A. mellifera		7 -> 26
	A. dorsata		≤ 5 - 8

A. mellifera honey had the lowest average of 18.75%.

Reducing sugar

Reducing sugar content was in the range 58.1–80.3% (Table 1). The highest and lowest reducing sugar content was found in *A. cerana* honey. Only 5.3% of the *A mellifera* samples contained less than 65 % reducing sugar, where as 25% of the *A. cerana* samples and 50% of the *A. dorsata* samples did. This indicates that *A. cerana* honey and *A. dorsata* honey contain less reducing sugar than *A. mellifera* honey.

Sucrose

The maximum and minimum sucrose contents recorded were 0.55% and 13.0% (Table 1). Although one sample of *A. cerana* honey collected directly from the hive contained 13% sucrose, most samples contained less than 5% sucrose. One sample of *A. mellifera* honey contained 8.39% sucrose and the rest were lower than 5%. All samples of *A. dorsata* honey contained less than 5%.

HMF

The semi-quantitative method used to analyse HMF content of 221 honey samples gave the following results.

HMF content (mg/kg)	No. of samples
Less than 10	158
Between 10–20	49
Between 20–30	12
Between 30–40	2

The HMF content of all honey samples tested was less than 40 mg/kg (Table 1). Only heated and adulterated honey contains more than 40 mg/kg of HMF.

Peroxide accumulation

Peroxide accumulation was highest in *A. mellifera* samples. It ranged from 2.5 to 50 µg/g/hr at 20°C in *A. mellifera* honey and 0 to 25 µg/g/hr at 20°C in *A. cerana* and *A. dorsata* honey (Table 1).

Peroxide accumulation (µg/g/hr at 20°C)	*A. cerana* (% of sample)	*A. mellifera* (% of sample)	*A. dorsata* (% of sample)
0.0	6	0	20
2.5	35	6	10
10.0	49	21	50
25.0	10	45	20
50.0	0	28	0

Relationship between HMF and peroxide accumulation showed that where peroxide accumulation was greater than 10 µg/g/hr at 20°C, then HMF was below 20 mg/kg.

pH and electrical conductivity

The pH of *A. cerana* honey showed the greatest range from 3.35 to 5.85, and the average (4.11) was lowest for *A. mellifera* (Table 1). Electrical conductivity of *A. cerana* also showed the greatest range from 200 to 1010 and the average (303) was again lowest for *A. mellifera* honey.

Diastase

Diastase values for *A. cerana* and *A. dorsata* were lower than those of *A. mellifera* (Table 1).

Conclusion

- Honey-quality analysis to assess adulteration and authenticity can be carried out using simple low-tech and cheap methods.
- Quality analyses of Nepalese honey indicated that in general there is good compliance with codex regulation. Each type of honey has its own characteristics. *A. mellifera* honey showed the most desirable characters while *A. dorsata* showed the least desirable ones.
- Further study on botanical origin of the honey is necessary to find out the reasons for differing values of parameters.

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Chapter 37

Honeydew Honey in Nepal

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Honeybees produce honey from nectar (secreted by floral and extrafloral nectaries) and honeydew (excretions of plant-sucking insects). Honeydew is derived from phloem sap not from actively secreted nectar. Phloem sap is inaccessible to bees unless it seeps from a surface wound. Some insects belonging to the order Rhynchota are able to puncture plant tissues with special sucking apparatus through which they gain access to plant sap. From the sap they extract the nutrients they require. Excess food passes through the insect's gut and is found on leaves, twigs, etc. in small droplets known as honeydew (Crane, 1980, 1990; Maurizio, 1975). Honeydew contains enzymes such as invertase and diastase derived from secretions of the salivary glands and gut of the plant-sucking insects (Kloft, 1965; Kloft and Ehrhardt, 1962; Maurizio, 1965, 1975). It also contains amino acids, amides and organic acids, especially citric and more rarely malic, succinic and fumaric acids (Gray, 1952; Tamaki, 1964, 1968). This means that honeydew honey differs in its composition from phloem sap and from nectar honey. It has a higher total content of minerals than nectar honey (0.58% compared to 0.26%) and is darker in colour (Crane, 1990).

The origin of honey (floral or honeydew) can be determined by measuring its electrical

Cure for high blood pressure with honey from blossoms of *Carissa*

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Studies were conducted on the effects on high blood pressure (HBP) of honey derived from different flora. In trials, honey produced from *Carissa* plus medicinal plants (2 tablespoons in 2.2 l of water daily) proved useful for normalising HBP. It was tested on 75 patients. During treatment, HBP became normal in most patients in 1–3 days. Treatment was continued for 35 days. Some 11–42 days after stopping treatment, patients' BP started rising. It was normalised again with honey treatment for 1–2 days. When BP rose again after 4–12 weeks, honey treatment for 1 day was sufficient for normalising it. This treatment cured HBP in 83% of patients.

Some 9% of patients suffered from abnormalities in diastolic and systolic BP. Treatment with honey normalised both types of abnormalities in 6–23 days. Treatment was continued for 35 days. The abnormalities again started in some patients and treatment with honey cured them in 3–11 days. Later, the abnormalities did not occur. Whenever BP started rising it was normalised by honey treatment for 1 day. Honey treatment did not show any curative action in 8% of patients possibly owing to allergies or some other reasons. However, in 92% of patients the cost of curing HBP was reduced by 82–95% with honey treatment as compared to allopathic medicines.

conductivity. Vorwohl (1964) proposed the use of electrical conductivity measurements with pollen analysis for identifying honey sources and for detecting the proportion of honeydew. Electrical conductivity values will depend on the concentration of mineral salts, organic acids, protein and polyols (Crane, 1990; White, 1975a, 1975b). Pure floral honey shows electrical conductivity <700 µS/cm and pure honeydew honey shows electrical conductivity >1200 µS/cm; electrical conductivity of 700–1200 µS/cm indicates that the honey is derived from a mixture of nectar and honeydew although there are some exceptions (Bogdanov *et al.*, 1997). Other honeydew indicators such as algae and sooty moulds (Maurizio, 1975), pollen grains of wind-pollinated plants, and soot and dust (Crane, 1975), fungal spores and hyphae can be seen in honey pollen slides.

Most honey from high altitudes is all or partly from honeydew whereas that from valleys is from nectar. Plachy (1944) reported that samples of honey produced at altitudes over 1000 m had at least twice the bactericidal activity of samples from lower areas. Buchner (1966) found that honeydew honey has greater bactericidal activity than floral honey. Although in Nepal there are reports of honeydew plants, there are no reports as yet of honeydew-excreting insects or honeydew honey (Partap, 1997). To close this gap, the present study was carried out to determine the source (floral or honeydew) of honey harvested from different bee species and from different ecozones.

Materials and Methods

Honeydew samples were collected from Jumla district (2500 m) in western Nepal in May 1994. Honeydew-producing insects from these samples were identified at the Institut fur Toxikologie, Berlin, Germany. Honey samples from *Apis cerana* bees were collected from Langtang, Jumla (2000 m), Dadeldhura (600 m), Kathmandu valley (1500 m) and Chitwan (250 m) during field visits made between January 1994 and September 1997. Some samples were collected from commercial beekeepers associated with the ICIMOD apiary and Himalayan Bee Concern. Also samples from different bee species (*A. cerana, A. dorsata* and *A. mellifera*) were collected at one time and from the same locality in Chitwan district. All samples were kept in a deep freezer and analysed at the Institut fur Bienenkunde, Lunz am See, Austria.

Pollen analysis was carried out according to the method published by the International Commission of Bee Botany (Louveaux *et al.*, 1978). Identification was made by comparing pollen grains found in the samples with those collected by hand from known plants.

Electrical conductivity, pH and water content were measured according to the harmonised methods published by the European Honey Commission (Bogdanov *et al.*, 1997).

Results and Discussion

Three honeydew-secreting insect species were identified: *Cinara eastopi* (Pintera) on *Pinus wallichiana* (Jackson), and *Cinara comater* (Doncaster) and an unidentified *Cinara* species on *Picea smithiana* (Wallich). Many plant sources of honeydew honey reported in other parts of the world are also found in Nepal (e.g., *Larix* spp., *Quercus* spp., *Populus* spp., *Abies spectabilis, Pinus sylvestris, Cedrus deodara, Tsuga dumosa, Sapium insigne, Saccharum officinalis*); but whether insects that produce honeydew are found on them is still unexplored (Partap, 1997). Of these plants, most are found at high altitudes (above 1500 m); only *Saccharum officinalis* and *Populus* spp. are found at low altitudes.

The electrical conductivity of honey harvested from different ecozones is shown in Table 1. The electrical conductivity of Langtang honey averaged 1295.5 ± 517.6 µS/cm; Jumla honey averaged 862.8 ± 145 µS/cm; Dadeldhura honey averaged 851 ± 323 µS/cm; Kathmandu honey averaged 814.8 ± 550 µS/cm; and Chitwan honey averaged 693 ± 465 µS/cm. Honey collected from commercial beekeepers averaged 495.7 ± 273 µS/

Table 1: Electrical conductivity, pH and water content of *Apis cerana* honey collected from different ecozones of Nepal

Locality	EC (μS/cm)			PH			Water content (%)		
	Mean ±SD	Min. value	Max. value	Mean ±SD	Min. value	Max. value	Mean ±SD	Min. value	Max. value
Langtang (n = 8)	1295.5 ± 517	324	1767	4.52 ± 1.14	3.05	6.76	21.3 ± 1.8	17.2	22.6
Jumla (n = 52)	862.86 ± 145	476	1092	3.69 ± 0.26	3.21	4.21	20.96 ± 2.5	15.8	26.0
Dadeldhura (n = 56)	851 ± 339	304	1290	3.74 ± 0.61	2.99	5.65	22.8 ± 3.2	17.0	26.0
Kathmandu (n = 61)	814.8 ± 550	182	1898	3.81 ± 0.78	2.27	6.5	22.3 ± 1.98	19.0	25.4
Chitwan (n = 16)	693.1 ± 465	211	1568	3.74 ± 0.34	3.2	4.37	19.17 ± 1.96	17.0	21.4
Commercial beekeeper (n = 12)	495.7 ± 273	186	819	3.59 ± 0.38	3.0	4.11	17.98 ± 2.0	14.0	20.4

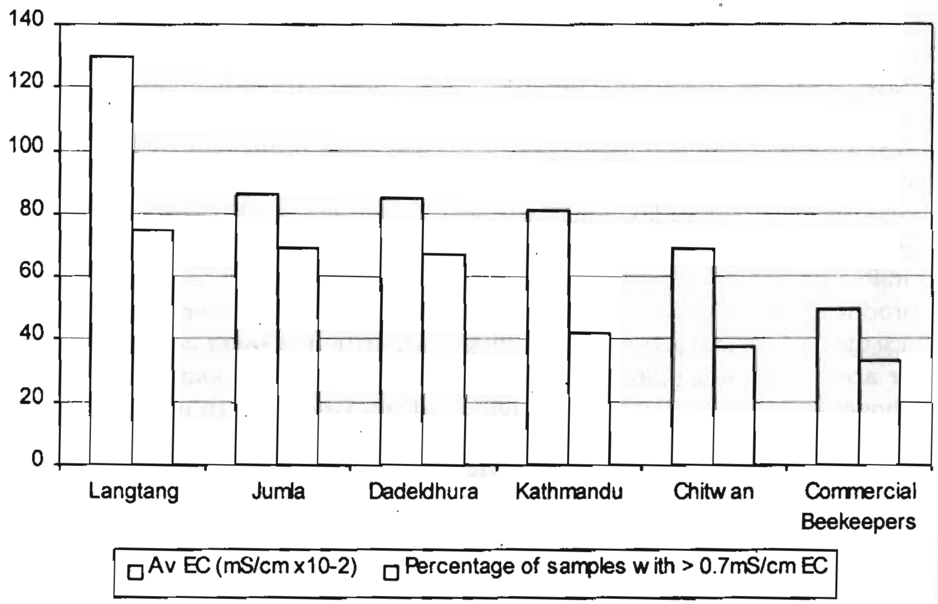

Fig. 1. Electrical conductivity of *Apis cerana* honeys from different altitudes in Nepal

cm. These results indicate that honey harvested from high altitudes has higher electrical conductivity than that from low altitudes.

The percentage of samples derived at least in part from honeydew is shown in Fig. 1. The majority (75%) of honey samples from Langang had >700 μS/cm followed by Jumla (69.23%), Dadeldhura (67.3%), Kathmandu (42%) and Chitwan (37.5%). Honey from commercial beekeepers had only 33.3% samples with >700 μS/cm. The results show that at higher altitudes honey is more likely to be derived from pure honeydew or a mixture of honeydew and nectar.

The electrical conductivity of honey harvested from different bee species (*A. cerana, A. dorsata* and *A. mellifera*) on the same day and from the same locality are shown in Table 2. The results show that conductivity values differ from species to species. The electrical conductivity value of the wild bee species, *A. dorsata,* averaged 1167 ± 758 μS/cm, and the native hive-bee, *A. cerana,* averaged 693 ± 465 μS/cm and *A. mellifera,*

Table 2. Electrical conductivity, pH and water content of honey harvested from different bee species in Chitwan, Nepal

Bee species	EC (µS/cm)			PH			Water content (%)		
	Mean ±SD	Min. value	Max. value	Mean ±SD	Min. value	Max. value	Mean ±SD	Min. value	Max. value
Apis cerana (*n* = 16)	693.1 ± 465	211	1568	3.79 ± 0.65	3.2	4.37	20.98 ± 2.5	17.0	21.4
Apis dorsata (*n* = 24)	1167 ± 758	378	2230	3.79 ± 0.34	3.4	4.31	20.9 ± 1.94	17.2	24.2
Apis mellifera (*n* = 17)	316.8 ± 167	148	711	3.38 ± 0.29	3.0	4.22	18.21 ± 2.6	14.0	21.9

averaged 316.8 ± 167 µS/cm. The highest percentage (41.1%) of honey samples produced from pure honeydew was recorded from *A. dorsata* followed by *A. cerana* (18.7%). There were no pure honeydew samples from *A. mellifera* (one sample recorded 711 µS/cm). In *A. dorsata*, 8.3% samples were mixed honey and in *A. cerana* 18.7 % samples were mixed honey.

Water content and pH values are also shown in Tables 1 and 2. In general, the results show that the higher the electrical conductivity the higher the pH value. However, this was not the case with all samples. The pH value also depends on the range of variation in electrical conductivity. The pH value for Langtang averaged 4.52 ± 1.14, for Jumla 3.69 ± 0.26, for Dadeldhura 3.74 ± 0.61, for Kathmandu 3.81 ± 0.78, for Chitwan 3.74 ± 0.34 and for commercial beekeepers 3.59 ± 0.38. Water content percentage averaged for Langtang 21.3 ± 1.8, for Jumla 20.96 ± 2.5, for Dadeldhura 22.8 ± 3.2, for Kathmandu 22.3 ± 1.98, for Chitwan 19.17 ± 1.96 and for commercial beekeepers 17.98 ± 2.However, the water content at high altitudes was slightly higher than at low altitudes. The lowest water content (18.2%) was recorded in *A. mellifera* honey. This may be because all *A. mellifera* colonies were reared in movable-frame hives and so it was possible to collect only sealed-comb honey. The pH value for *A. cerana* is slightly lower than the value recorded by Shrestha (1996) and the water content of many samples is higher than the Codex Alimentarius standard (<21%) of the European Honey Commission (Bogdanov *et al.*, 1997). Shrestha (1996) recorded pH 4.17–5.5, water content 17–21%, and EC 360–1060 µS/cm for Nepalese honey (source of honey not mentioned). Phadke (1967,1968) in India recorded water content of 20 ± 2% in *A. indica* (*cerana*) honey and 20.9 % in *A. dorsata* honey. Mitra and Mathew (1968) in Calcutta, India, also recorded water content of 20.5% for *A. cerana* honey and 23.5% for *A. dorsata*.

Pollen spectra of Chitwan honey were also analysed. The results show that bee species have different foraging preferences. While the foraging distance of *A. mellifera* is more or less equal to *A. dorsata*, it preferred cultivated crops mainly *Brassica* and *Fagopyrum*. *Apis cerana* foraged on both cultivated plants and wild plants such as *Eupatoreum odoratum, Zizyphus jujuba*, etc. *Apis dorsata* preferred wild plants such as *Eupatoreum odoratum, Dalbergia sissoo, Albizzia* spp., *Bombax ceiba*, etc.

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Chapter 38

Queen-rearing and Royal-jelly Production in Asian Honeybee *Apis cerana*

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The Asian hive-bee, *Apis cerana*, exhibits remarkable genetic diversity in the region of its distribution. Several sub-species/geographical ecotypes have been identified (Ruttner, 1986; Verma, 1990) each of which is adapted to its particular area and shows significant variation in biological and economic performance. The scientific and commercial potential of this diversity is related to the fact that populations of *A. cerana* in some parts of the Hindu Kush-Himalayas match the European counterpart, *A. mellifera*, in size and productivity. Selection and queen-rearing in such populations might produce a line of *A. cerana* that is suitable for commercial beekeeping. Therefore, the present study was undertaken. Royal-jelly production was studied to explore its economic potential in the selected population.

Materials and Methods

Three ecotypes of *A. cerana* – high hill (2500 m), mid-hill (1500 m) and foothill (500 m) – were established at the University research-cum-demonstration apiary (1250 m) and subjected to selection over five years through 10 generations. Experiments on queen-rearing and royal-jelly production were then conducted on the selected stock only. The experimental colonies were classified as follows.

- Cell-builder colony: This was a strong selected colony with a 10-frame bee strength in its brood chamber. It had 3–4 combs of honey, 120–150 cm^2 of pollen, a young and emerging worker brood and an abundance of nurse bees. This colony was rendered queenless.
- Donor colony: This was also a strong selected colony. It had over 500 cm^2 of brood of less than 48 hr of age at the time of experiment. It was queen-right.
- Acceptor colony: This was a queenless nucleus or a small colony or a divide from a strong colony. It had at least one comb with a young, emerging worker brood and nurse bees. The new queen was introduced in it.

Queen-rearing frames each with two parallel bars were used. Ten wax discs each measuring 15 mm^2 and 5 mm thick were mounted on each bar with wax. Queen cups were made from beeswax with a special cell-forming rod. The cups were attached to the discs with warm wax facing downwards. The frame was placed in the centre of the cell-builder colony and left overnight for the bees to clean and glean the cups. Larvae of different ages—12–24 hr and 24–48 hr—were used in two parallel sets of experiments. Larvae were picked up with a grafting needle from the donor colony and grafted into the prepared cups. The cups and brood frames were kept covered with moist muslin cloth to prevent drying out of larvae. When all the cups in the queen-rearing frames had been provided with suitable larvae, the frame was reintroduced in its position in the cell-builder colony. Sugar syrup was provided to encourage the workers to accept the cups and raise them into queen cells. These manipulations were accomplished in as short a time as possible to prevent chilling of the brood.

For queen-rearing, five well-attended cells were selected. When the cells became ripe, these were enclosed in queen-cell protectors. One newly emerged queen was then introduced into queenless acceptor colonies to make them queen-right. For royal-jelly extraction, 3–5 accepted queen cups were removed 48 and 72 hr after grafting. The cups were cut open a few millimetres above the larva embedded in the royal jelly. The larva was gently removed and discarded. Royal jelly was then extracted with a spatula and weighed with an electronic balance.

Results and Discussion

Results of experiments on queen-rearing and royal-jelly production are presented in Tables 1 and 2.

It was observed that percentage acceptance of artificial queen cups was higher in late spring-early summer than in autumn (Table 1). Maximum average amount (202.9 mg) of royal jelly was collected from 12–24 hr grafts after 72 hr during late spring-early summer (Table 2). It has previously been reported that queen-rearing

Table 1. Queen-rearing in *Apis cerana*

No. of larvae grafted	Total number of cells accepted				Queen production success (%) from five selected cells			
	12–24 hr		24–48 hr		12–24 hr		24–48 hr	
	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn
20	17(85)	13(65)	15(75)	11(55)	80	70	70	60
20	15(75)	12(60)	14(70)	13(65)	60	60	60	40
20	18(90)	15(75)	16(80)	12(60)	100	70	80	80

Figures in parentheses are percentages.

Table 2. Royal-jelly production in *Apis cerana*

No. of larvae grafted	Weight of royal jelly/cup extracted 48 hr after grafting(mg)				Weight of royal jelly/cup extracted 72 hr after grafting(mg)			
	12–24 hr		24–48 hr		12–24 hr		24–48 hr	
	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn
20	179.6	154.5	172.0	168.6	210.9	180.7	162.1	134.7
20	182.9	148.7	222.7	179.6	197.5	172.6	158.5	142.5
20	165.2	151.5	190.7	167.7	200.3	179.5	176.9	153.5
Average	175.9	151.6	198.3	172.0	202.9	177.6	165.8	143.6

and/or royal-jelly production is dependent upon nectar and pollen sources available during the period (Chang and Hsieh, 1993; Wongsiri *et al.*, 1988). The location where the study was conducted abounds in late spring-early summer flora, mainly stone and pome fruits. These provide good bee-forage and probably explain the results obtained during the study. Wongsiri *et al.* (1988) conducted queen-rearing with *A. cerana* in Thailand and reported more than 90 % acceptance both in single and double grafts although only 12.5% cells could be raised during the rainy season. Although royal-jelly production in *A. mellifera* is extensively exploited (Chang and Hsieh, 1993; Crane, 1990; Smith, 1959; Rana, 1996), this is the first report of obtaining economically viable amounts of royal jelly from a selected high-hill population of *A. cerana* from India.

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Chapter 39

Honeybee Fauna in Mahakali Zone and their Ayurvedic Relations

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Eight species of honeybee are described in Ayurveda, the science of traditional medicine. According to Ayurvedic experts these species, found in the Himalayas, have differing medical values although no scientific work has yet been carried on this aspect. Their Sanskrit names are Makchhika, Kschudra, Chhatra, Bhramara, Pouttika, Aoudalaka, Arghya and Dala. The present study was carried out to survey honeybee species and identify them in Ayurvedic terms.

Materials and Methods

Collection of bees and honey

Four species of honeybee were collected from 14 sites in the districts of Darchula, Dadeldhura, and Kanchanpur in the Mahakali zone of Nepal. They were *Apis cerana, A. dorsata, A. florea* and *Trigona* sp. The medical value of these bees was traced from Ayurvedic texts (Charak, n.d.; Sen and Sen, 1346; Sushruta, 1827), and local knowledge was collected with a simple questionnaire.

Samples of honey were collected. Temperature, altitude, humidity, rainfall and surrounding flora was also noted as they can affect the quality of honey. To collect honey of *A. cerana* (nine samples) and *A. dorsata* (six samples), hives was smoked to evacuate the bees and then cut open with a knife. The honey was squeezed into a sterile collecting jar. Honey of *A. florea* (two samples) was collected without using smoke. The hive was cut open and the honey squeezed into a plastic bucket before being transferred to a sterile collecting jar leaving behind particles of nest, leaves and larvae. The honey of *Trigona* sp. (two samples) was collected with bare hands from holes in a dry tree and transferred to a collecting jar.

Collection of bee flora

Sixty-five samples of flora were collected from within 500 m of the hives. The flora were identified by the Central Department of Botany.

Microbial test

As honey is described as of great value in skin infections, wounds and fever, samples were collected for microbial testing against two bacteria species, *Staphyllococcus aureus* and *Salmonella typhi*. The microbial test was done after Hugo and Russel (1984). Mueller Hinton agar medium was used for culture of the pathogens. Unprocessed honey was used. Honey solutions were prepared in four concentrations by volume: 50%, 20%, 10% and 5%. Distilled water was used as the solvent. Culture plates were treated with honey after Efem *et al.* (1992), and then incubated at 37°C for 24 hr. The plates were observed for zones of inhibition.

Results

Honeybee fauna and their Ayurvedic names

Four species of honeybee were identified and matched with their Ayurvedic name (Table 1).

Honeybee species and surrounding flora

Bee species collected and surrounding ecology are noted in Table 2.

Honeybees collected and their medical relations

Medical importance of honey was gathered from Ayurvedic texts: Charak (a traditional book), Sen and Sen (1346), Shaligram (1897) and Sushruta (a traditional book). Local knowledge was also collected (Table 3).

Microbial test

After 24 hr, the incubated plates were observed for zones of inhibition (Tables 4 and 5).

All honey samples showed high antimicrobial activity at 50% concentration against *S. aureus*; the highest (16.75) by honey of *A. dorsata*. As the concentration was lowered, the activity gradually decreased. At 5% concentration all samples showed a negative response. For honey of *A. cerana*, samples collected from Darchula showed the greater zone of inhibition (15).

Honey of *A. florea* showed the highest zone of inhibition (12.75 at 50% concentration) against *S. typhi*. This honey showed a positive response even at 5% concentration. Honey of *A. dorsata* also showed a strong effect. Honey of *A. florea* was similar to that of *A. cerana* from Darchula.

Discussion

Honeybee fauna

Ayurvedic experts describe eight types of honeybee. However, identification is limited to traditional names. During this study, four species have been matched to Ayurvedic nomenclature (Table 1). Also *Bombus* spp. can be compared to Bhramara in Ayurveda. *Ceratina* spp. are called Bhramara by local people, but their characteristics do not match the Bhramara described in Ayurveda. Three types have not been identified yet although they have great medicinal value: Aoudalaka is good against infectious wounds; Arghya is good for eye and throat infections; and, Dala stimulates bile production and is good for vomiting. Attempts are being made to trace them. *Apis cerana* was found at all sites and showed slight variations. *Apis dorsata* also showed some variation. This could account for different Ayurvedic types.

Honeybee flora and quality of honey

There was some variation in bee flora at different sites and considerable variation with respect to season. In Ayurveda it is clearly explained that the quality of honey varies with respect to honeybee species. Sushruta (1827) mentions seasonal variation in the medical effect of honey of different species. This could be due to flora they visit.

Antimicrobial effects of honey

Considerable work has also been carried out in relation to the use of honey for wounds.

Table 1. Bee species recorded

Bee species	Local name	Ayurvedic name	No. of bees / hive
Apis cerana	Ghar mahuri	Makchhika	500–2000
Apis dorsata	Bheri, ghar mahuri Chhatra	–	5000–8000
Apis florea	Kathori	Kschudra	500–1000
Trigona sp.	Puttunga	Pouttika	2000–5000

Table 2. Bee species collected and site information

Bee species	Collection site	Hive type	Temp. (°C)	Altitude (m)	Surrounding flora
Darchula					
A. cerana	Sipti	Log hive	20	2200	*Brassica* spp., *Bassia* spp., *Citrus* spp., *Psidium guajava, Syzygium cumini*
A. cerana	Gokuleswor	Wall hive	30	1000	*Mangifera indica, Psidium guajava, Brassica* spp.,
A. cerana	Guljar	Wall hive	28	1800	*Musa* spp., *Brassica* spp., *Ficus religiosa, Raphanus sativus*
A. dorsata	Gokuleswor	Branch of mango tree	30	1000	*Mangifera indica, Musa sapientum, Zizyphus jujuba*
A. florea	Gokuleswor	Branch of *Woodfordia fruticosa* and *Pinus roxburghii*	30	1000	*Pinus* spp.,*Shorea robusta, Acacia catechu,Dalburgia sissoo, Mangifera indica, Zanthoxylum armantum, Trifolium repens*
Trigona sp.	Gokuleswor	Crack of tree	30	1000	*Musa* spp., *Psidium guajava, Carica papaya, Musa* spp., *Mangifera indica, Cedrela* spp.
Trigona sp.	Lalinath	Crack of tree	28	1200	*Ficus religiosa, Ficus benghalensis, Brassica* spp., *Musa* spp., *Mangifera indica, Citrus aurantifolia*
Dadeldhura					
A. cerana	Jogbudha	Log hive	30	896	*Shorea robusta, Acacia* spp., *Mangifera indica, Psidium guajava, Musa* spp.
A. cerana	Rupal	Wall hive	25	1997	*Brassica* spp., *Malus domesticus, Citrus* spp., *Citrus aurantifolia, Zanthoxylum armentum, Rhododendron* spp., *Myrica esculanta*
A. cerana	Pokhara	Wall hive	28	1884	*Citrus* spp., *Brassica* spp., *Berberis* spp., *Woodfordia fruticosa*
A. dorsata	Jogbudha	Branch of *Dalbergia sissoo* and *Shorea robusta*	30	896	*Shorea robusta, Mangifera indica, Acacia* spp., *Berberis* spp., *Musa* spp., *Woodfordia fruticosa*
Kanchanpur					
A. cerena	Gobariya	Branch of fallen lemon tree	30	116	*Musa* spp., *Mangifera indica, Rosa sinensis, Psidium guajava , Dalbergia sissoo, Acacia catechu, Bassia* spp., *Shorea robusta , Hibiscus* spp.
A. cerena	Gobariya	Wall hive	30	116	*Musa* spp., *Shorea robusta, Dalbergia sissoo, Psidium guajava, Mangifera indica, Brassica* spp.
A. cerena	Belauri	Wall hive	30	186	*Shorea robusta, Dalbergia sissoo, Woodfordia fruticosa, Musa* spp.
A. dorsata	Mahendrangar	Hanging on the ceiling	30	116	*Ficus religiosa, Psidium guajava, Brassica* spp.
A. dorsata	Gaddachowki	Branch of *Dalbergia sissoo*	30	110	*Mangifera indica, Dalbergia sissoo, Shorea robusta, Bombax ceiba*
A. dorsata	Dodhara	Branch of *Dalbergia sissoo*	30	120	*Dalbergia sissoo and Shorea robusta*
A. florea	Suklaphanta	Branch of *Shorea robusta*	30	198	*Shorea robusta, Dalbergia sissoo, Acacia* spp., *Azadirachta indica, Ficus religiosa, F. bengalensis, Lotus.*
Trigona sp.	Jhalori	Inside hollow of dried tree	30	213	*Bassia* spp., *Musa* spp., *Helianthus annuus, Psidium guajava, Brassica* spp., *Raphanus sativus*

Leszczynska and Microslaw (1993) studied antibacterial properties of various types of honey against *S. aureus, S. dublin, S. agona, Escherichia colii* and *Pseudomonas aeruginosa.* They found different types of honey differed in antibacterial activity. Efem *et al.* (1992) studied the antimicrobial spectrum of honey and found moderate inhibition of *S. aureus* but only at 100% and 50% concentration. Gupta *et al.* (1992) found honey to be more effective than a mixture of ampicilin and honey in infected wounds of buffalo. In the present study, honey of *A. dorsata*

Table 3. Medical properties of honey from bee species collected

Bee species	Ayurvedic view	Local knowledge
Apis cerana	It cures jaundice, piles, cough, asthma, tuberculosis. It is also good for optic health. It also cures one of urinary disease. Honey produced by this bee is best quality.	Uncooked honey is effective for cough, fever, stomach pain and urinary disorder. It is also fed to women after delivery.
Apis dorsata	Good for helminth, dearrangement of blood produced by acidity (rakta-pitta), leucoderma, gonorrhoea, giddiness, etc. It also cures one of urinary disease (diabetes). A little difficult to digest.	Honey is used in diarrhoea and vomiting.
Apis florea	Cures urinary disease. It is also said to cure eye disease. Possesses same properties as *A. cerana* honey.	Honey is used in snake-bite, stomach pain and general headache.
Trigona sp.	Cures urinary disease, but gives burning feeling in case of overdose. It has some bad effects on nerves.	Honey is used in infections. Wax is particularly useful for sealing pots.

Table 4. Impact of honey on *Staphyllococcus aureus*

Honey samples	Mean zone of inhibitions at various concentrations			
	50%	20%	10%	5%
A. cerana [1]	7.75	+ve	+ve	–ve
A. cerana [2]	15	12.25	+ve	–ve
A. dorsata	16.75	13.25	+ve	–ve
A. florea	9.75	+ve	–ve	–ve
Trigona sp.	11.25	+ve	+ve	–ve

Note: 1 from Kanchanpur; 2 from Darchula.

Table 5. Impact of honey on *Salmonella typhi*

Honey samples	Mean zone of inhibitions at various concentrations			
	50%	20%	10%	5%
A. cerana [1]	9.75	+ve	+ve	–ve
A. cerana [2]	12	10.5	+ve	–ve
A. dorsata	9	+ve	9.25	–ve
A. florea	12.75	11.5	+ve	+ve
Trigona sp.	+ve	+ve	+ve	–ve

Note: 1 from Kanchanpur; 2 from Darchula.

showed the highest zone of inhibition and was positive even at 20% and 10% concentration. *Staphyllococcus aureus* infection is serious but treatment is a problem as this pathogen produces b-lactamase which destroys antibiotics (Hope *et al.*, 1996). Thus further study on treatment with honey of *A. dorsata* could be of great medical value. Honey of *A. florea* showed the highest zone of inhibition against *S. typhi*.

Floral variations also seem to have some effect upon antibacterial activity of honey. Honey of *A. cerana* from Kanchanpur and Darchula showed variation in the zone of inhibition for both *S. aureus* and *S. typhi*. This could be due to floral variation at the two sites. Further study on the effects of *A. cerana* honey could identify flora that increases antibacterial activity.

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Chapter 40

The Chemical Compounds of Beeswax from *Apis* Species

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At present, eight species of *Apis* are recognised. All of them construct their nests with beeswax. Beeswax is a complex mixture of chemical compounds, mainly monoester, diester, free fatty acids, etc. This study was undertaken to examine whether there is a difference in the chemical compounds of beeswax among *Apis* species.

Method

Wax samples from the following species were investigated: *A. mellifera* L. (29 samples from different regions of Europe, Nepal and Africa), *A. cerana* (six samples from Nepal and Thailand), *A. florea* (four samples from Thailand), *A. dorsata* (four samples from Nepal, India and Thailand) and *A. laboriosa* (one sample, a mixture of many colonies, from Nepal). Chemical analysis was made using high temperature gas chromatography (HTGC) and HTGC-mass spectrometry.

Results and Discussion

Results are shown in Figs. 1 and 2. The bee species investigated can be easily identified by the wax they produce. The types of chemical compounds are more or less the same in all bee species. Elution patterns of monoester, diester, hydroxy-monoester and hydroxy-diester show characteristic profiles (Fig. 1). The results confirm the phylogenic differences between the species investigated.

Taxonomically, it is still not clarified if *A. dorsata* Fabricius, 1798 and *A. laboriosa* Smith, 1871 are separate species. No differences in the elution profiles of components with higher molecular weights were observed but these species can be distinguished by alkene fractions. The wax of *A. dorsata* shows a significantly lower content of alkenes compared to wax of *A. laboriosa* (Fig. 2).

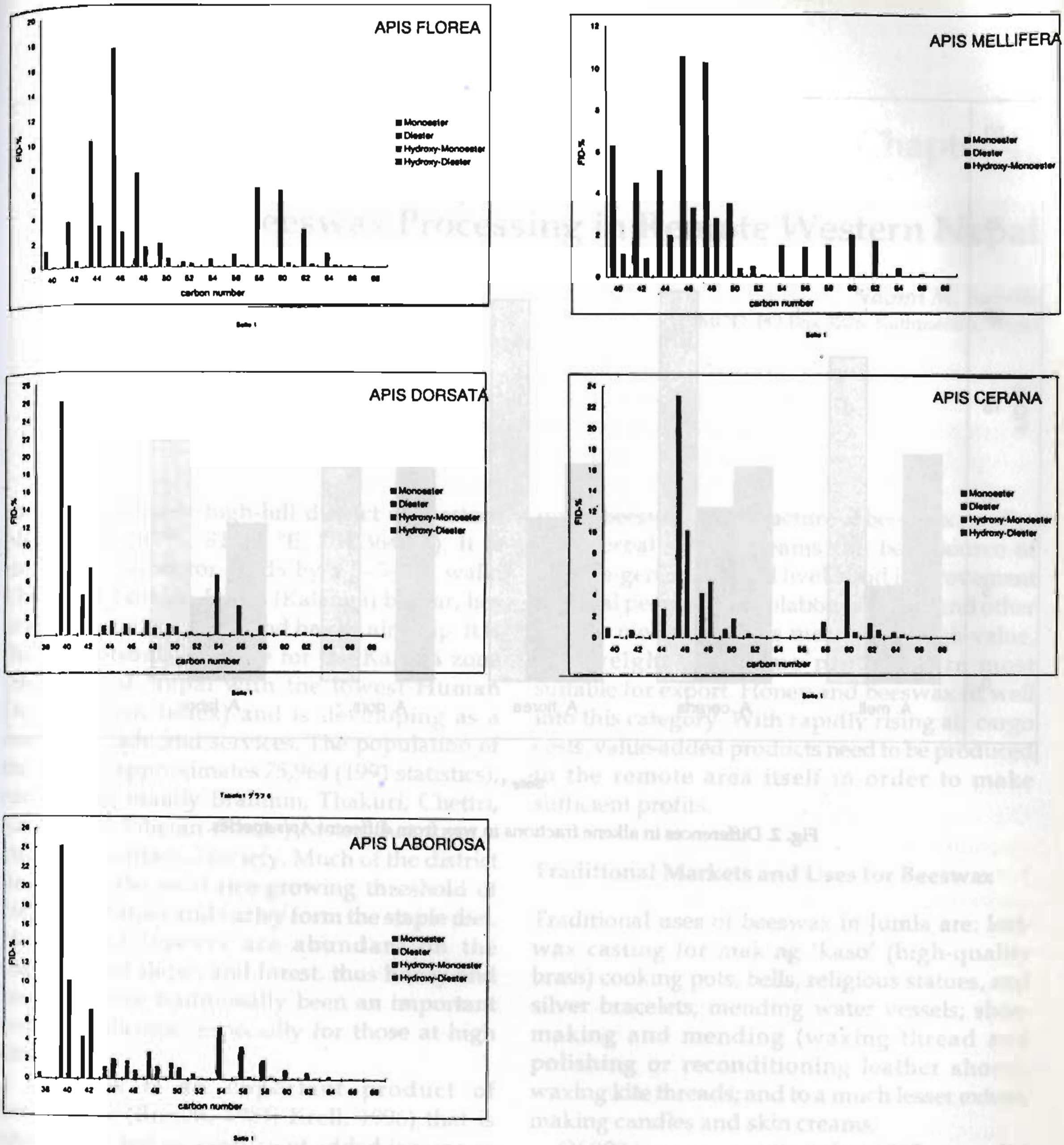

Fig. 1. The Chemical compounds isolated from bees wax of *Apis* species

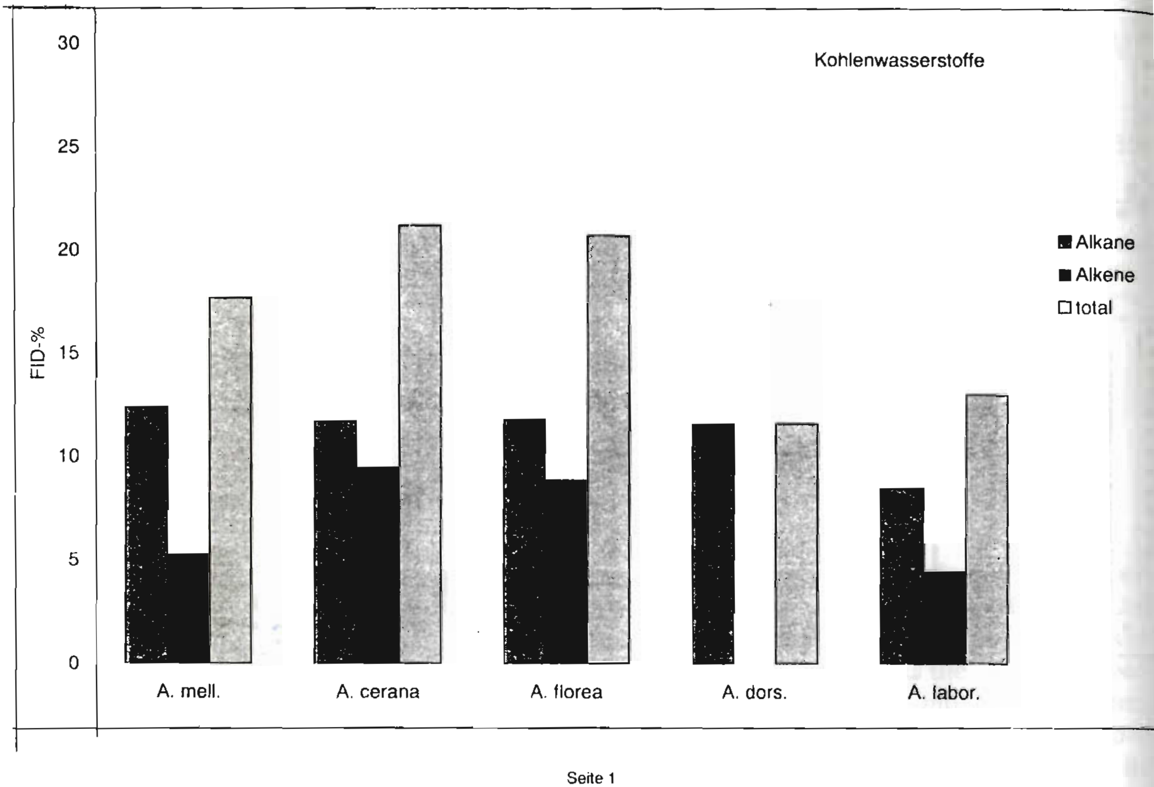

Fig. 2. Differences in alkene fractions in wax from different *Apis* species.

Chapter 41

Small-scale Beeswax Processing in Remote Western Nepal

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Jumla is a remote high-hill district of western Nepal (28–29 °N, 81–82 °E, 254,364 ha). It is isolated from motor roads by a 3–5-day walk. The district centre, Jumla (Kalanga) bazaar, lies at an altitude of 2500 m and has an air-strip. It is the administrative centre for the Karnali zone (the area of Nepal with the lowest Human Development Index) and is developing as a centre of trade and services. The population of the district approximates 75,964 (1991 statistics), comprising mainly Brahmin, Thakuri, Chettri, Kami, and Tibetan (Bhote) castes that form a strongly traditional society. Much of the district lies above the local rice-growing threshold of 2600 m; potatoes and barley form the staple diet. Here, wild flowers are abundant on the uncultivated slopes and forest, thus honey and beeswax have traditionally been an important source of income, especially for those at high altitudes.

Beeswax is an important product of beekeeping (Brown, 1981; Krell, 1996) that is often neglected as a source of added income or as a resource to be utilised within the household. In Jumla, the International Centre for Integrated Mountain Development (ICIMOD) in collaboration with a local non-governmental organisation (NGO) called Surya Social Service Society (or 4S Jumla) have been promoting the use of beeswax. Manufacture of beeswax candles and herbal salves/creams can be a source of income-generation and livelihood improvement for local people. The isolation of Jumla and other remote mountain areas means that high-value, low-weight-to-volume products are most suitable for export. Honey and beeswax fit well into this category. With rapidly rising air cargo costs, value-added products need to be produced in the remote area itself in order to make sufficient profits.

Traditional Markets and Uses for Beeswax

Traditional uses of beeswax in Jumla are: lost-wax casting for making 'kaso' (high-quality brass) cooking pots, bells, religious statues, and silver bracelets; mending water vessels; shoe-making and mending (waxing thread and polishing or reconditioning leather shoes); waxing kite threads; and to a much lesser extent, making candles and skin creams.

Of 302 farmers questioned in 1997, most did not sell or use their beeswax, but at least 126 of them traded it in a barter system with low-caste (Kami and Sunar) people who use it for lost-wax casting of iron and gold respectively. The usual 'price' is 1:1 weight for weight with metal items, often pots and pans. The metal varies: 89 farmers said that they exchanged it for unspecified metal pots; six exchanged for kaso; two for copper; and 20 for iron. Many farmers appear to keep the wax at home and trade it with visiting Kami, but some farmers (16 of those interviewed) carried it with them on trading trips to lower altitudes (for example, Nepalgung and Surkhet) where they deal with metal-workers. Only five farmers claimed to use the wax themselves and only eight quoted a wax price in rupees. This varied from 40 to 200 Rs/kg with an average of Rs 118 (SE of mean 20.9) (US$ 1 = Rs 62.5).

When the Jumla Beekeeping Project started, a few traditional beekeepers were already making candles using the high-altitude bamboo (locally called nigalo) as a mould, and others were making (mustard) oil and wax ointments for the hands and face. Seeing these indigenous methods and realising the value of them the project has worked to promote the use of beeswax in these two ways.

Importance of Beeswax when Honey Crops Fail

As Thai Sac Brood Virus (TSBV) and European Foul Brood (EFB) has decimated the population of *Apis cerana* in Jumla since 1994, promotion of the use of beeswax has been particularly important as a means of encouraging beekeepers not to give up. It is hoped that such efforts may contribute to the preservation of the now relatively rare *Apis cerana cerana* local to the area (Verma, 1998). When colonies abscond or die, they leave combs behind that need to be removed for disease-control purposes. Processing of these combs to make pure beeswax not only sanitises the wax and removes a source of re-infection, but also provides at least a small income from the lost colony. With the failure of honey harvests, exploration of a market for beeswax products is an attempt to improve the economic value of beekeeping until the local bee population evolves adequate resistance to these diseases and honey harvests can increase again.

Beekeeping for Beeswax Instead of Honey Alone

In tests of appropriate technology in beekeeping in Jumla, farmers favour top-bar hives that are adapted from traditional log hives. When extracting honey from these hives, combs are usually cut and squeezed rather than honey being extracted by centrifugal action and the combs being re-used. Hence, beeswax becomes an important product of beekeeping rather than a by-product. Value-added products are potential sources of extra income.

Development of a Beeswax Collection and Processing Centre

In December 1996 a beeswax collection and processing centre was established in Jumla for the promotion of beeswax processing and marketing. This centre buys raw and dirty beeswax from local farmers at a locally negotiated rate of 150 Rs/kg for relatively clean, processed beeswax and Rs 80–90 Rs/kg for dirty wax. This wax is collected during field visits by farmer-trainers of the Jumla Himalayan Beekeepers' Association (HIBA) and by the two staff employed by 4S Jumla to run the beeswax centre. Wax is also collected from the neighbouring districts of Mugu and Kalikot.

Before the wax can be made into value-added products, it has to be repeatedly cleaned and filtered to remove dirt and soot particles. Solar wax-extractors (Tomlinson, 1991) can be used in Jumla to extract wax from old combs during the warmest months of the year (May and June). Black soot is a major problem in quality control. Pine firewood, which is high in resin and produces copious soot, is the normal means of cooking and lighting in Jumla. Soot-contaminated candles, although perhaps darker in colour than pure beeswax, are not significantly different from candles made with cleaner wax, but soot-contaminated creams have a smoky smell that is disliked by most potential customers outside Jumla. Hence the centre has been seeking means of heating wax without fire.

Kerosene, the common alternative to firewood for cooking in the plains of Nepal, is only available in Jumla bazaar (not in rural areas) and is expensive owing to being carried rather than flown in. Electricity supplies however, although unavailable in most villages, are generated by a small hydro-electric power plant that serves Jumla bazaar for much (at least half) of the time. This electricity, although much slower at generating heat to melt beeswax, is a more forest-friendly means of doing so. Despite low and severely fluctuating voltages, an electrically powered wax-melting / candle-dipping tank has been constructed and is under test. It was made as follows. A black polythene water tank was cut open to make a large (c. 175 l) water bath. It was fitted with a thermostatically-controlled heating rod. Two aluminium rectangular boxes for holding wax are then placed in the water bath, close to but not touching the heating rod. The temperature of the rod is adjusted to about 80°C, so that the wax melts. The water bath is insulated with wood shavings enclosed in a wooden box.

An alternative to the use of electricity is the use of solar panels. To date this is effective for small volumes of wax using a 12-V solar panel that charges a small 12-V gel battery. This is connected to a ceramic resistor that heats up slowly and is put in direct contact with the beeswax in a plastic Thermos flask with a secure (insulated) lid. Wax will melt in about 30 min when battery charge is high, but no more than a litre of wax can be melted at one time. Such technology allows wax processing activities to be done regularly even when there is no electricity or firewood, but the equipment is too expensive for village-level production and is not yet developed for large quantities.

Beeswax Products using Local Resources

In addition to candles, medicinal beeswax preparations are also manufactured. Although the beeswax centre has bought in coconut, mustard and essential oils from the plains for making creams in large quantities, Jumla has comparative advantage in the production of certain unusual natural oils. These include hemp-seed (*Cannabis sativa*), dhatelo (*Prinsepia utilis*), tilkuro (*Perilla occimoides*), walnut (*Juglans regia*), apricot kemal (*Prunus persica* and *Prunus* spp.), 'devdar' (*Cedrus deodara*), and jatamansi (*Valeriana jatamansi*). The latter two are 'essential oils' with medicinal application and the others have excellent skin-conditioning properties. Hemp-seed oil is traditionally used as a massage oil for painful joints and muscles. It is now being made into a massage ointment for application like 'deep-heat', and is found to be highly effective. Others are made into various skin creams. Means of increasing the production and helping to remove the drudgery in producing these oils are needed. Currently they are produced by labour-intensive and time-consuming hand-pressing. Research into the many medicinal healing herbs of the area is also underway to discover which are suitable for formulation into creams and in what quantity. To date turmeric (*Curcuma longa*) is being used in antiseptic creams to good effect. *Paris polyphylla* and *Picrorhiza kurrooa* will also be used in the future.

Beeswax Products as a Means to Improving Livelihoods

Aside from its value in income-generation, beeswax can also help improve the livelihood of Jumla people. Beeswax candles give off a bright light and non-toxic sweet-smelling fumes. Lighting for most Jumla families comprises 'jharro', sticks of resin-rich pinewood that give off a thick black sooty smoke. Jharro is harvested at great cost to the forest since it is usually cut from living trees. Candles can contribute both to improved family health and lower levels of forest destruction. School children can read and write by their light, which is not possible with jharro.

The climate of Jumla is harsh with cold, drying winds that chap the lips and skin. Women's hands in particular suffer from manual work with the soil, cutting firewood, scrubbing pots with ash, mud and ice-cold water, plastering floor and walls of their houses with mud and cow-dung, and so on. Many people work in the fields and forests without shoes, often incurring minor wounds to the feet and suffering from cracked heels and soles. Medicinal skin preparations made from oils that villagers make themselves or buy for cooking, combined with beeswax and sometimes local healing herbs help to relieve the suffering of chapped skin, lips and feet. They can also heal wounds that might otherwise go untreated. In remote areas with minimal health services such applications of local resources are very valuable.

Acknowledgements

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Chapter 42

Trends in the Market and Research of Propolis in Japan

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Major honeybee products consumed in Japan are *honey* – around 50,000 t, more than 90% of which are imported from China, North and South America; *royal jelly* – around 350 t, almost all of which come from China; and *propolis*. All are sold commercially as health foods.

Propolis, known also as bee glue, was imported from Europe in the 1960s by a Japanese company at a high price. Propolis was highlighted in Japan in 1985 when the Apimondia Congress was held in Nagoya. Several reports were delivered in the apitherapy section (Apimondia, 1985), and some beekeepers responded keenly. During the five years after 1985, bee products companies imported 10–20 t raw propolis per year from China and Brazil. Since Africanized honeybees seem to better foragers of propolis, Brazil has become a major supplier in recent years. Over 40 t was imported in 1991, and over 60 t in 1995 (Yamamoto, 1996). Market size is over 20 billion yen (approx. US$ 170 million); and 10 ml of ethanol extracted propolis (EEP) is sold for about 2000 yen (approx. US$ 17). EEP usually contains 10–30% solids of raw propolis. Almost all propolis is sold as health food although a few toiletries such as dental paste and skin-care cream are also marketed.

Many general and introductory books with empirical descriptions are published and they are popular among people who care for their health. To further development of the market, the Japan Propolis Conference (JPC) was established in 1987 and by 1997 had 13 member companies. In 1995, a quality standard for EEP was set up by JPC (Table 1). The Japanese Health and Nutrition Food Association also deals with propolis. It has a similar standard but also requires flavonoid determination: total flavonoid content as quercetin equivalent, qualitative flavonoid colouration with a reagent, presence of *p*-cumaric acid or cinnamic acid with HPLC analysis.

Table 1: Quality standards by Japan Propolis Association for ethanol extracted propolis (EEP)

Dry matter:	more than 8% (w/v)
Quercetin:	should be detected
UV absorbency:	maximal at 270–310 nm
Ethanol:	more than 50%

FOR OTHER THAN EEP
(granule, tablet, etc.) further requirements

General microbial counts should be less than 5×10^4/g
Escherichia coli should be negative

Recently extraction methods have diversified with water extraction, micellized extraction, super-critical extraction, etc. JPC is trying to standardize quality but new techniques are being developed and JPC is struggling with water-soluble products. In contrast to EEP of which the main components are flavonoids, the new products do not have distinctive main components. Ministry of Health and Welfare regards these products solely as health foods, and prohibits their sale as medical agents.

Research in Japan on propolis has included the following. Dr Tetsuya Matsuno (NIH, Japan) reported antitumor activities of three compounds in propolis at the Japan Cancer Society meeting in 1991. This triggered extensive research at national and private institutions and universities on the effect of propolis (and its components) as antiviral, immune-activating, antimicrobial (against *Helicobacter pylori*, MRSA, etc.) agents (Yamamoto, 1997). Now reports are frequently found in the annual meetings of cancer, pharmaceutical, medical, and agro-chemical societies. Propolis Researchers' Association (PRA) was established in November 1997 with the aim of providing contact between researchers, producers, and consumers of propolis. Contact address of PRA: Nakane Building #301, Shinjuku 22-3-11, Tokyo 160-0022, Japan; (Fax 81-3-3226-5943).

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Part 6
Advances in Crop Pollination and Bee Flora Research

Chapter 43

Management of Bees for Pollination

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Bees are effective pollinators of crops. They increase seed yield of many entomophilous crops (Free, 1993; Sihag, 1986). Honeybees and some solitary bees are especially helpful and have been successfully managed for this purpose. For effective bee pollination management is required at two levels: crop and pollination. This paper briefly describes methods for management of pollinators.

Management of Crop Environment

To increase the visitation frequency and pollen–gathering efficiency of bees, the agro-ecosystem can be manipulated. The following are required.

Crops attractive to bees

Crops with good floral fragrance, nectar quality, nectar volume and concentration, and pollen mass can be grown or bred (Hawkins, 1969).

Sprays, bee attractants and repellants

To encourage foraging on certain crop and to repel it from others, sprays can be used (Boch, 1982; Frisch, 1967; Praagh and Ohe, 1983; Woodrow *et al.*, 1965).

Removal of floral competitors

Some crops are more attractive to bees than others (Rathi and Sihag, 1993; Sihag, 1982, 1990a, 1995). For pollination of a less attractive crop, the more attractive crops should be removed.

> **Foraging ecology of *Apis cerana* and *Bombus tunicatus* in pollinating balsam flowers**
>
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>
> Balsam (*Impatiens balsamina*) is a major source of nectar in the Himalayan region. A survey of insect pollinators showed 20 species on this crop in the Shimla hills; *Apis cerana* and *Bombus tunicatus* were the chief pollinators. Foraging studies revealed that peak periods of foraging activity were 1000–1100 h for *B. tunicatus* and 1100–1200 h for *A. cerana*. Both species differed significantly only in a few foraging parameters. *Apis cerana* showed diurnal fluctuations in population of pollen and/or nectar collectors.

Management of Bee Pollinators

Honeybees

Two species of honeybee, *Apis mellifera* and *Apis cerana*, are usually utilised for pollination of crops. Following points should be kept in mind.

Selective breeding of honeybees through artificial insemination to produce desired strains is possible. Strains with traits promoting strong colonies and high pollination efficiency can be bred (Cale and Rothenbuhler, 1978; Gary and Witherell, 1977; Meekensen and Nye, 1966).

General colony and apiary management practices for beekeeping in the tropics and temperate climates are now well known (Sihag, 1990b, 1991; Dadant and Sons, 1993). The following conditions should be ensured for strong colonies: presence of newly mated and laying queen; presence of ample brood and honey; colonies should be free from diseases, pests and predators; specific management.

In the tropics, *A. mellifera* is often infested by the ecto-parasitic mite, *Tropilaelaps clareae*, (Sihag, 1991) and in temperate climates, *Varroa jacobsoni* has become a threat (Sihag, 1997a). Diseases infecting this honeybee and their control measures have been listed by Dadant and Sons (1993). *Apis cerana* in India is affected by Thai Sac Brood Virus Disease (TSBVD). Other enemies are common to *A. mellifera*. Therefore, management practices for the dearth period and for management of diseases, pests and predators are required in both climates (Sihag, 1990b, 1991; Dadant and Sons, 1993).

Stingless bees

Stingless bees are mainly natives of tropical climates. Many species of these bees that can be kept in artificial hives have now been identified (Roubik, 1995; Sihag, 1997b).

Bumble bees

Bumble bees are natives of cold climates. They are excellent pollinators of crops with large corollas especially glasshouse vegetable crops. Domestication is possible (Sihag, 1997b) and a large number of bumble bee species have been utilised for pollination of crops.

Carpenter bees

Two species of carpenter bees have successfully been managed. These are *Xylocopa fenestrata* and *X. latipes*. The former can be cultured in hollow castor/*Arundo* tunnels and the latter in specially devised wooden hives (Mardan, 1995; Sihag, 1997b).

Solitary bees

Several species of solitary bees are managed throughout the world for pollination of crops. The nomid of the genus *Nomia* and megachilids of the genus *Megachili*, *Chalicodoma* and *Osmia* are important bees whose management practices are now known (Sihag, 1997b). Their parasites, predators and enemies have also been identified and control methods are known.

Methods of Utilising Bee Pollinators

For better pollination of crops, the method of utilising bee pollinators is important. Methods are different for honeybees and solitary bees.

Honeybees

For honeybee pollination, four things must be kept in mind: time of movement of colonies (Free *et al.*, 1960); site of placement of colonies (Free and Williams, 1974); orientation and dispersion of colonies (Gary, 1979); kinds and numbers of colonies (Burgett *et al.*, 1984; Sihag, 1997c, 1997d).

Other bees

Bees other than honeybees (except some larger species) are generally short fliers with a small foraging range. Therefore, their domiciles must be placed near target crops.

Number of Foragers Required

For maximisation of pollination, optimisation of forager strength (number) is important. Standard honeybees colonies (Burgett *et al.*, 1984) with a given forager strength (Danka and Gary, 1987) are used for pollination of crops. The number of pollinators required is determined on the basis of the following relationship (Sihag, 1997c, 1997d).

$$N = \frac{d}{PE} x \frac{\overline{Y}}{T} x\ a$$

where, N = number of the bees required
d = floral longevity/receptivity
PE = pollinating efficiency of the species with reference to the given crop
Y = average floral density
T = average activity duration of the species on the given crop
a = crop area

Likewise, the number of females/foragers of other bee species required for a given crop area can be determined and this number can be provided by artificial manipulation.

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Chapter 44

Effect of Pollination Strategies on Fruit Set of Apple in Himachal Pradesh

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Most apple cultivars grown on a commercial scale in Himachal Pradesh are self-unfruitful. They require a compatible cultivar for cross-pollination to set a good crop. Red Delicious, Royal Delicious and its bud sports are commercial cultivars, and Golden Delicious and Red Gold are pollinising cultivars generally used in Himachal Pradesh. Orchardists rely on honeybees for effective pollination.

The indigenous Asian hive bee, *Apis cerana*, is available in the vicinity of apple orchards but its population has been drastically reduced since the outbreak of Thai Sac Brood Virus Disease in 1984. In order to supplement the bee population at flowering, the European hive bee, *Apis mellifera*, has been tried (Verma, 1992; Kakar, 1993). Pollinator management in apple orchards in the Himalayas may differ on different aspects (north, south, east, west). Also the placement of bee colonies at top, middle and bottom of slopes may affect fruit set and yield. The proximity of bees to the polliniser and competing crops are other important considerations. Therefore, investigations were undertaken to study the effect of various pollination strategies on fruit set of apple.

Materials and Methods

Studies on pollinator management were conducted in the University apple orchards located at 2282 m during 1994–95. Apple trees were selected randomly and data on bee visits and fruit set were recorded for different distances from hives on northwest, northeast and southwest aspects; for colonies placed at the top, middle and bottom of a slope; for different distances from the polliniser; and, for different distances from other competing crops such as mustard, radish and clover.

Colonies of *A. cerana* (6–7 frames) and *A. mellifera* (8–9 frames) were introduced into the orchard at 5–10% flowering. Data on bee visits were recorded by counting number of bees visiting marked blooms (10 or 100 flowers) during a 10-min period. Data on fruit set was recorded by tagging pre-counted flowers (buds) and later counting number of fruits set.

Results and Discussion

Effect of aspect

Data on bee visits and fruit set on three aspects are presented in Table 1.

Table 1. Performance of honeybees on different aspects in apple orchards

Aspect	Bee species	No. of bees/100 flowers at different distances from hive						Fruit set (%) at different distances from hive					
		6.5 m	13.0 m	19.5 m	26.0 m	32.5 m	39.0 m	6.5 m	13.0 m	19.5 m	26.0 m	32.5 m	39.0 m
Northwest	*Apis cerana*	4.5	8.0	14.0	18.0	20.0	11.0	9.0	11.5	13.5	15.0	14.5	14.0
	Apis mellifera	6.0	7.5	10.0	12.0	14.0	15.0	8.0	9.5	12.0	12.5	11.0	10.5
Northeast	*Apis cerana*	11.0	14.0	15.0	20.0	15.0	16.0	6.0	10.5	13.0	14.0	14.5	13.5
	Apis mellifera	7.5	9.0	11.0	12.5	15.0	13.0	7.5	9.0	11.5	11.0	10.0	9.5
Southwest	*Apis cerana*	5.0	6.0	6.5	8.0	7.5	6.0	2.0	2.5	3.5	4.0	3.5	2.5
	Apis mellifera	4.5	4.0	4.5	5.0	6.0	5.5	1.5	2.0	2.5	3.0	2.0	2.0

There was gradual increase (6 to 15 bees/100 flowers) in visits to blooms by *A. mellifera* on northwest aspects from trees located near (6.5 m) the hive to those further away (39 m). Whereas *A. cerana* only increased its visits up to 32.5 m (4.5 to 20 bees/100 flower) then dropped to 11 bees/100 flowers for 39.0 m. This second trend in bee activity was similar for both species on northeast and southeast aspects. Maximum *A. cerana* and *A. mellifera* foraging occurred on trees located on sunny aspects and minimum for those on shady aspects. Highest fruit set (12–15%) was recorded for trees on northwest and northeast aspects; 2–4% fruit set was recorded on southwest aspects. These results indicate that more bees visit blooms on sunny aspects than shady ones.

Effect of location of bee colonies

Data on location of bee colony are presented in Table 2.

Results show that when colonies were maintained in the middle of the orchard a maximum number of bees visited blooms: 3–4 bees/10 flowers for *A. cerana* and 2–4 bees/10 flowers for *A. mellifera*. The number of bees foraging on trees located at the top and bottom of the slope were lower: 2.5–3.0 for *A. cerana* and 2.0 for *A. mellifera* at the top, and 1.0–1.5 for *A. cerana* and 2.0–2.5 for *A. mellifera* at the bottom. The greater number of bees pollinating flowers in the middle of the orchard may be owing to ease of access.

As a result of higher numbers of bees visiting blooms in the middle, there was greater fruit set: 10–15% for *A. cerana* and 8.5–10% for *A. mellifera*. Lowest fruit set—2.5–3.0% for *A. cerana* and 4.0–5.0% for *A. mellifera*—was recorded on trees at the bottom of the orchard. Moderate fruit set—3.5–4.0 % for *A. cerana* and 3.0–4.5% for *A. mellifera*—was recorded on trees at the top.

Table 2. Effect of placement of honeybee colonies on bee visits and fruit set of apple

Bee species	Location of colony	No. of bees/10 flowers at a distance of		Fruit set (%) at a distance of	
		6.5 m	13 m	6.5 m	13 m
Apis cerana					
	Top level	2.5	3.0	3.5	4.0
	Middle level	3.0	4.0	10.0	15.0
	Bottom level	1.5	1.0	2.5	3.0
Apis mellifera					
	Top level	2.0	2.0	3.0	4.5
	Middle level	2.0	4.0	8.5	10.0
	Bottom level	2.0	2.5	4.0	5.0

Effect of distance from polliniser

Data on the effect of distance from pollinising cultivars is given in Table 3.

Maximum fruit set (6.08%) was recorded when pollinisers were located at the shortest distance (6.5 m). There was gradual reduction in fruit set from 5.60% to 4.44% as the distance from the polliniser increased (13 to 32.5 m). Therefore, for a higher fruit set the commercial cultivar and the polliniser should be located near to each other. Planting pollinisers at 15% (third tree in every third row) is advised because every tree is adjacent to a polliniser (Mayer *et al.*, 1985).

Table 3. Effect of distance from polliniser on fruit set

Polliniser	Fruit set (%) recorded at different cultivar distances from pollinisers				
	6.5 m	13.0 m	19.5 m	26.0 m	32.5 m
Granny Smith	6.0	5.50	4.75	4.25	4.00
Red Gold	5.71	6.60	6.00	5.25	5.00
Tydeman Early Worcester	7.50	5.00	4.50	4.20	4.00
Golden Delicious	5.70	5.86	5.25	5.00	5.00
Lord Lambourne	5.50	5.00	4.50	4.50	4.20
Average	6.08	5.60	5.00	4.64	4.44

Table 4. Visiting of honeybees in apple orchard with and without competing crops

Description of orchard	Per cent reduction in bee population in comparison to control		
	Apis mellifera	*Apis cerana*	Other insects
Apple orchard with competing crops*	20.0	15.0	No effect
Apple orchard without competing crops (control)	Normal	Normal	No effect

* Competing crops were mustard, radish and clover

Effect of competing crops on fruit set of apple

The flowering period of apple (April) coincides with flowering of other crops such as mustard, radish and clover. Bee colonies introduced into apple orchards for pollination at initiation of flowering are reported to shift to these competing crops. In order to ascertain the shift in bee population, an apple orchard with no competing crops and an apple orchard with competing crops were selected. Data are presented in Table 4.

Results show that normal non-bee activity was recorded in apple orchards but there was sizable reduction in both *A. mellifera* (20%) and *A. cerana* (15%) populations. The reduction may be owing to greater attraction to competing crops.

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Chapter 45

Pollination of Kiwifruit in Himachal Pradesh

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Kiwifruit (*Actinidia chinensis*), also known as Chinese gooseberry, is functionally dioecious and, therefore, requires interplanting of male plants with females in the ratio 1: 9 for fruit production. Flowers are visited by pollinators only for pollen as there is little nectar and so are not particularly attractive to bees. It has been suggested that bees can be stimulated to collect pollen by feeding colonies with sugar syrup (Goodwin, 1997). The cultivation of this exotic fruit has been a great success under mid-hill conditions of Himachal Pradesh in areas at 600–1700 m and is now being extended to other Himalayan regions of the country. The present studies were undertaken to discover the pollinator complex and to study the effect of using bee colonies for pollination on fruit set and quality of fruit.

Materials and Methods

The present studies were undertaken in the kiwi (var. Allison) orchard of Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (1275 m) during April to November 1996. Pollinators visiting flowers were counted and identified. One colony of *Apis mellifera* and four colonies of *A. cerana* were placed in one corner of the orchard when about 5% of the crop had bloomed. Kiwi vines at 8, 12, 25 and 55 m away from bee colonies were marked. Floral buds on two branches of each vine were counted for three types of pollination: open pollination, hand pollination and caged pollination. Data on fruit set were recorded in July 1996. Observations on the visits of insect pollinators during different day hours were recorded. Ten fruits were harvested in November and the weight of each fruit from each mode of pollination was recorded. Kiwifruit have thousands of seeds so for comparision fruits were cut into transverse and longitudinal sections and the number of seeds revealed were counted.

Results and Discussion

Six species of insect pollinators visited the kiwi bloom: *A. mellifera, A. cerana, A. dorsata, Eristalis* sp., *Episyrphus* sp. and *Orthellia* sp. However, *A. dorsata* was the predominant visitor constituting 40.5% of total. *Apis mellifera* and *A. cerana* constituted only 7.87% and 4.42% respectively despite placement of five colonies in the orchard. This indicated that hive bees preferred other flora. This is contrary to the findings of Barbattini *et al.* (1994) who reported that *Apis mellifera* was the most important pollinator of this crop. The dipteran flies, *Episyrphus* and *Orthellia*,

Table 1. Percentage fruit set in kiwi at various distances from bee colonies at Nauni during 1996

Distance (m)	Average fruit set (%)	Range
8	81.03 ± 3.86	66.67–92.59
12	93.35 ± 2.48	82.00–96.67
25	92.85 ± 0.85	91.43–96.42
55	96.05 ± 1.08	93.10–97.50

Average fruit set (%) = 90.82 ± 2.89

represented 27.07% and 13.85% of the insect visitors. However, as pointed out by Macfarlane (1995), flies carry only 10% of the pollen that bees can carry on their bodies, so the role of flies in kiwi pollination remains limited.

Average fruit set at various distances from bee colonies kept in the orchard was 81.03% at 8 m, 93.35% at 12 m, 92.85% at 25 m, and 96.05% 55 m (Table 1). This indicates that placement of colonies did not influence fruit set. The heavy fruit set obtained was due to wild pollinators and wind pollination. Wind is known to play an important role in kiwi pollination since pollen produced by male flowers is dry. Ferguson and Pusch (1991) have reported that pistillate flowers of kiwi capture viable pollen even without insect visitation and postulated that air currents were the vector and electrostatic charges and acoustics were implicated in kiwi pollination. However, Costa *et al.* (1993) found that although wind pollination can result in 81–98 % fruit set, the fruits weigh less from such pollination. In the present study, fruit set from hand pollination was 100% and caged pollination (indicating wind pollination) was 40–50%.

Fruits collected from hand-pollinated vines were heavier (61.63 ± 1.46 g) than those from open pollination (47.41 ± 2.4 g) and caged pollination (15.17 ± 0.68 g). Qualitatively also, the placement of bee colonies did not influence the weight of fruit. There was no trend in the weight of fruits harvested at 8–55 m. The number of seeds was not significantly different in fruits taken from hand- and open-pollinated blooms. There were few seeds in fruits from caged treatments. The results suggest that under Solan conditions, hand pollination is more effective than open pollination using bee colonies in quality-kiwifruit production.

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Chapter 46

Pollination of Peach and Plum by *Apis cerana*

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Peaches and plums are widely planted in the middle hills of Nepal. Varieties of plum are self-incompatible and require cross-pollination to produce fruit. Peach is self-compatible; however, cross-pollination increases yield and improves fruit quality (Free, 1993). Cross-pollination is brought about by insect pollinators that visit flowers for pollen and nectar. Among pollinating insects, honeybees, in particular, are attracted to these crops and are reported to be of great benefit (Choi and Lee, 1988; Free, 1993; Mann and Singh, 1983). The flowers provide good amounts of pollen and nectar for about two to three weeks. Plum blooms one to two weeks earlier than peach. The present investigation looked at the impact of *Apis cerana* on the yield and quality of peach and plum.

Materials and Methods

The experiment was carried out on plum (*Prunus domestica*) during the last week of February 1997 and on peach (*Prunus persica*) during mid-March 1997 at ICIMOD's Trial and Demonstration Farm, Godavari in the Kathmandu valley of Nepal.

To determine the effect of *A. cerana* pollination on fruit yield and quality, three treatments were replicated three times: control (plants in a cage with no insect pollinators); open pollination (plants accessible to naturally occurring insect pollinators); and honeybee pollination (plants caged with *A. cerana*). For control, three trees were covered with a cage (15 m × 3 m × 2.5 m) to exclude all natural insect pollinators including free-ranging honeybees. In open-pollinated plots, observations were taken of trees not protected by cages thus permitting naturally occurring insect pollinators to visit flowers freely. In honeybee-pollinated plots, three trees were covered with a cage (15 m × 3 m × 2.5 m) so that no insect pollinator could enter; when plants started blooming, one medium-sized colony of *A. cerana* having seven frames covered with bees and free of any sign of disease was placed in each cage for each crop.

For each treatment, two to four branches on each tree (8–12 branches for each treatment) were marked and the number of flowering buds were counted. About one month after petal fall, the number of fruits on each branch were counted. After ripening, 5–10 fruits from each branch (60–120 fruits from each treatment) were collected. Fruits from each treatment were weighed. Length and diameter of each fruit were measured.

Data were analysed statistically using analysis of variance.

Results

Table 1 summarises the impact of *A. cerana* pollination on the yield and quality of fruit in peach and plum.

Bee pollination significantly increased fruit set in peach by 21.9% over control and 9.4% over open pollination, and in plum by 13.0% over control and 8.6% over open pollination. It also significantly increased the weight per peach fruit by 43.8% over control and 25.6% over open pollination and the weight per plum fruit by 38.6% over control and 10.8% over open pollination. Similarly, it increased the length per peach fruit by 28.9% over control and 21.6% over open pollination and the length per plum fruit by 11.4% over control and 2.1% over open pollination, and the diameter per peach fruit by 22.5% over control and 12.1% over open pollination and the diameter per plum fruit by 13.6% over control and 4.2% over open pollination. Bee pollination decreased the time required for ripening of fruit by one week in both peach and plum.

Discussion

Since plum and peach bloom during early spring in the Kathmandu valley, *A. cerana* is important for pollination as natural insect pollinators are only present in small numbers because of low temperatures. Partap *et al.* (1999) reported that *A. cerana* mostly worked flowers from on top and collected mainly pollen indicating its efficiency in fruit-crop pollination. Top workers collecting pollen are considered to be better pollinators than side workers collecting nectar.

Apis cerana pollination enhanced fruit set and fruit weight, and increased both length and diameter of fruits as compared to control and open-pollinated plants. Increase in fruit set and fruit weight as a result of bee pollination could be because of greater numbers of pollinators in the plots caged with bees and the superior pollinating efficiency of honeybees. Natural insect pollinators, on the other hand, because of their lower numbers and lower pollinating efficiency resulted in lower fruit set and fruit weight. Any fruit set in plots caged without pollinating insects resulted from a limited amount of self-pollination that might have occurred by pollen blown from anthers on to stigmas.

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Table 1. Impact of *Apis cerana* pollination on the yield and quality of fruit in peach and plum in the Kathmandu Valley, Nepal. Values are mean SE.

Parameter	Control	Open-pollinated	Bee-pollinated	Increase over control	Increase over open-pollinated	Values of *f* and degrees of freedom
Peach						
% Fruit set	18.04 ± 4.7	30.5 ± 4.3	39.9 ± 3.9	21.9	9.4	$F = 11.9$; $df = 33$
Weight per fruit (g)	111.7 ± 16.4	127.7 ± 27.2	160.5 ± 21.7	43.8	25.6	$F = 61.81$; $df = 76$
Length of fruit (cm)	8.3 ± 0.8	8.8 ± 0.7	10.7 ± 0.9	28.9	21.6	$F = 11.61$; $df = 77$
Diameter of fruit (cm)	18.2 ± 2.5	19.9 ± 1.5	22.3 ± 1.1	22.5	12.1	$F = 22.74$; $df = 77$
Plum						
% Fruit set	3.9 ± 2.1	8.3 ± 1.9	16.9 ± 1.8	13.0	8.6	$F = 18.9$; $df = 33$
Weight per fruit (g)	22.3 ± 5.9	27.9 ± 3.7	30.9 ± 2.9	38.6	10.8	$F = 59.65$; $df = 76$
Length of fruit (cm)	4.4 ± 0.5	4.8 ± 0.5	4.9 ± 0.7	11.4	2.1	$F - 21.5$; $df = 83$
Diameter of fruit (cm)	11.0 ± 0.6	12.0 ± 0.8	12.5 ± 0.4	13.6	4.2	$F - 39.4$; $df = 71$

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Chapter 47

Foraging Behaviour of *Apis cerana* on Sweet Orange (*Citrus sinensis* var. Red Junar) and its Impact on Fruit Production

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The sweet oranges (*Citrus sinensis* var. Red Junar) have been widely planted under the middle hill region of Nepal. They bloom during March–April and produce plenty of nectar and pollen. Flowers are usually self-compatible but benefit to a great deal from cross-pollination by honeybees. Honeybees collect lots of honey from citrus flowers.

The pollination requirements of the different kinds of citrus vary from almost complete self-sterility in some cultivars to complete self-fertility in others. While in the self-sterile cultivars pollen must be transferred from those of another compatible varieties for maximum fruit production, in self-fertile cultivars the plant is benefited if pollen is moved from flower to flower within the cultivar or within the species. In addition, there are varying degrees of parthenocarpic development of the fruit, for example, 'Washington Navel' oranges have the ability to set parthenocarpic fruit (Webber *et al*, 1943). Therefore, studies on foraging behaviour of *Apis cerana* on the commonly planted sweet orange (*Citrus sinensis*, a local variety called Red Junar) flower and its impact on the quality and yield in the middle hill areas were carried out.

Materials and Methods

Foraging behaviour of *Apis cerana* on the flowers of a local variety of sweet orange (*Citrus sinensis* var. Red Junar) and its impact on fruit production was studied at HMG's Horticulture Farm, Kirtipur, in the Kathmandu valley of Nepal. Observations on floral biology included the number of flowers per plant per day, size of flowers, and total blooming period of the crop. Observations on the foraging behaviour of the bees were made on the daily time of initiation and cessation of foraging, total duration of foraging activity, peak foraging hours, time spent on the flower, number of flowers visited per minute, number of foragers per 1,000 flowers per 10 minutes, and the weight of pollen load carried by an individual bee. For other logistics of foraging behaviour studies, methods given by Partap and Verma (1994), and Verma and Partap (1994) were followed. Observations of time spent on flower, number of flowers visited per minute, pollen loads collected and pollen vs. nectar collectors were recorded at 1000, 1200 and 1400 h.

For the pollination studies, three treatments were applied as follows: control (plants in a cage with no insect pollinators); open pollination (plants accessible to naturally occurring insect pollinators); and honeybee pollination (plants caged with *Apis cerana*). For details of the experimental design, please see Chapter 46 on "Pollination of peach and plum by *Apis cerana* (Partap *et al*, 1999 a) of this book. Data were analyzed statistically using analysis of variance.

Results

Flowering started in the spring (late March to early April). The flowers were whitish in colour, had a pleasant fragrance and were highly attractive to the bees. The size of flowers varied from 2.0–2.5 cm. They open primarily from 9 a.m. to 4 p.m. with the peak period about noon. The flowers never close; the petals shed a few days later. Each flower had five oblong, glossy petals, ten stamens consisting of upright white filaments, united into three groups at the base, with yellow anthers on the tip and a greenish multilocular overy with 9–13 locules, a style and a globose yellowish stigma that terminated the style. A nectariferous disc was situated at the base of the ovary.

Apis cerana started their foraging activities early in the morning at 0600 h and ceased late in the evening at 1835 h. The total duration of foraging activity was 12.05 hours and the average duration of a foraging trip 22.6 minutes. Peak foraging activity was observed between 1000–1200 h. A nectar collector spent an average of 9.3 seconds and a pollen collector spent 4.1 seconds per flower, and visited an average number of 5.5 and 8.2 flowers per minute respectively. A pollen collector on an average collected 6.5 mg of pollen load (Table 1).

Apis cerana enhanced fruit set by 24.2 per cent and nine per cent, and reduced fruit drop by 45.9

Table 1. Foraging behaviour of *Apis cerana* on sweet orange bloom

Parameter	Measurement
Initiation of foraging activity (time of day)	06.30 ± 0.2
Cessation of foraging activity (time of day)	18.35 ± 0.3
Total duration of foraging activity (h)	12.05 ± 5
Peak foraging hours (time of day)	10.00 - 12.00
Time spent per flower by a bee (s)	
i. Pollen collector	4.1 ± 0.8
ii. Nectar collector	9.3 ± 1.3
Number of flowers visited per minute by a bee	
i. Pollen collector	8.2 ± 1.3
ii. Nectar collector	5.5 ± 1.2
Number of bees per 1000 flowers per 10 minutes	6.1 ± 1.2
Weight of pollen load	6.5 ± 1.7

and 2.98 per cent as compared to control and open pollinated respectively. Bee pollination also enhanced the fruit quality by enhancing the fruit size, fruit weight, amount of fruit juice and the amount of sugars in the fruit juice. It increased the fruit length by 8.9 and 2.5 per cent, and fruit diameter by 34.8 and 9.8 per cent as compared to control and open pollinated respectively. Bee pollination enhanced the amount of fruit juice by 67.7 and 44.4 per cent, and fruit sugar by 39.1 and 25.5 per cent as compared to control and open pollinated respectively. It also increased the number of seeds per fruit. Bee pollination reduced the citric acid content by 29.2 per cent compared to control, there was no difference in the citric acid content in the fruits from bee-pollinated and open-pollinated plants (Table 2).

Discussion

Sweet orange blooms during spring in the Kathmandu valley. Its flowers are visited by a number of different kinds of insects for their abundant nectar and pollen. But honeybees are important for pollination. They collect both pollen and nectar from citrus. The flower is so constructed that if the bee has visited a previous pollen-producing flower, some pollen is likely to be transferred to the next stigma visited, thus

Table 2. Effect of *Apis cerana* pollination on quality and yield of sweet orange

Parameter	Control	Open Pollinated	Bee Pollinated	% Increase over Control	% Increase over Open Pollinated
Initial Fruit set (%)	15.5±5.7	30.7±4.9	39.7±2.6	24.2	9.0
% Fruit drop	50	12.1	4.06	-45.9	-2.98
Final fruit set (%)	7.5±7.5	26.9±6.7	38.09±4.4	30.6	11.8
Weight per fruit (g)	146	157.5	170	35.04	7.9
Fruit length (mm)	60.6	64.4	66.0	8.9	2.5
Fruit diameter (mm)	54.9	67.4	74.0	34.8	9.8
Peel thickness (mm)	6.6	5.9	4.4	-33.3	-25.2
Juice per fruit (g)	155	180	260	67.7	44.4
% Citric acid	2.4	1.7	1.7	-29.2	No difference
% Sugar in juice	9.2	10.8	12.8	39.1	25.5

affecting pollination. Thus, honeybee is unquestionably the primary pollinating agent of citrus, other pollinating insects are minor they are not present in abundance in nature and can not be managed for pollination. Wind and gravity can not affect pollination in citrus (Free 1993, McGregor, 1976)

Our observation on the foraging behaviour that the pollen collectors spent comparatively less time and visited more number of flowers than nectar collectors agree to that of Hassanein and Ibrahim (1959) who reported that the nectar collectors spent 15-20 s per flower compared to 5-8 s by the pollen collectors. *A. cerana* mostly worked flowers from top and collected mainly pollen indicating its greater efficiency in fruit-crop pollination. Top workers collecting pollen are considered to be better pollinators than side workers collecting nectar. Nectar collectors, on the other hand alight on the petals and collect nectar without touching the anthers. Similar results were reported by Hassanein and Ibrahim (1959) for citrus and Partap *et al.* (1999 b) for peach and plum.

Apis cerana pollination enhanced fruit set and fruit weight, and increased both length and diameter of fruits as compared to control and open-pollinated plants. However, it also increased the number of seeds per fruit, which can be considered as a negative impact on quality of fruit in citrus. Thus one has a choice of managing bee pollination for having higher fruit set and fruits with more juice of higher sugar content or lower fruit set with less number of seeds with relatively less juice and lower sugar content. Increase in fruit set and fruit weight as a result of bee pollination could be because of greater numbers of pollinators in the plots caged with bees and the superior pollinating efficiency of honeybees. Natural insect pollinators, on the other hand, because of their lower numbers and lower pollinating efficiency resulted in lower fruit set and fruit weight. Any fruit set in plots caged without pollinating insects resulted from a limited amount of self-pollination that might have occurred by pollen blown from anthers on to stigmas. However, on the basis of available literature, McGregor (1976) analyzed that the results of bee pollination in citrus depend upon the cultivars.

Our results agree with those of Glukhov (1955) who reported that orange trees (cultivar not mentioned) pollinated by bees produced four times as much fruit as trees isolated from bees. Similarly, Zavrashvili (1966) reported that the orange crop in cages without bees was 54.4 per cent lower than that on trees in the open. The cultivar was not identified nor was there a measure of cage effect on the plant other than pollination effect. Wafa and Ibrahim (1963) obtained 31 per cent increase in set of fruit on the 'Elfelaha' orange, 22 per cent increase in fruit weight, 33 per cent more juice, and 36 per cent more seeds from fruits on trees visited by bees than on trees from which bees were excluded. Hassanein and Ibrahim (1959) reported a set of 2.6 per cent of flowers of the 'Khalili' orange where insects were excluded, 10.4 per cent set where honeybees were present, and 7.4 per cent on open blooms. Although the results of tests are meager, some beneficial effects of pollination on oranges are indicated.

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Pollination of Strawberry by the Asian Hive Bee, *Apis cerana*

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Today, commercialisation of agriculture is being promoted on a large scale in countries of the Hindu Kush-Himalayan region. In recent years farmers in the Kathmandu valley of Nepal have started cultivating strawberry as it is one of the high payoff fruit crops. Scientific reports available from different countries show that the yield, size and shape of strawberry fruit depend upon the adequate pollination of its flowers by different insects (McGregor, 1976; Crane, 1990). Among different species of pollinating insects, domesticated species of honeybees such as *Apis cerana* and *Apis mellifera* are reported to be the principal pollinators of strawberry flower (Nye and Anderson, 1974; Singh, 1979).

So far, studies on strawberry pollination have been carried out in the European countries using *Apis mellifera*. These studies show that the honeybee (*Apis mellifera*) pollination enhances both quality and yield of strawberry fruit (Free, 1968; Moeller and Koval, 1973; Nye and Anderson, 1974; Goodman and Oldroyd, 1988). However, since very little work has been done on its pollination using the Asian hive bee, *Apis cerana* in the Hindu Kush-Himalayan region countries, therefore, we studied the foraging behaviour of *Apis cerana* and its impact on the quality and yield of strawberry fruit under the agroecological conditions of the Kathmandu valley of Nepal.

Materials and Methods

Plants of strawberry (*Fragaria ananassa* var. Nyoho) were raised on the experimental plots of ICIMOD's Trial and Demonstration Farm, Godavari, in the Kathmandu valley of Nepal (27°35'N and 85°24'E) at a plant to plant distance of 30–40 cm and row to row distance of 40–50 cm. Observations were recorded for number of flowers per plant per day, size of flowers, and total blooming period of the crop.

For the pollination studies, three sets each of three experimental groups were used: control (plants in a cage with no insect pollinators); open pollination (plants accessible to naturally occurring insect pollinators); and honeybee pollination (plants caged with *Apis cerana*). For the control plots, about 50 plants were covered with a cage to exclude all natural insect pollinators including free ranging honeybees. In open-pollinated plots observations were taken of the plants not protected by cages which permitted naturally occurring insect pollinators to visit the flowers freely. In honeybee-pollinated plots about 200 plants were covered with a cage 12 m long, 3 m wide, and 2-2.5 m high, so that no insect pollinator could enter. Three such pollination cages were used. When strawberry started blooming, a medium-sized colony of *Apis cerana* having seven frames covered with bees and free of any sign of disease was placed in each of the three pollination cages.

Observations on foraging behaviour were recorded for the daily initiation and cessation of foraging, peak hours of foraging activity, duration of foraging trips, the individual bee's choice of nectar or pollen, the weight of pollen carried by a bee, the time spent on each flower, and the number of flowers visited per minute. Observations of the weight of pollen load, time spent on the flower, the number of flowers visited per minute by a bee and the number of pollen and nectar collectors were taken at three different times of the day i.e.09.00 (2.57 h after sun rise), 12.00 (5.57 h after sun rise) and 15.00 h (8.57 h after sun rise).

In order to differentiate between nectar and pollen collectors, returning foragers were collected with the aid of an aspirator at the hive entrance and frozen to prevent regurgitation of nectar. The frozen bees were sorted for the type of forage, following the method of Erickson *et al.* (1973). The peak hours of foraging activity were determined by counting the number of bees entering the hive in a three-minute period each hour from early morning until late evening. The weight of pollen loads were determined by anaesthetizing samples of returning bees with carbon dioxide (Frisch, 1967), removing their pollen loads, and weighing them. Duration of foraging trip was determined by marking 25 forager bees with nail polish of different colours and noting the times when each of these marked bees leaves the hive for foraging and comes back.

After ripe, the berries from control, open-pollinated, and bee-pollinated plants were picked up. Berries from each treatment were counted and weighed. Number of well-formed (perfect) as well as misshapen berries from each treatment were also counted. Changes in the quality and quantity of berries as a result of bee-pollination were assessed by comparison of the counts of number of berries, weight of berries and percent of misshapen berries. Data were analyzed statistically using analysis of variance.

Results

Strawberry plants had an average number of 3.2 ± 1.1 flowers each day. White flowers were 2.4 ± 0.3 cm in diameter (Table 1). The flowers remained open for three to four days. Strawberries started flowering during mid-February till mid-May and the total flowering period of the crop lasted for about three months.

Table 1: Floral biology of strawberry in the Kathmandu valley, Nepal. Values are mean ± s.e.

Parameter	**Measurement**
No. of flowers/plant/day	3.2 ± 1.1
Diameter of flower	2.4 ± 0.3 cm
Total flowering period	Three months(Mid-February to Mid-May)

Observations on the foraging behaviour of *Apis cerana* are summarised in Table 2. Worker bees of *Apis cerana* foraged on strawberry flowers for 11.27 h per day, starting at 06.59 h (56 min after sun rise) in the morning and stopping at 18.28 h (10 min after sun set) in the evening. Peak foraging occurred from 11.00 to 14.00 hours when the outside temperature was 23–27°C and relative humidity ranged between 58–77%. The average duration of each foraging trip was 18.2 ± 2.3 min. Each foraging bee made an average of 11.5 ± 1.9 trips per day and visited an average number of 157.9 ± 27.9 flowers per trip.

Each worker bee of the *Apis cerana* spent on an average 4.5, 4.3 and 8.8 s on each flower and visited an average number of 9.6, 9.9 and 6.7 flowers per minute at 09.00 (2.57 h after sun rise), 12.00 (5.57 h after sun rise), and 15.00 h (8.57 h after sun rise) respectively. At 09.00 h pollen collectors outnumbered nectar collectors (P:

Table 2: Foraging behaviour of *Apis cerana* on strawberry flowers in the Kathmandu valley, Nepal. Values are mean ± s.e. Statistical results are from analysis of variance.

Parameter	Measurement
Initiation of foraging (time of day)	06.59 ± 0.04 h (56 min after sunrise)
Cessation of foraging (time of day)	18.28 ± 0.05 h (10 min after sun set)
Duration of foraging activity (h)	11.27 ± 0.04 h
Peak foraging hours (time of day)	1100 – 1400 h
Duration of foraging trip	18.2 ± 2.3 min
Number of foraging trips per day	11.5 ± 1.9
Number of flowers visited per trip	157.9 ± 27.9
Time spent on flower	
09.00 h (2.57 h after sun rise)	4.5 ± 0.06 s
12.00 h (5.57 h after sun rise)	4.3 ± 0.03 s
15.00 h (8.57 h after sun rise)	8.8 ± 0.03 s
	F = 108.9
	df = 147
No. of flowers visited per minute	
09.00 h (2.57 h after sun rise)	9.6 ± 0.7
12.00 h (5.57 h after sun rise)	9.9 ± 0.3
15.00 h (8.57 h after sun rise)	6.7 ± 0.9
	F = 27.1
	df = 147
Weight of pollen load (mg)	
09.00 h (2.57 h after sun rise)	9.4 ± 0.9
12.00 h (5.57 h after sun rise)	11.7 ± 1.2
15.00 h (8.57 h after sun rise)	6.8 ± 2.8
	F = 21.6
	df = 27
Ratio between pollen-collectors and nectar-collectors (P: N)	
09.00 h (2.57 h after sun rise)	1.0 : 0.4
12.00 h (5.57 h after sun rise)	1.0 : 1.5
15.00 h (8.57 h after sun rise)	1.0 : 2.3

Note: Differences in the time on flower, number of flowers visited per minute and the weight of pollen loads carried between 09.00, 12.00 and 15.00 h of the day are significant at P<0.01

N=1.0: 0.4) whereas at 12.00 h and 15.00 h nectar collectors outnumbered pollen collectors (P: N= 1.0: 1.5 at 1200 h and P: N=1.0: 2.3 at 1500 h). Pollen loads averaged 9.4 ± 1.3 mg, 11.7 ± 1.9 mg and 6.8 ± 1.8 mg at 09.00 h, 12.00 h, and 15.00 h respectively.

The effects of *Apis cerana* pollination on the yield and quality of berries are summarised in Table 3. Bee pollination enhanced fruit set by 112.3 and 21.4%; and weight per fruit by 47.9 and 20.3% in comparison to control and open pollinated plants respectively. It reduced the percentage of misshapen fruits by 41.7 and 31.8% compared to control and open pollinated plants respectively.

Discussion

Strawberries start blooming during spring season in Kathmandu valley of Nepal. Pollination of its flowers is possible by using domesticated honeybees as well as other natural insect pollinators. But during recent years the populations of the natural insect pollinators is decreasing rapidly because of the heavy use of pesticides on agricultural and horticultural crops and the loss of habitat quality and quantity. Therefore, domesticated species of honeybee remain the most important crop pollinators. The total flowering period of crop extending upto three months suggests that this crop can be a good source of nectar and pollen to bees.

Results of the present investigation show that the duration of foraging activity of *Apis cerana* worker bees was 11.27 h per day. Our earlier studies (Partap and Verma, 1994; Verma and Partap 1993; 1994) on the foraging behaviour of *Apis cerana* on other crops flowering during early spring season in Kathmandu valley of Nepal also show that duration of foraging activity was 11.03 h on cauliflower; 12.05 h on cabbage and 11.5 h on radish. The potential for long foraging hours enables honey bees to pollinate a maximum number of flowers per day and makes them efficient pollinators.

The peak hours of foraging activity were between 11.00 to 14.00 h whereas Singh (1979) observed the maximum activity of *Apis cerana* between 09.00 and 14.00 h, with only a few bees flying after 16.00 h under the agroclimatic conditions of Uttar Pradesh hills in India. Our observation that the worker bees spent 4.5–8.8 s on each flower agrees to those of Petkov (1965) and Free (1968) who reported that *A. mellifera* worker bees (nectar collectors) averaged 7–10 s

Table 3: Effects of *Apis cerana* pollination on strawberry fruit. Values are mean ± s.e. Statistical results are from analysis of variance.

Parameter	Control	Open-pollinated	Bee-pollinated	% Increase over control	% increase over open pollinated	Values of F and degrees of freedom
Number of fruits/plant/picking	1.6 ± 0.7	2.8 ± 0.9	3.4 ± 0.4	112.3	21.4	$F = 136.3$ $df = 87$
Weight per fruit	4.8 ± 1.9	5.9 ± 1.0	7.1 ± 0.7	47.9	20.3	$F = 85.6$ $df = 57$
% misshapen fruits	64.3	22.5	12.6	–	–	$F = 97.1$ $df = 21$

per flower and that the pollen collectors spent less time on each flower. Worker bees of *Apis cerana* collected heavier pollen loads during morning and noon hours. This might be because the maximum number of pollen grains was presented by this crop during morning and noon hours. Thus, the temperature (21–25°C) and relative humidity (50–78%) during these hours are not only best suited for the peak foraging activities of worker bees but also for gathering heavier pollen loads. This is further supported by the fact that pollen collectors outnumbered nectar collectors ($P > N$) during morning hours and nectar collectors outnumbered pollen collected ($N > P$) during afternoon hours. The possible reason for this change from pollen to nectar collection during the day might be a depletion of available pollen as foragers collected it in the morning hours.

Apis cerana pollination enhanced fruit set and fruit weight compared to control and open-pollinated plants. Increase in fruit set and fruit weight as a result of bee pollination could be due to greater number of the pollinators in the plots caged with bees and the superior pollinating efficiency of honeybees. Natural insect pollinators, on the other hand, due to their lower number and lower pollinating efficiency pollinated fewer flowers which resulted in low fruit set and fruit weight. Fruit set in the plots caged without pollinating insects was due to some amount of self pollination which might have occurred by pollen blown from anthers on to the stigmas. Studies carried out in the developed countries also show that honeybee (*Apis mellifera*) pollination increased fruit set by 10–25% and fruit yield by 18–100% depending upon the cultivar (Free, 1968; Moeller and Koval, 1973; Nye and Anderson, 1974; Lackett and Burkhardt, 1979; Svensson, 1991).

Apis cerana pollination also enhanced the fruit quality by reducing the percentage of misshapen fruits. Strawberry flower has many carpels and it is necessary that all of these should contain a fertilised ovule (i.e. produce a seed) in order to produce a well-formed berry. Honeybees micromanipulated the flowers and transferred sufficient pollen grains to fertilise all the ovules in more flowers, thereby resulting in higher number of perfect berries and reducing the percentage of misshapen fruits compared to the control and open pollinated flowers. It has been already reported that honeybee (*Apis mellifera*) pollination increased the number of large and perfect fruits by 7–16% and decreased malformed fruits by 9–41% (Free, 1968; Moeller and Koval, 1973; Nye and Anderson, 1974; Goodman and Oldroyd, 1988).

Low fruit set and higher percentage of misshapen fruits in the plots caged without pollinating insects were due to insufficient pollination. Hughes (1961) also reported that plants caged without pollinating insects resulted in decreased yield and produced large percentage of malformed fruits. It has been reported that about 11–15 bee visits per flower are necessary to fertilise all the ovules (Skrebtsova, 1957; Jaycox, 1970). Skrebtsova

(1957) also reported that more than 20 visits increased the mean weight of the berries. Such a large number of visits per flower can be ensured by managing pollination through domesticated species of honeybee only.

Large attractive berries are faster to pick, thus saving the time of the farmer. Such berries also fetch higher market price compared to small, misshapen ones, thus increasing the income of the farmers. Honeybee pollination of strawberry is therefore, of great benefit to the farmers.

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Chapter 49

Impact of Number of Bee Visits on Cauliflower Pollination

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Insect pollinators, particularly honeybees, are known to increase yield in *Brassica* crops that are more or less self-incompatible. Sakharov (1958) reported that the weight of 1000 cabbage seeds produced in the absence of bee visits was only 1.1 g, with a few visits 2.2 g, and with ample visits 3.6 g. The present studies were, therefore, undertaken to quantify the increase in yield with increases in the number of bee visits in order to ascertain how many bee visits are needed for maximum yields (Landridge and Goodman, 1982). In Himachal Pradesh, both *Apis cerana* and *A. mellifera* are domesticated. Hence a comparison was also made on the effect of number of visits of each bee species on siliqua set and number of seeds per siliqua of cauliflower.

Material and Methods

These studies were carried out at Bairty, Solan (1150 m) in the vegetable-seed multiplication farm of the Department of Agriculture, Himachal Pradesh. Seedling of cauliflower var. Pusa and var. Snowball-1 were transplanted to 3.6 m x 3 m plots with spacing of 60 cm x 60 cm. These plots were given the usual agronomical practices.

To assess the influence of visits of *A. cerana* and *A. mellifera* on seed yield, two plants in each of 10 selected plots of equal vigour and growth under each treatment were used. On each plant, 20–25 buds (ready to open) were marked at the base of the flower filament and caged. Each morning, opened flowers from these marked buds were marked and tagged for the number of bee visits (1, 3, 5, 7 and 9). Observations were continued until 1, 3, 5, 7 and 9 visits of each bee species to tagged flowers were obtained. No other pollinator was allowed to visit marked flowers. After bee visits, marked flowers were individually bagged in perforated butter paper envelopes (6 cm x 4.5 cm). Replicates consisted of 15–20 flowers/plant for each number of visits for each bee species. The experiment was repeated for three continuous days. Butter paper bags were removed after six days anthesis. Percentage siliqua set and number of seeds per siliqua were recorded after one month. Observations were recorded on crop sprayed with insecticides (either endosulfan 0.05% or oxydemeton methyl 0.025%) during pre-bloom stage and on unsprayed crop.

Results and Discussion

Effect of bee visits on siliqua set are presented in Table 1.

The number of the visits irrespective of bee species per flower significantly affected siliqua

Table 1. Effect of number of bee visits on the siliqua set in cauliflower

Insecticides	Number of bee visits									
	1		3		5		7		9	
	A. mell	*A. cer*	*A. mell*	*A. cer*	*A. mell*	*A. cer*	*A. mell*	*A. cer*	*A. mell*	*A. cer*
Endosulfan (0.05%)	36.11	33.33	50.00	47.22	63.88	55.55	58.33	58.33	61.11	66.67
	(36.75)*	(35.11)	(43.00)	(45.36)	(53.29)	(48.23)	(50.02)	(51.65)	(51.65)	(54.89)
Oxydemeton-methyl	32.12	30.55	44.44	41.67	52.77	50.00	63.88	66.67	66.67	61.11
(0.025 %)	(34.36)	(33.33)	(41.77)	(40.13)	(46.64)	(45.05)	(53.25)	(55.33)	(54.89)	(51.65)
Control	47.22	33.33	58.33	47.22	66.67	61.11	63.88	63.88	61.11	55.55
	(43.36)	(35.11)	(50.02)	(43.40)	(55.41)	(51.65)	(53.25)	(53.82)	(51.46)	(48.23)
Mean	38.48	32.40	50.92	45.37	61.11	55.55	62.03	62.03	62.96	61.11
	(38.16)	(34.52)	(45.59)	(42.30)	(51.78)	(48.31)	(52.17)	(52.39)	(52.57)	(51.59)
Mean visit (irrespective	35.44		48.15		58.33		62.03		62.04	
of bee species)	(36.46)		(43.95)		(50.05)		(52.28)		(52.13)	

CD(0.05) * Figures in parentheses are angular transformed values
Visits = 4.47 + *A. mellifera*
Interaction (bee x visits) = NS ++ *A. cerana*
Interaction (bee x visits x insecticides) = NS

Table 2. Effect of number of bee visits on seeds per siliqua in cauliflower

Insecticides	Number of bee visits									
	1		3		5		7		9	
	A. mell	*A. cer*	*A. mell*	*A. cer*	*A. mell*	*A. cer*	*A. mell*	*A. cer*	*A. mell*	*A. cer*
Endosulfan (0.05%)	6.15	4.31	9.06	7.71	11.27	9.97	12.71	13.06	11.72	13.05
Oxydemeton-methyl (0.025%)	4.17	3.31	7.88	5.81	11.02	9.75	12.62	11.94	12.56	12.72
Control	3.80	4.50	6.64	6.42	13.65	10.03	13.03	13.58	12.76	13.02
Mean	4.70	4.04	7.86	6.65	11.90	9.92	12.79	12.86	12.35	12.93
Mean (irrespective of bee species)	4.37		7.25		10.95		12.82		12.64	

CD(0.05)
Visits = 0.72 + *A. mellifera*
Interaction (bee x visits) = 1.02 ++ *A. cerana*
Interaction (bee x visits x insecticides) = NS

set in cauliflower (Table 1). One bee visit resulted in only 35.44% siliqua set and increased significantly to 48.15% with three visits and 58.33% with five visits. However, with further increase in visits there was no significant increase in corresponding siliqua set. It ranged from 58.33% to 62.04% with 5–9 visits per flower. Dhaliwal (1980) also reported that there was substantial increase in per centage siliqua set with up to six visits by *A. cerana*. Siliqua set in the present study was not influenced by whether flowers were visited by *A. cerana* or *A. mellifera*. Application of insecticides did not affect siliqua set significantly in comparison to control.

Results on the effect of number of bee visits on seeds per siliqua are presents in Table 2.

The numbers of seeds per siliqua irrespective of bee species was maximum in flowers having seven (12.82 seeds) and nine (12.64 seeds) bee visits. Siliqua formed from flowers having one, three and five bee visits averaged 4.37, 7.25 and 10.95 seeds per siliqua respectively (Table 2).

Interestingly, the number of visits of a particular bee species, influenced the number of seeds per siliqua. Flowers having three visits from *A. mellifera* resulted in siliqua having 7.86 seeds in comparison to only 6.65 seeds for three visits from *A. cerana*. Similarly five visits from *A. mellifera* produced 11.9 seeds per siliqua and from *A. cerana* 9.92 seeds per siliqua. However, with seven and more visits per flower, there were no significant variation in the number of seeds per siliqua whether the flower were visited by *A. mellifera* or *A. cerana*. There were no significant difference in the number of seeds per siliqua in the insecticide sprayed and the control crop.

The results suggested that there was no apparent effect on percentage siliqua set in cauliflower whether flowers were visited by *A. mellifera* or *A. cerana*. However, the number of bee visits significantly increased siliqua set up to five visits per flower. Furthermore, although maximum set may be obtained with five bee visits, seven visits per flower are needed for maximum filling of siliqua. In relation to bee species, at least five visits of *A. mellifera* resulted in maximum number of seeds, whereas seven visits of *A. cerana* were needed. This may be because the comparatively bigger size of *A. mellifera* results in more loose pollen grains being available for pollination. Although Free (1970) considered relative efficiencies of pollinators on the basis of abundance, foraging rate and foraging methods, other factors such as body size, loose pollen on body and number of visits required for maximum pollination are equally important to determine the efficiency of pollination (Adlerz, 1966; Badar and Anderson, 1962; Drake, 1948; McGreger *et al.*, 1965).

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Chapter 50

Role of *Apis cerana himalaya* Pollination on Yield and Quality of Rape Seed and Sunflower Crops

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A separate race of Asian hive bee, *Apis cerana himalaya*, exists in the northeast Himalayan region (Singh and Verma, 1992; Singh *et al.*, 1990). Although this native bee has been successfully managed for the production of honey and beeswax, its effectiveness as a pollinator of entomophilous crops is not understood and often underestimated. Therefore this study details investigations into the role of this bee on seed production of commonly grown oilseed crops (rape seed, *Brassica campestris*, and sunflower, *Helianthus annuus*).

Materials and Methods

Field experiments were conducted for two consecutive years during winter 1992 and 1993 on rape seed var. M-27 and sunflower var. Morden at the Oilseed Research Farm of the College of Agriculture, Central Agricultural University, Imphal, India (24° 49′ N and 93° 8′ E).

Three treatments replicated four times were imposed on each crop as follows: control (plants in a cage with no insect pollinators); open pollination (no cage with plants accessible to

Utilisation of honeybees in sunflower hybrid-seed production

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Studies on the foraging behaviour of honeybees on female and maintainer lines of sunflower, *Helianthus annuus*, and their utilisation in the production of hybrid seeds revealed their potential. All 5 species of honeybees foraged on the crop throughout the day. Filled-seed weight, seed number and oil content were considerably increased in plots pollinated by honeybees. Seed weight was greatest (25.42 g/head) in honeybee-pollinated plots followed by hand-and-bee-pollinated (24.73 g/head), other pollinators (13.59 g/head) and exclusively hand-pollinated (12.98 g/head) plots in the female parent. Filled grain (92.95%) and oil content (53.10%) were also greatest in bee-pollinated plots. In the maintainer line, seed weight was greatest (14.49 g/head) in plots pollinated by bees and other pollinators followed by exclusively hand-pollinated (12.66 g/head), and without hand or bee pollination (9.75 g/head). Number of seeds was (407.95) in plots pollinated by bees and other insects followed by exclusively hand-pollinated (395.31), and without hand or bees pollination (238.70).

naturally occurring insect pollinators); and, bee pollination (*A. c. himalaya* in a cage with plants). For the control and bee-pollinated plots, mosquito nets of 24 mesh were erected on the standing crop just before the initiation of flowering. In the bee-pollination treatment, all four plots were covered with one pollination cage (24 m × 5 m × 3 m) and a medium-sized colony of *A. c. himalaya* (with seven frames covered with bees and free of any sign of disease) was placed when about 10% of the crop was in bloom. The bees were kept inside the pollination cage until the end of flowering. For control plots, individual cages (6 m × 5 m × 3 m) were erected on each plot so that no insect pollinators could enter the cage and pollinate the flowers.

After the rape seed crop was mature, 10 plants were collected randomly from each replication of control, open-pollinated and bee-pollinated treatments. Effects on the quantity and quality of seed production as a result of bee pollination were assessed in terms of per centage siliqua set, siliqua length, number of seeds per siliqua, weight of 1000 seeds, seed yield, per centage seed germination and oil content.

Similarly, 10 sunflower heads were collected randomly from each replication of the three treatments. Per centage seed set, weight of 1000 seeds, number of seeds per gram, seed yield, per centage seed germination and oil content were determined.

Data were analysed statistically using analysis of variance.

Results

The effects of bee pollination on the quantity and quality of rape seed production are summarised in Table 1.

Siliqua setting in plots caged with bees (BP) exhibited an increase of 239.77 % over plots pollinated without insects (PWI) and 2.65% over open pollinated (OP) plots. BP increased the siliqua length by 14.72% compared to PWI and 8.65 % compared to OP. BP also significantly increased the number of seeds per siliqua and seed weight by 50.55% and 17.41 % over PWI, and by 17.85 % and 2.16 % over OP. The increase in seed yield in the BP treatment was 586.22 % over PWI and 8.73 % over OP treatments. The quality of seeds assessed in terms of per centage seed germination and oil content was found to be highest in BP treatment. The germination of seeds from BP plants was 50.90 % greater than from PWI and 2.5 % greater than from OP plants. Moreover, seeds from BP plants showed 21.3 %

Table 1. Quantitative and qualitative effects of *Apis cerana himalaya* pollination on rape seed

Yield parameters	Control (PWI)	Open-pollinated (OP)	Bee-Pollinated (BP)	CD at 5%	% increase over PWI	% increase Over OP
Siliqua set (%)	20.67 (26.39)	68.42 (56.01)	70.23 (57.34)	(5.00)	239.77	2.65
Siliqua length (cm)	3.94 (2.11)	4.16 (2.12)	4.52 (2.24)	(0.07)	14.72	8.65
No. of seeds per siliqua	9.12 (3.14)	11.65 (3.52)	13.73 (3.80)	(0.24)	50.55	17.85
Wt. of 1000 seeds (gm)	2.01 (1.66)	2.31 (1-75)	2.36 (1-76)	NS	17.41	2.16
Seed yield (q/ha)	1.96	12.37	13.45	2.90	586.22	8.73
Seed Germination(%)	55.00 (47.93)	81.00 (65.98)	83.00 (66.02)	(5.21)	50.90	2.50
Oil content (%)	33.25 (35.18)	38.75 (38.48)	40.33 (39.41)	(0.81)	21.30	4.10

Figures in parentheses are transformed values.

Table 2. Quantitative and qualitative effects of *Apis cerana himalaya* pollination on sunflower

Yield parameters	Control (PWI)	Open-pollinated (OP)	Bee-Pollinated (BP)	CD at 5%	% increase over PWI	% increase Over OP
Seed set (%)	2.93	60.50	71.58		2343.00	18.31
	(9.84)	(51.13)	(57.81)	(2.20)		
Wt. of 1000 seeds (gm)	50.32	64.29	54.88	3.26	9.06	17.15
No. of seeds per gm	20.87	16.58	17.04	2.77		
	(4.63)	(4.13)	(4.19)	(0.37)		
Seed yield (q/ha)	2.06	16.60	18.55	1.47	800.49	11.75
Seed germination (%)	69.88	86.50	91.13		30.41	5.35
	(56.78)	(68.80)	(74.55)	(11.94)		
Oil content (%)	35.96	46.79	43.70		21.52	7.07
	(36.85)	(43.16)	(41.38)	(1.32)		

Figures in parentheses are transformed values.

higher oil content than PWI plants and and 4.1 % than OP plants.

The effects of bee pollination on the quantity and quality of sunflower seed production are summarised in Table 2.

The crop pollinated by bees (BP) enhanced seed set 2343 % compared to pollination without insects (PWI) and 18.31 % compared to open pollination (OP). However, OP increased seed weight by 27.76% compared to PWI and 17.15 % compared to BP plants. The maximum number of filled seeds per gram was obtained in PWI plants with 25.87 % increase over OP plants and 22.48 % over BP plants. The increase in seed yield in BP treatment was 800.49 % greater than PWI and 11.75 % than OP. The germination of seeds from BP plants was 30.41 % higher than seeds from PWI and 5.35 % higher than OP plants. However, the maximum oil content was obtained in seeds from OP plants with 30.12 % increase over PWI and 7.07 % over BP plants.

Discussion

Bee pollination increased siliqua set, siliqua length, number of seeds per siliqua, seed weight, seed yield, germination rate and oil content of seeds in comparison with open-pollinated rape seed plants. Increase in siliqua set and seed set as a result of bee pollination could be owing to both greater numbers of pollinators in the plots caged with bees, and to a superior pollinating efficiency of honeybees. Natural insect pollinators, on the other hand, owing to their lower numbers and lower pollinating efficiency pollinated fewer flowers. Similar studies (Bisht *et al.*, 1980; Langridge and Goodman, 1975; Radchenko, 1964; Sihag, 1986) have shown that cross-pollination by honeybees increased the per centage of siliqua setting in rape seed. Svendsen (1990) reported that rape seed flowers after bee pollination had longer siliqua length and many seeds, which agrees with the present observations.

The longer siliqua with higher seed content in bee-pollination plots may be owing to better and timely pollination, and fertilisation of more ovules per ovary. Increase in seed weight as a result of bee pollination could be owing to the better pollination efficiency of honeybees that might help in the production of auxin, a growth hormone, resulting in better size of seed. Panda *et al.* (1989) also observed a similar trend in rape seed: 1000 seed weight was highest in the plants enclosed with bees. The yield difference between bee-pollination and control treatments indicates the extent of self-sterility and self-incompatibility of the rape seed variety and the relative increase in crop yield due to bee pollination. Moreover, yield differences between bee-pollination and open-pollination treatments indicated a lack of natural insect pollinators needed for maximum pollination at the experimental site, and suggested that the provision of bees would increase potential yield. Rahman (1945) also reported that by placing two colonies of *A. cerana* per acre of toria crop, seed yield was increased by 10–25 %.

The quality of seeds can be assessed by their oil content and germination efficiency. Honeybee pollination increased oil content and seed germination over open pollination. It may be because in bee pollination, flowers are pollinated in the phase of fully functional generative organs producing better quality seeds. Similarly, Radchenko (1964) and Panda *et al.* (1989) found a higher per centage of oil content and an increase in seed germination after bee pollination.

Bee pollination increased seed set, seed yield and germination rate of seeds compared with open-pollinated sunflower plants. This could be owing to both greater numbers of pollinators in the plots with caged bees and to a superior pollinating efficiency of honeybees. Negligible seed set due to self-pollination in bagged sunflower plants indicated that the crop is self-incompatible and requires cross-pollination by insect pollinators. Stamm and Schuster (1989) also reported that the per centage seed set of sunflower was 70–80% in plants caged with bees and 30–40% in the plants caged without insects. Increase in seed yield of sunflower after bee pollination has been reported frequently (Goyal and Atwal, 1973; Krause, 1983; Mahmood and Furgula, 1983; Panda *et al* ., 1993).

El-Suhhar and Ewies (1977) reported that seeds obtained from the bee-pollinated sunflower plants gave higher germination rates. This confirms with the present findings. However, oil content was maximum in seeds obtained from open-pollinated plants.

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Chapter 51

Diversity, Visitation Frequency, Foraging Behaviour and Pollinating Efficiency of Insect Pollinators Visiting Turnip Blossoms

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Turnip (*Brassica rapa*) is a self-incompatible crop and needs pollen vectors for cross-pollination of its flowers (Free, 1993; Sihag, 1985). Several species of pollinators visit its flowers (Sihag, 1986). However, all are not equally important. Some make a better contribution to pollination because of their more suitable attributes. These include abundance, foraging behaviour, number of loose pollen grains carried on the body, foraging rate and activity duration. An index value derived from these attributes was used to compare the efficiency of the pollinators of pigeon pea (*Cajanus cajan*) (Sihag and Rathi, 1994). This paper uses the same approach to study the pollinators of turnip.

Materials and Methods

These investigations were conducted in 1995 at the Vegetable Research Farm and Zoology Department of CCS Haryana Agricultural University, Hisar, India. Among visitors to turnip blossoms, pollinators and non-pollinators were characterised on the basis of their foraging mode (Sihag, 1988). Visitors were collected with a sweep net and identified. Abundance of visitors was recorded in five randomly selected 1 m × 1 m plots of the crop for 5 min at 2-h intervals from morning until evening on the observation day. These observations were repeated at weekly intervals during the entire blooming period of the crop. Foraging rates in terms of number of flowers visited per minute were calculated for 10 insects. Mean foraging activity duration was determined using the following formula.

$$T = \sum_{i=1}^{x} \frac{ni \times ti}{N}$$

where, T = mean activity duration of the pollinator (in hours)

n_i = total number of insects of a species active at i^th hour of the day

t_i = total foraging activity duration of the visitors of a species active at i^th hour of the day

N = total number of visitors of a species through the course of the day

Number of loose pollen grains adhered to the body of the pollinator was counted with a haemocytometer as suggested by Kumar *et al.*

(1985). To determine the pollinating efficiency of pollinators, performance scores were derived by using the following formula suggested by Sihag and Rathi (1994).

$$P_{sij} = \frac{N_{ij}}{N_j} \times S$$

where, i = 1 to x and j = 1 to r, both taking positive, whole number and finite values

P_{sij} = performance scores of i^{th} species for j^{th} attribute

N_{ij} = importance value of ith species for j^{th} attribute

N_j = total importance value of all the species for j^{th} attribute

S = total number of species

The values of performance scores for different attributes of a species were multiplied to obtain its pollination index. Then pollinators were ranked for their pollinating efficiency.

Table1. Insects visiting the flowers of *Brassica rapa* at Hisar

Insect visitor	Order	Family
Apis dorsata	Hymenoptera	Apidae
Apis florea	Hymenoptera	Apidae
Apis mellifera	Hymenoptera	Apidae
Halictus sp.	Hymenoptera	Halictidae
Chrysomya bezzaina (villeneuve)	Diptera	Calliphoridae
Gasterophilus sp.	Diptera	Gasterophilidae
Sarcophaga sp.	Diptera	Sarcophagidae
Eristalis sp.	Diptera	Syrphidae
Coccinella septumpunctata	Coleoptera	Coccinellidae
Danis chrysippus	Lepidoptera	Danaidae
Potanthus rectifasciata	Lepidoptera	Hesperiidae
Chaetoprocta odata	Lepidoptera	Lycaenidae
Eurema hecaba	Lepidoptera	Pieridae
Pieris brassicae	Lepidoptera	Pieridae

Results and Discussion

Blossoms of turnip were visited by 14 insect pollinators (Table 1). *Apis mellifera* was the most abundant. Foragers of *A. mellifera* visited the greatest number of flowers per minute.

Average foraging rate of *A. mellifera* was also greatest, followed by *A. dorsata, A. florea, Halictus* sp. and the flies. *Apis mellifera* remained active for a longer duration than other pollinators. Bee species also carried a greater number of loose pollen grains on their bodies than dipterans. On the basis of maximum abundance, highest foraging rate, longer mean activity duration, greater number of loose pollen grains carried on its body and maximum pollination index, *A. mellifera* was ranked as the best pollinator of turnip (Table 2). *Apis dorsata* and *A. florea* followed *A. mellifera*. The role of dipterans as pollinators was less than hymenopterans.

Among pollinators of turnip, the major proportion consisted of hymenopterans; dipterans and others followed. *Apis mellifera* was the most abundant and had the highest foraging rate. This was perhaps because of the compatibility of its tongue length with the depth of the corolla of the turnip flower. Inouye (1980) and Free (1993) reported the role of tongue length of the visiting species in deciding its suitability to a host plant. Mean activity duration of *A. mellifera* was greatest because more bees were active throughout the day. Bees carried a larger number of loose pollen grains because they have more branched hairs on their body than other pollinators, and *A. mellifera* had the highest pollinating efficiency.

Since there are only 24 ovules in the ovary of turnip flower and each bee transfers more pollen grains than this in a single visit, all bee species are capable of enhancing full seed set in a single visit. On the basis of a single visit, pollinators of this crop cannot be ranked. For determining the pollinating efficiency of visitors to turnip blossoms, therefore, observation of their behavioural attributes is important. Pollination index values show the relative contribution of each species towards pollination of turnip. As used earlier by Sihag and Rathi (1994), the present method of ranking, therefore, seems to be logical.

Table 2. Pollinating efficiency ranking of turnip pollinators on the basis of different pollinating attributes (all mean values)

Insect pollinators	Abundance (No./m²)	Foraging rate (No./min.)	Mean activity duration(h)	No. of loose pollen grains	Pollinating index	Pollinating efficiency ranking
Apis florea	1.86 (0.909)	6.42 (1.041)	2.15 (1.015)	6506.40 (1.380)	1.325	3
Apis mellifera	8.89 (4.344)	11.31 (1.834)	2.61 (1.232)	8793.25 (1.866)	18.315	1
Apis dorsata	3.24 (1.583)	9.91 (1.607)	2.47 (1.166)	9720.40 (2.062)	6.116	2
Halictus sp.	0.62 (0.303)	5.40 (0.876)	2.11 (0.996)	5622.35 (1.193)	0.315	4
Chrysomya bezzaina	0.29 (0.142)	3.32 (0.538)	1.77 (0.835)	1534.25 (0.325)	0.021	8
Gasterophilus sp.	0.40 (0.195)	4.04 (0.655)	1.84 (0.868)	1798.50 (0.382)	0.042	7
Sarcophaga sp.	0.46 (0.225)	4.17 (0.676)	1.99 (0.939)	1836.10 (0.390)	0.056	6
Eristalis sp.	0.61 (0.298)	4.76 (0.772)	2.01 (0.949)	1890.95 (0.401)	0.087	5
Others	0.80	-	-	-	-	-

Notes: Figures in parenthesis are performance scores; – observations not recorded.
CD ($p \leq 0.05$): abundance = 1.155; foraging rate = 1.001; loose pollen grains = 760.250.

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Chapter 52

Comparative Foraging Behaviour of *Apis cerana* and *Apis mellifera* in Pollinating Peach and Plum Flowers in Kathmandu Valley, Nepal

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Peaches and plums are widely planted in the middle hills of Nepal. Varieties of plum are self-incompatible and require cross-pollination to produce fruits. Peach varieties are self-compatible; however, cross-pollination has been reported to increase yield and improve fruit quality (Free, 1993). Cross-pollination of peach and plum is brought about by insect pollinators that visit their flowers for pollen and nectar. Among pollinating insects, honeybees in particular are attracted to these crops and are reported to be of great benefit (Choi and Lee, 1988; Free, 1993; Mann and Singh, 1983). Practically no work has been done on the pollination of either peach or plum under the agroclimatic conditions of the Kathmandu valley of Nepal. Therefore, in the present investigation the foraging behaviour of two honeybee species – the native bee, *Apis cerana,* and the exotic bee, *A. mellifera* – on peach and plum flowers have been compared in order to assess their role as pollinators of these fruit crops. Such studies assume great importance under the local ecological conditions of Kathmandu valley where *A. mellifera* has been recently introduced from India.

Material and Methods

Foraging behaviour of *A. cerana* and *A. mellifera* on plum (*Prunus domestica* var. Maithili) flowers was studied during the last week of February 1996 and on peach (*Prunus persica* var. Perigreen) flowers during mid-March 1996 at HMG Horticultural Farm, Godavari (27°35' N and 85°24' E) in the Kathmandu valley of Nepal. Two colonies (one colony of each species containing almost the same number of worker bees and free of any sign of disease) were placed in the centre of each orchard at 5–10% flowering to ensure that bees foraged only on the flowers of the crop under investigation and ignored alternative forage in the vicinity. Bees were kept in the field until the end of flowering.

Observations on the foraging behaviour of the bees on plum and peach flowers were recorded for the daily time of initiation and cessation of foraging, total duration of foraging activity, time spent on the flower, number of flowers visited per minute, individual bee's choice of pollen and nectar, per centage of 'top worker' (TW) and 'side worker' (SW) bees, and the weight of pollen load carried by an individual bee. For other logistics of foraging behaviour studies, methods given by Partap and Verma (1994) and Verma and Partap (1994) were followed. Observations of time spent on flower, number of flowers visited per minute, pollen loads collected and pollen vs. nectar collectors were recorded at 1000, 1200 and 1400 h.

Proportions of 'top worker' and 'side worker' bees were determined as follows: worker bees alighting upright on stamens to collect pollen or nectar were considered as top workers and those alighting on petals and collecting nectar were considered as side workers (Verma and Rana, 1994). In order to check whether a returning forager has collected nectar, it was caught at the hive entrance and its abdomen pressed to regurgitate nectar. Peak hours of foraging activity were determined by counting the number of bees entering the hive in a 3-min period each hour from early morning until late afternoon. Weight of pollen loads was determined by catching returning pollen collectors at the hive entrance, removing their pollen loads with a fine camel-hair brush and weighing the loads. In order to determine the number and duration of foraging trip, 20 bees were marked with nail polish of different colours and observations of the individual marked bee were recorded. Contents of pollen loads were determined by preparing glycerin jelly slides (Erdtman, 1969) and studying the slides microscopically. Data were analysed statistically using 't' tests or one-way analysis of variance.

Results

Observations on the foraging behaviour of *A. cerana* and *A. mellifera* on peach and plum flowers are presented in Table 1.

For times of initiation; cessation and duration of foraging activity, duration of foraging trip; and weights of pollen loads, differences between the two honeybee species are significant ($P < 0.01$). Differences are also significant between the bee species and between TW and SW for the time spent per flower and the number of flowers visited per minute.

Apis cerana workers bees began foraging earlier in the morning (07.31 h on peach and 08.12 h on plum flower) compared to *A. mellifera* worker bees that started foraging at 08.01 h on

Table 1: Foraging behaviour of *Apis cerana* and *Apis mellifera* on peach and plum flowers during February/March in the Kathmandu Valley, Nepal. Values are mean ± SE

Parameter	Peach		Plum	
	A. cerana	*A. mellifera*	*A. cerana*	*A. mellifera*
Initiation of foraging (time of day)	07.31 ± 0.7	08.01 ± 0.4	08.12 ± 0.4	08.37 ± 0.6
Cessation of foraging (time of day)	18.06 ± 0.36	17.35 ± 0.7	17.51 ± 0.6	17.02 ± 0.3
Duration of foraging activity (h)	10.35 ± 0.92	9.34 ± 0.88	9.39 ± 0.5	8.25 ± 0.37
Peak foraging hours (time of day)	11.00–14.00	11.30–13.30	11.00–13.30	11.30–13.00
Duration of foraging trip (min)	20.3 ± 0.22	25.9 ± 0.2	21.4 ± 0.2	25.1 ± 0.7
Time spent on flower (s)	TW 4.8 ± 0.2	5.4 ± 1.5	3.8 ± 0.9	4.6 ± 1.8
	SW 12.6 ± 1.3	16.4 ± 1.7	9.1 ± 0.8	13.3 ± 1.7
Number of flowers visited per min.	TW 9.7 ± 0.9	8.9 ± 1.5	14.8 ± 1.2	13.7 ± 2.2
	SW 4.1 ± 1.6	3.1 ± 1.0	9.7 ± 1.1	7.9 ± 1.9
Pollen loads (mg)				
1000h	12.5 ± 0.9	18.9 ± 2.4	13.3 ± 1.7	17.1 ± 1.4
1200h	14.3 ± 1.6	16.8 ± 1.9	12.2 ± 1.2	16.7 ± 1.7
1400h	6.7 ± 2.2	9.3 ± 2.3	5.9 ± 1.7	8.7 ± 2.7

peach and 08.37 h on plum. In the evening *A. mellifera* stopped earlier (17.35 h on peach and 17.02 h on plum) than *Apis cerana* (18.06 h on peach and 17.51 h on plum). The duration of foraging activity for *A. cerana* was significantly longer (10.35 h per day on peach and 9.39 h per day on plum) than *A. mellifera* for which foraging activity was 9.34 h per day on peach and 8.25 h per day on plum. Differences in all three parameters were significant at $P < 0.01$. On both peach and plum, foraging activity of *A. mellifera* diminished greatly with only few bees foraging after 15.30 h whereas that of *A. cerana* continued until 17.00 h.

The peak of foraging activity for *A. cerana* (mean number of incoming bees/ three minutes) occurred earlier and was longer (11.00–14.00 h on peach and 11.00–13.30 h on plum) than for *A. mellifera* (11.30–13.30 h on peach and 11.30–13.00 h on plum). The duration of an individual foraging trip by *A. cerana* (20.3 min on peach and 21.4 min on plum) was significantly shorter ($P < 0.01$) than for *A. mellifera* (25.9 min on peach and 25.1 min on plum).

A forager of *A. cerana* averaged significantly less time (4.8 s by TW and 12.6 s by SW on peach, and 3.8 s by TW and 9.1 s by SW on plum flower) than *A. mellifera* that, on average, spent 5.4 s for TW and 16.4 s for SW on peach, and 4.6 s for TW and 13.3 s for SW on plum flower. *Apis cerana* foragers averaged significantly more flowers per minute (9.7 by TW and 4.1 by SW on peach; 14.8 by TW and 9.7 by SW on plum) than *A. mellifera* that averaged 8.9 peach flowers by TW and 3.1 by SW; and 13.7 plum flowers by TW and 7.9 by SW in one minute.

Bees of both the species collected either nectar or pollen during a single foraging trip. For *A. cerana* $P > N$ throughout the day ($P < 0.01$) on both peach and plum whereas for *A. mellifera* $P > N$ ($P = 0.01$) in the morning at 10.00 h, $N = P$ at 12.00 h and $N > P$ at 14.00 h. $P : N$ ratios were significantly higher for *A. cerana* than *A. mellifera* throughout the day on both peach and plum (Table 2).

Number of top or side worker foragers showed fluctuations at different hours of the day (Table 3). For *A. cerana*, more bees worked from top position (TW>SW) throughout the day whereas for *A. mellifera* more bees worked from the top position (TW>SW) during the morning (10.00 h) but from the side position (SW>TW) during the afternoon (14.00 h) on both peach and plum. Proportion of the top workers was more for *A. cerana* than for *A. mellifera*.

Worker bees of *A. mellifera* carried significantly heavier pollen loads from both peach and plum flowers than those of *A. cerana* (Table 1). Both

Table 2. Per centage of *A. cerana* and *A. mellifera* honeybees collecting pollen (P) and nectar (N) from peach and plum flowers during different hours of the day in Feb/March in the Kathmandu Valley, Nepal. n=number of observations, NS= not significant.

	1000h		1200h		1400h	
	A. cerana	*A. mellifera*	*A. cerana*	*A. Mellifera*	*A. cerana*	*A. Mellifera*
Peach						
$P(n = 100)$	78	61	72	44	59	38
$N(n = 100)$	22	39	29	66	41	62
$P : N$	3.5: 1.0	1.6: 1.0	2.5: 1.0	0.7: 1.0	1.4: 1.0	0.6: 1.0
Plum						
$P(n = 100)$	89	71	78	50	57	43
$N(n = 100)$	11	29	22	50	43	67
$P : N$	8.1: 1.0	2.5: 1.0	3.5: 1.0	1.0: 1.0	1.3: 1.0	0.6: 1.0

For *A. cerana* $P > N$ at 10.00 h, 12.00 h, and 14.00 h on both peach and plum ($P < 0.01$). For *A. mellifera* $P > N$ at 10.00h and $N > P$ at 12.00h and 14.00h on peach ($P < 0.01$); and on plum $P > N$ at 10.00h and N>P at 14.00h (P<0.01), $P = N$ at 12.00h (NS).

Table 3. Per centage of top workers (TW) and side workers (SW) visiting peach and plum flowers; and per centage of unifloral (UF) and multifloral (MF) pollen loads carried by honeybees at different hours of the day. Data for *Apis mellifera* are given in parentheses; n =number of observations; NS = not significant

Parameter	Time of the day		
	1000h	1200h	1400h
Peach			
TW (n = 150)	82.9 (68.3)	79.1 (51.6)	51.1 (29.2)
SW (n = 150)	17.1 (31.7)	20.9 (48.4)	48.9 (70.8)
TW : SW	4.8: 1.0 (2.2: 1.0)	3.4: 1.0 (1.1: 1.0)	1.04: 1.0 (0.4: 1.0)
UF(n = 50)	98.5 (98.3)	97.7 (97.0)	97.1 (95.2)
MF(n = 50)	1.5 (1.7)	2.3 (3.0)	2.9 (4.8)
Plum			
TW (n = 150)	91.0 (77.3)	80.7 (53.2)	68.2 (37.4)
SW (n = 150)	9.0 (22.7)	19.3 (46.8)	31.8 (62.6)
TW : SW	10.1: 1.0 (3.4: 1.0)	4.2: 1.0 (1.1: 1.0)	2.1: 1.0 (0.6: 1.0)
UF (n = 50)	98.1 (97.9)	97.5 (97.2)	96.8 (95.7)
MF (n = 50)	1.9 (2.1)	2.5 (2.8)	3.2 (4.3)

For *A. cerana* TW > SW at 10.00h, 12.00 h and 14.00 h on both peach and plum ($P < 0.01$). For *A. mellifera* TW > SW at 10.00 h ($P < 0.01$), TW > SW at 12.00 h (NS) and SW > TW at 14.00 h ($P < 0.01$) on both peach and plum. On peach and plum UF > MF for both *A. cerana* and *A. mellifera* ($P < 0.01$).

species showed the same floral fidelity during pollination; foragers on both peach and plum collected pollen loads that were more than 95 % unifloral (Table 3).

More bees of both *A. cerana* and *A. mellifera* were observed foraging near the hive; the number decreased with the distance ($P < 0.01$). In the peach orchard, the number of foragers of *A. cerana* and *A. mellifera* per 1000 flowers per 10 min was 11.2 and 12.5 respectively at a distance of 50 m; and 6.4 and 6.9 respectively at 150 m. In the plum orchard, the number of *A. cerana* and *A. mellifera* bees was 13.1 and 12.9 respectively at 50 m; and 5.5 and 7.2 at 250 m (Table 4).

At 50 m number of foragers of both the species are more ($P < 0.01$) than at 250 m.

Table 4. Effect of distance on the foraging of *A. cerana* and *A. mellifera* on peach and plum flowers. Values are mean ± SE of 21 observations

Crop	Honeybee species	Number of bees per 1000 flowers/10 minutes	
		50 m	150 m
Peach	*A. cerana*	11.2 ± 2.4	6.4 ± 1.1
	A. mellifera	12.5 ± 1.9	6.9 ± 2.0
Plum	*A. cerana*	13.1 ± 2.9	5.5 ± 0.9
	A. mellifera	12.9 ± 1.7	7.2 ± 1.0

Discussion

Since plum and peach bloom during early spring in the Kathmandu valley, the hive bees, *A. cerana* and *A. mellifera*, are important for their pollination because natural insect pollinators are present in much smaller numbers during this period owing to low temperatures. The flowers of these crops are attractive to both species of honeybee and provide good amounts of pollen and nectar for about two weeks.

Comparative foraging-behaviour data suggest that worker bees of *A. cerana* started foraging activities earlier in the morning and ceased later in the evening that *A. mellifera* workers. The total duration of foraging activity of *A. cerana* worker bees is significantly more than those of *A. mellifera*. This enables *A. cerana* worker bees to forage and pollinate flowers for extended periods of time compared to *A. mellifera*. Moreover, the duration of peak foraging activity was longer for *A. cerana*. Verma and Partap (1994) observed that duration of foraging activities of

Table 3. Per centage of top workers (TW) and side workers (SW) visiting peach and plum flowers; and per centage of unifloral (UF) and multifloral (MF) pollen loads carried by honeybees at different hours of the day. Data for *Apis mellifera* are given in parentheses; n =number of observations; NS = not significant

Parameter	Time of the day		
	1000h	1200h	1400h
Peach			
TW (n = 150)	82.9 (68.3)	79.1 (51.6)	51.1 (29.2)
SW (n = 150)	17.1 (31.7)	20.9 (48.4)	48.9 (70.8)
TW : SW	4.8: 1.0 (2.2: 1.0)	3.4: 1.0 (1.1: 1.0)	1.04: 1.0 (0.4: 1.0)
UF(n = 50)	98.5 (98.3)	97.7 (97.0)	97.1 (95.2)
MF(n = 50)	1.5 (1.7)	2.3 (3.0)	2.9 (4.8)
Plum			
TW (n = 150)	91.0 (77.3)	80.7 (53.2)	68.2 (37.4)
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TW : SW	10.1: 1.0 (3.4: 1.0)	4.2: 1.0 (1.1: 1.0)	2.1: 1.0 (0.6: 1.0)
UF (n = 50)	98.1 (97.9)	97.5 (97.2)	96.8 (95.7)
MF (n = 50)	1.9 (2.1)	2.5 (2.8)	3.2 (4.3)

For *A. cerana* TW > SW at 10.00h, 12.00 h and 14.00 h on both peach and plum ($P < 0.01$). For *A. mellifera* TW > SW at 10.00 h ($P < 0.01$), TW > SW at 12.00 h (NS) and SW > TW at 14.00 h ($P < 0.01$) on both peach and plum. On peach and plum UF > MF for both *A. cerana* and *A. mellifera* ($P < 0.01$).

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Plum	*A. cerana*	13.1 ± 2.9	5.5 ± 0.9
	A. mellifera	12.9 ± 1.7	7.2 ± 1.0

Discussion

Since plum and peach bloom during early spring in the Kathmandu valley, the hive bees, *A. cerana* and *A. mellifera*, are important for their pollination because natural insect pollinators are present in much smaller numbers during this period owing to low temperatures. The flowers of these crops are attractive to both species of honeybee and provide good amounts of pollen and nectar for about two weeks.

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A. cerana was 12.1 h on cabbage and 11.03 h on cauliflower during March. The differences that were observed between the species with respect to the time of initiation and peak hours of foraging activity agree with those of Verma and Dulta (1986). These differences in foraging preferences may have reflected the differences in temperature and relative humidity preferences. The present findings on the duration of peak foraging differ from those of Verma and Dulta (1986) who reported that under the agroecological conditions of high-mountain areas, the peak of foraging activities of *A. mellifera* on apple flower begins after the peak foraging activity of *A. cerana* decreases. These workers, therefore, suggested that both these bee species are complimentary in apple pollination.

The mean duration of an individual foraging trip was significantly longer for *A. mellifera* than *A. cerana*. These differences might be attributable to a difference in foraging efficiency and glycogen supply (energy) to flight muscles. *Apis mellifera* has more glycogen for fuel than *A. cerana* (Dulta and Verma, 1989).

The number of flowers visited per minute by a TW and a SW *A. cerana* worker bee was greater compared to an *A. mellifera* worker bee; however, this difference was not statistically significant. However, more foragers of *A. cerana* worked flowers as top workers and collected mainly pollen whereas *A. mellifera* bees worked mostly as side workers and collected nectar from both peach and plum flowers. Top workers collecting pollen are considered to be better pollinators than side workers collecting nectar. Our observations on high floral fidelity exhibited by both the species agree with those of Verma and Rana (1994) who found only 2-7 % of pollen loads were mixed.

The heavier pollen loads carried by *A. mellifera* compared to that carried by *A. cerana* may be related to the larger size of body parts for the former species (Mattu and Verma, 1980; 1983; 1984 a, b, c). Free (1960) and Kendall and Solomon (1973) observed that insects with smaller body parts carry little pollen compared to larger, hairy-bodied insects. Foragers of both species collected significantly heavier pollen loads during morning hours than afternoon hours. This may be because bees collect most of the available pollen during the morning hours, therefore the amount of pollen available during afternoon is less.

For *A. cerana*, pollen collectors outnumbered nectar collectors throughout the day on both peach and plum whereas for *A. mellifera* pollen collectors outnumbered nectar collectors in the morning and in the afternoon nectar collectors outnumbered pollen collectors on both peach and plum. P: N ratio was significantly higher for *A. cerana* throughout the day than *A. mellifera*. This may be because flowers of both peach and plum presented pollen in the morning and nectar in afternoon. In the present investigation, worker bees of both species collected either pollen or nectar but not both during a single foraging trip. This may be because in this crop nectar and pollen are not equally attractive to a forager at the same time. Earlier studies (Verma and Partap, 1994) showed that *A. cerana* when visiting cauliflower and cabbage collected either pollen or nectar but never both on an individual foraging trip. Similar observations were recorded by Free (1960) for *A. mellifera*.

Observations that the number of forager bees of both species was greater near the hive agree with earlier observations of Eckert (1933) and Lavin (1959) who reported that if sufficient forage is available, bees prefer to work close to their hives. Based on the observations discussed above, it can be concluded that *A. cerana* is a better pollinator than *A. mellifera* of peach and plum in the Kathmandu valley of Nepal.

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Chapter 53

Foraging Behaviour of *Apis cerana himalaya* on Sunflower and Rape Seed

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Previous biometric studies revealed the occurrence of a separate race of Asian hive bee named *Apis cerana himalaya* from the northeast Himalayan region (Singh and Verma, 1992; Singh *et al.*, 1990. As yet, no information is available on the foraging behaviour of this new race. There is potential for their use in the production of insect-pollinated seed crops. Rape seed and sunflower, the source of edible oil in northeast India, require pollinators, particularly honeybees, for increasing crop yield, improving seed quality and for exploitation of heterosis. Studies were, therefore, conducted on the foraging behaviour of *A. c. himalaya* on sunflower and rape seed under the agro-climatic conditions of the northeast Himalayan region.

Material and Methods

Foraging observations were made during winter 1992 and 1993 on sunflower var. Morden and rape seed var. M-27 at the Oilseed Research Farm of the College of Agriculture, Central Agricultural University, Imphal, India. The crops were raised in plots of 25 m × 12 m and replicated four times using the recommended local agronomic practices. However, no insecticidal application was made after the commencement of flowering.

Observations on the relative abundance of insect pollinators were recorded from 0600 to 1700 h at one-hour intervals on 10 plants over a 5-min period. Observations were recorded for daily time of initiation and cessation of foraging, duration of foraging activity, peak hours of foraging activity, duration of foraging trip, number of flowers visited by one bee per minute, time spent on flower, distance covered from flower to flower, individual bee's choice of forage (nectar or pollen), and weight of pollen load carried by bees at different hours of the day.

In order to differentiate between nectar and pollen collectors, returning foragers were collected with an aspirator at the hive entrance and frozen to prevent regurgitation of nectar. Frozen bees were sorted for type of forage, following the method of Erickson et al. (1973). The weight of pollen load was determined by anaesthetising samples of returning bees with carbon dioxide (Frisch, 1967), and then removing and weighing their pollen loads. Duration of foraging trip was determined by marking 10 bees with nail polish of different colours and noting the time of ingress and egress of the marked bees.

Table 1. Relative abundance of insect pollinators on sunflower at different hours of the day during winter seasons of 1992 and 1993.

Pollinators	Number of pollinators at different hours of the day													
	0600h	0700h	0800h	0900h	1000h	1100h	1200h	1300h	1400h	1500h	1600h	1700h	Mean	% of total
Apis cerana himalaya	4.35 ±0.39	6.60 ±0.90	4.35 ±0.55	4.50 ±0.56	2.35 ±0.37	1.70 ±0.38	1.05 ±0.36	1.35 ±0.21	1.55 ±0.25	1.00 ±0.30	1.90 ±0.45	2.25 ±0.22	2.75 ±0.41	46.37
Apis dorsata	1.50 ±0.48	3.15 ±0.97	3.50 ±0.70	2.90 ±0.40	2.40 ±0.43	2.20 ±0.25	1.95 ±0.31	1.80 ±0.28	1.85 ±0.32	2.75 ±0.39	3.05 ±0.46	2.85 ±0.50	2.49 ±0.46	41.99
Bombus haemorrhoidalis	0.12 ±0.09	0.20 ±0.12	0.40 ±0.22	0.75 ±0.20	0.55 ±0.15	0.85 ±0.21	1.00 ±0.28	0.75 ±0.22	0.25 ±0.13	0.25 ±0.14	0.25 ±0.20	0.05 ±0.04	0.45 ±0.17	7.59
Nomia curvipes	0.0 ±0.0	0.10 ±0.06	0.10 ±0.09	0.30 ±0.14	0.35 ±0.17	0.65 ±0.14	0.60 ±0.20	0.35 ±0.14	0.15 ±0.7	0.20 ±0.14	0.05 ±0.04	0.0 ±0.0	0.24 ±0.10	4.05

I: Mean ± standard error of 20 days observations: for population recorded in 10 plants per 5 min.

Table 2. Relative abundance of insect pollinators on rape flower at different hours of the day during winter seasons of 1992 and 1993

Pollinators	Number of pollinators at different hours of the day								
	0900h	1000h	1100h	1200h	1300h	1400h	1500h	Mean	% of Total Pollinators
Apis cerana himalaya	11.96 ±0.67	11.73 ±0.67	9.02 ±0.76	6.53 ±0.66	4.86 ±0.52	4.00 ±0.45	0.74 ±0.16	6.98 ±0.56	86.50
Episyrphus balteatus	0.19 ±0.11	0.31 ±0.14	0.59 ±0.14	0.74 ±0.19	0.92 ±0.28	0.73 ±0.15	0.25 ±0.13	0.53 ±0.16	6.57
Apis dorsata	0.20 ±0.14	0.32 ±0.11	0.30 ±0.13	0.30 ±0.11	0.42 ±0.18	0.35 ±0.12	0.15 ±0.06	0.29 ±0.12	3.59
Pieris brassicae	0.04 ±0.03	0.30 ±0.14	0.29 ±0.09	0.34 ±0.19	0.74 ±0.45	0.18 ±0.08	0.0 ±0.0	0.27	3.34

1: Mean ± standard error of 23 days observations; for population recorded in 10 plants per 5 min.

Bees on the flowers were observed with a magnifying lens.

Results

Apis cerana himalaya was the main pollinator of sunflower constituting 46.37%, closely followed by *A. dorsata* (41.99%). Other visitors were *Bombus haemorrhoidalis* (7.59%) and *Nomia curvipes* (4.05%) (Table 1). Similarly, *A. c. himalaya* predominantly foraged on rape seed bloom and constituted 86.5% of the total pollinators population. Other visitors were *Episyrphus balteatus* (6.57%), *Apis dorsata* (3.59%) and *Pieris brassicae* (3.34%) (Table 2).

The foraging behaviour of *A. c. himalaya* on sunflower and rape seed is summarised in Table 3. Bees started foraging activity earlier (05.19 h) on sunflower than rape seed (08.04 h) and ceased later (18.08 h compared to 16.02 h). Thus, the average duration of foraging activity was longer on sunflower (12.49 h) than rape seed (07.58 h). Peak foraging activity was between 06.00 h and 09.00 h for sunflower, and between 09.00 h and 11.00 h for rape seed. The duration of individual foraging trips was longer on sunflower (8.60 min)

Table 3. Foraging behaviour of *Apis cerana himalaya* on sunflower and rape seed during winter seasons of 1992 and 1993

Parameter	Sunflower	Rape seed
Initiation of foraging (time of day)	05.19 ± 0.08h	08.04 ± 0.04h
Cessation of foraging (time of day)	18.08 ± 0.12h	16.02 ± 2.01h
Duration of foraging activity (h)	12.49 ± 0.18	07.58 ± 0.05
Peak foraging hours (time of day)	06.00–0900	09.00–11.00
Duration of foraging trip (min)	3.37 ± 0.19	8.60 ± 1.69
No. of flowers visited/min	1.70 ± 0.10	9.90 ± 0.42
Time spent on flower (sec)	52.98 ± 3.88	6.37 ± 0.73
Distance covered from flower to flower (cm)	74.63 ± 7.45	30.04 ±2.12
No. of stigmas touched/visit	68.65 ± 6.71	–
Pollen load (mg) at:		
08.00h	2.35 ± 0.08	–
10.00h	3.27 ± 0.08	8.20 ± 0.45
12.00h	5.12 ± 0.07	9.60 ± 0.67
14.00 h	5.78 ± 0.10	7.50 ± 0.40
Ratio between pollen collectors and nectar collectors (P: N) at:		
08.00 h	1.0: 2.4	–
10.00 h	1.0: 4.2	1.0: 2.5
12.00 h	1.0: 17.9	1.0: 6.4
14.00 h	1.0: 16.5	1.0: 57.8

Values are mean ± standard error

than rape seed (3.37 min). *Apis cerana himalaya* visited a fewer sunflowers (1.7) per minute than rape flowers (9.9) spending more time on sunflower (52.98 sec) than on rape seed (6.37 sec). Bees covered longer distance from flower head to head of sunflower (74.63 cm) as compared to rape flower (30.04 cm). While foraging on sunflower, *A. c. himalaya* contacted 68.65 stigmas per flower visit. The average pollen load carried by an individual worker bee was maximum at 14.00 h for sunflower weighing 5.78 mg, whereas the maximum pollen load was carried at 1200 h for rape seed weighing 9.60 mg. In both crops, the ratio between pollen and nectar collectors increased from morning to evening, with greater amounts of pollen collected in the morning and greater amounts of nectar collected in the evening.

Discussion

Apis cerana himalaya was found to be the main pollinator of sunflower and rape seed under the agro-climatic conditions of the northeast Himalayan region. This is probably because other pollinators are little attracted to these crops and also because they are generally not present in sufficient numbers in nature during these cropping seasons.

Bees commenced foraging activity earlier and ceased later on sunflower than rape flowers, thus increased the duration of foraging activity. This is probably because observations were taken at different months during the peak flowering stage of sunflower (April) and rape seed (January) with different temperature regimes. Bisht (1966) also quoted difference in the mean time of initiation (5.00 to 10.30 h) and cessation (13.30 h to the end of the day) of pollen gathering activity of *A. cerana* during different seasons in Delhi.

In our study, foraging activity of *A. c. himalaya* peaked between 06.00 h and 09.00 h for sunflower, whereas it was 09.00 h and 11.00 h for rape seed. The duration of individual foraging trip was 3.37 min on sunflower and 8.60 min on rape seed. However, Benedek and Prenner (1972) reported duration of foraging trip of *A. cerana* on *Brassica campestris* as 35.5 min. Ribbands (1949) opined that the duration of foraging trip is influenced by the number of flowers available, their nectar and pollen content and the amount of competition. This investigation shows that bees visited 9.90 rape flowers spending 6.37 sec on each flower. However, Murell and Nash (1981) recorded that *A. cerana* spent 3.0 sec on *Brassica campestris* var. toria. Further it was observed that bees spent an average of 52.98 sec per sunflower head with foraging rate of 1.70 flower heads/min.

However, Panchabhavi *et al.* (1976) observed in Bangalore that *A. cerana* spent 130.4 to 154.3 sec per head of sunflower. The variation in the number of flowers visited and the time spent may be due to the amount of nectar available in the individual flower and also to the distances that the bees had to cover to find a suitable source. Pollen loads on *A. c. himalaya* foragers were heaviest at 14.00 h for sunflower and at 12.00 h for rape seed. This may be because the maximum amounts of pollen and nectar are presented by these plants during afternoon hours. In the present investigation, bees collected either pollen or nectar during a single foraging trip, but never both. This may be because the nectar and pollen of these crops are not equally attractive to the foragers at the same time. The number of nectar collectors increased from morning to evening, however a reverse trend was observed for pollen collectors. The present findings are corroborate by the results of Cherian *et al.* (1947).

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Chapter 54

Comparative Attractiveness of Broad-leaf Mustard, Cauliflower and Radish to *Apis cerana* in Kathmandu Valley of Nepal

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Broad-leaf mustard, cauliflower and radish are widely cultivated in and around the Kathmandu valley of Nepal. These crops bloom simultaneously during February–March. The flowers produce good amount of nectar and pollen and are quite attractive to pollinating insects particularly honeybees. Many cultivated varieties are partially or completely self-sterile and require cross–pollination to produce fruit and seed (Partap, 1997; Partap and Partap, 1997; Verma and Partap, 1993, 1994). When these crops are grown in adjacent plots bees visit the crop that is most attractive and ignore the less attractive crops. Thus, pollination and, therefore, seed set in the less attractive crop is adversely affected.

Studies were conducted to find out the comparative attractiveness to bees of these three commonly planted cruciferous crops. Such studies are important in formulating strategies to manage pollination of crops that are planted in adjacent plots and bloom at the same time.

Material and Methods

Studies on the comparative attractiveness to the Himalayan honeybee, *Apis cerana*, of three cruciferous crops-broad-leaf mustard (*Brassica juncea* var. Khumal Broad-leaf), cauliflower (*Brassica oleracea botrytis* var. Kathmandu Local) and radish (*Raphanus sativus* var. Meno Early) were conducted on the FAO/HMG Nepal Vegetable – Seed Production Farm, Khumaltar in the Kathmandu valley of Nepal during March (i.e. when these crop are in bloom).

The crops were planted adjacent plots and started blooming during late -February. One strong colony of *A. cerana*, having eight frames covered with bees and free of any sign of disease, was placed in the middle of each plot. The number of bees foraging in 1 m^2 (about four plants) in a -minute period were counted for each crop for one week at 10.00 h. Ten such plots (1 m × 1 m) were marked for each crop.

To collect nectar and pollen, about 100 plants of each crop were covered separately with nylon cages (about 5 m × 3 m × 3 m) to prevent insects collecting either nectar or pollen. Nectar and pollen were collected daily around 10.00 h from flowers of almost the same age. Nectar was collected with graduated micro-capillaries. Ten such measurements were taken daily for one week for each crop. Sugar concentration in the nectar was measured with a hand refractometer. To collect pollen, flowers of the same age were plucked and pollen was extracted by sonication and weighed on an electronic balance. Ten such measurements were taken daily for one week for each crop. Nectar and pollen were extracted at the same time from flowers of all the three crops to minimise variations due to weather conditions.

Data were analysed statistically using arithmetic means and one-way analysis of variance.

Results

Results show that flowers of cauliflower were most attractive to *A. cerana* and those of radish were least attractive (Table 1). This was evident from the fact that the average number of foragers was highest on cauliflower (14.3 bees per m^2) followed by broad-leaf mustard (10.3 bees per m^2), and was lowest on radish (6.2 bees per m^2). Studies on the amount of pollen and nectar also revealed that radish produced more pollen (0.027 mg per flower) followed by cauliflower that produced 0.022 mg per flower and least in broad leaf mustard (0.016 mg per flower). Cauliflower produced 0.2 µl of nectar per flower, broad-leaf mustard produced 0.18 µl and radish produced 0.16 µl. Sugar concentration of nectar was highest in cauliflower (51%), 46% in broad-leaf mustard and least in radish (38%).

Table 1. Number of foragers per five minutes on 1 m^2 plots of cauliflower, broadleaf mustard and radish and the amount of nectar and pollen produced by a flower of cauliflower, broadleaf mustard and radish

Parameter	Cauliflower	Broadleaf mustard	Radish
Number of foragers in 1m^2 plot in five minutes	14.3 ± 0.9	10.3 ± 2.1	6.2 ± 1.4
Amount of pollen produced by one flower (mg)	0.022	0.016	0.027
Amount of nectar produced per flower (µl)	0.2	0.18	0.16
Sugar concentration in nectar (%)	51	46	38

Discussion

The attractiveness of a plant depends upon the calorific and nutritional rewards available to pollinators, and the efficiency with which pollinators can collect the rewards (Heinrich and Raven, 1972; Pyke, 1984; Pyke *et al.*, 1977). Crops that produce more nectar of higher sugar concentration per flower are comparatively more attractive to bees and other pollinating insects than those producing less nectar of low sugar concentration. Results of the present study showed that flowers of cauliflower attracted the highest number of *A. cerana* foragers. This is because cauliflower produced highest amount of nectar per flower compared to broad-leaf mustard and radish. Sugar concentration in cauliflower nectar was also highest. Radish produced least amount of nectar with lowest sugar concentration. As a result, radish flowers are least attractive to bees and other pollinating insects.

Such studies are important in managing pollination of crops that bloom simultaneously and are planted in adjacent plots. Results of the present investigation reveal that the presence of a crop (or a variety) that is more attractive to bees near one that is less attractive substantially affects bee visits to the less attractive crop and therefore, its cross-pollination. The most attractive crop cauliflower, attracted 2.3 times more bees than least attractive crop, radish. Therefore, for effective pollination and seed yield, radish should not be grown near cauliflower or broad-leaf mustard.

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Chapter 55

Foraging Competition between *Apis cerana* and *Apis mellifera* and its Impact on Crop Pollination

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Apis mellifera is thought to displace the native pollinators from both floral resources and the geographic areas (Schwarz, 1948; Sakagami, 1959, Prance, 1976, Roubik, 1978). When two species compete for limited amount of food resources, an increase in resource harvest by one species corresponds to the diminished harvest by other (Roubik, 1978). Andrewartha and Birch (1954) made some field studies to demonstrate the importance of the interspecies competition for food.

Since its introduction in 1990, *A. mellifera* has replaced the traditional beekeeping in *terai* and mid-hill areas of Nepal. The possible reasons for this being the higher productivity of *A. mellifera,* transfer of diseases and parasites and competition for food etc. Thus, the information on such aspects as transfer of bee diseases and foraging competition between the two species is important for developing appropriate management practices for both the species. In this paper, therefore, the investigations have been made to study the foraging competition between *A. mellifera* and *A. cerana,* and its impact on crop pollination.

Material and Methods

Experiments were conducted on 5 × 5 sq m plots of four crops viz mustard (*Brassica campestris*), broadleaf mustard (*Brassica juncea*), cauliflower (*Brassica oleracea botrytis*), and radish (*Raphanus sativus*) on HMG's Vegetable Seed Production Farm, Khumaltar in the Kathmandu valley, Nepal. For each crop, three such plots were sampled. Each plot of mustard had about 50–60 plants whereas those of broadleaf mustard, cauliflower, and radish had 25–30 plants in each plot. Total number of flowers/plant were about 207 in mustard, 5636 in broadleaf mustard, 4200 in cauliflower and 1248 in radish.

Foraging competition between the species was studied by counting the number of foragers of *Apis cerana* and their foraging behaviour during the presence of and after the removal of *Apis mellifera* from the plots of the crops under investigation. For this, one colony each of *A. cerana* and *A. mellifera* was introduced near the plots and an hourly count of number of foragers of *A. cerana* per five minutes was made throughout the day (from 0800 h to 1600 h). Hourly observations on the foraging behaviour of *A. cerana* were recorded for the time spent per flower by a forager, number of flowers visited per minute, weight of pollen load carried by an individual bee, per centage of pollen collectors and other sources of pollen visited (i.e. per centage of foragers collecting pollen from other crops). Such observations were recorded for one week. After one week, *A. mellifera* colony was removed from the plots and similar observations on the number and foraging behaviour of *A. cerana* were recorded for another week in the absence of *A. mellifera.*

Results and Discussion

A. cerana foragers were less abundant when *A. mellifera* bees were present in the plots on all crops. Removal of *A. mellifera* colony from the plots led to reversal in the abundance trends among both the species. After removal of *A. mellifera,* the number of *A. cerana* foragers increased significantly from 12.6 to 20.8 in mustard, 12.3 to 18.3 in broadleaf mustard, 18.4 to 28.3 in cauliflower and from 9.7 to 16.2 in radish (Table 1). These results revealed that *A. cerana* responded to the increased number of available flowers by recruiting more foragers and the extent of this response varied depending upon the crop. Since the foraging was more profitable in terms of the amount of nectar produced and sugar concentration in the nectar of mustard, there was more increase in the number of foragers in this crop followed by cauliflower, broadleaf mustard and radish.

The results showed that the presence of *A. mellifera* in the field reduces the number of *A. cerana* bees in the field. It was also observed that the two species try to displace each other rather than visiting / pollinating the flowers. It can, therefore, be inferred that the presence of both *A. cerana* and *A. mellifera* in the same field may not be complementary for the pollination of vegetables and other crops. It may rather adversely affect the pollinating efficiency of both the species. For beekeeping, it has implications in planning and development.

Observations on the foraging behaviour of *A. cerana* (Table 2) showed that the removal of *A. mellifera* significantly increased the time spent per flower by a foraging bee from 3.3 to 4.9 seconds on mustard, 2.8 to 3.2 on broadleaf mustard, 5.8 to 6.7 on cauliflower, and 4.3 to 5.3 seconds on radish. Removal of *A. mellifera* also decreased the

Table 1. Number of *A. cerana* foragers during the presence and after removal of *Apis mellifera*

Crop	Number of *A. cerana* foragers/5 min in 5 x 5 sq.m plots		Values of '*t*' and degrees of freedom (*df*)
	During the presence of *A. mellifera*	After removal of *A. mellifera*	
Mustard	12.6 ± 1.2	20.8 ± 1.3	*t*= 12.2; *df*=8; (*p*=0.01)
Broadleaf mustard	12.3 ± 1.3	18.3 ± 2.1	*t*= 5.4; *df*=8; (*p*=0.01)
Cauliflower	18.4 ± 1.1	28.3 ±0.8	*t*= 16.6; *df*=8; (*p*=0.01)
Radish	11.7 ±0.9	16.2 ±1.4	*t*= 8.7; *df*=8; (*p*=0.01)

number of flowers visited per minute of each crop by foraging bees of *A. cerana,* for example, the number of *A. cerana* foragers decreased from 13.9 to 11.5, 13.8 to 11.9, 8.0 to 7.3, and from 9.0 to 8 in mustard, broadleaf mustard, cauliflower and radish respectively after removal of *A. mellifera.*

Weight of pollen load carried by an individual foraging bee of *A. cerana* increased from 6.9 to 9.8, 12.1 to 13.6, 7.1 to 9.3, and 7.0 to 10.0 mg on mustard, broadleaf mustard, cauliflower, and radish respectively after removal of *A. mellifera.* Similarly, the percentage of pollen collectors was also increased. Percentage of pollen loads from crops other than experimental crops significantly decreased from 19.7 to 3.6 after *A. mellifera* was removed.

Since a decrease in *A. mellifera* bees corresponds to the increased visitation time per flower and increased weight of pollen loads by the foragers of *A. cerana,* it appears that the bees responded to the increased pollen availability by spending more time on the flower for the collection of more available pollen by recruiting more pollen collectors. During the presence of *A. mellifera* in the experimental plots, more foragers of *A. cerana* visited other crops in the vicinity for pollen and nectar, but after its removal these switched back to the crops under investigation. This was evident by the fact that more bees of *A. cerana* brought pollen loads from

Table 2. Foraging behaviour of *A. cerana* during the presence and after the removal of *A. mellifera*

Parameter		Floral Resource (Crop under investigation)			
		Mustard	Broadleaf mustard	Cauliflower	Radish
Time on flower (s)	During *A. mellifera*	3.3 ± 0.7	2.8 ± 0.2	5.8 ± 0.2	4.3 ± 0.1
	After *A. mellifera*	4.9 ± 0.8	3.2 ± 0.2	6.7 ± 0.3	5.3 ± 0.3
		t = 10.7; df = 98	t = 10.1; df = 98	t = 18.0; df = 98	t = 22.7; df = 98
		P=0.01	*P=0.01*	*P=0.01*	*P=0.01*
Number of flowers visited/min	During *A. mellifera*	13.9 ± 1.3	13.8 ± 0.5	8.0 ± 0.5	9.0 ± 0.4
	After *A. mellifera*	11.5 ± 1.5	11.9 ± 0.6	7.3 ± 0.5	8.0 ± 0.5
		t = 8.6; df = 98	t = 17.3; df = 98	t =7.; df = 98	t = 11.1; df = 98
		P=0.01	*P=0.01*	*P=0.01*	*P=0.01*
Weight of pollen load (mg)	During *A. mellifera*	6.9 ± 0.5	12.1 ± 0.6	7.1 ± 1.2	7.2 ± 0.5
	After *A. mellifera*	9.8 ± 0.3	13.6 ± 0.5	9.3 ± 0.3	10.2 ± 0.5
		t = 15.8; df = 18	t = 8.6; df = 18	t = 5.7; df = 18	t = 13.4; df = 18
		P=0.01	*P=0.01*	*P=0.01*	*P=0.01*
Number of pollen collectors (%)	During *A. mellifera*	44.6 ± 4.6	45.7 ± 3.9	46.1 ± 3.7	39.5 ± 2.7
	After *A. mellifera*	56.7 ± 3.5	52.3 ± 4.7	59.3 ± 3.7	49.4 ± 3.4
		t = 4.8; df = 8	t = 2.4; df = 8	t = 5.6; df = 8	t = 5.1; df = 8
		P=0.01	*P=0.05*	*P=0.01*	*P=0.01*
Other pollen sources visited (% pollen loads of other crops)	During *A. mellifera*	19.7 ± 1.1	16.1 ± 2.1	12.7 ± 1.9	13.3 ± 1.9
	After *A. mellifera*	7.7 ± 1.2	9.6 ± 1.9	3.6 ± 0.3	5.7 ± 0.6
		t = 15.5; df = 8	t = 5.1; df = 8	t = 10.6; df = 8	t = 8.5; df = 8
		P=0.01	*P = 0.01*	*P=0.01*	*P=0.01*

other crops during the presence of *A. mellifera* but after its removal, the number of pollen loads from other crops decreased significantly (Table 2).

Receprocal shifts in the resource use pattern do not always imply competition, but when induced experimentally, these prove that resources are limiting and hence competition occurs (Roubik, 1978). Competitive superiority is necessary attribute of a species able to establish in a saturated community (McArthur and Wilson, 1967) and at floral resources is likely to be of major importance (Roubik, 1978). The present study revealed that *A. mellifera* being stronger and competitively superior, it can out-compete *A. cerana* in areas where it is introduced and this has been true in many areas. The introduction of *A. mellifera* in to the Hindu Kush-Himalayan region has led to the decline in *A. cerana* populations in their native habitat to the level that has threatened its extinction and traditional beekeeping.

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Chapter 56

Agroforestry: Its Role in Crop Pollination and Beekeeping

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Honeybees are among a few pollinators that have been managed for a long time. Unfortunately, the vital role that bees, other insects and animals play in agricultural production is almost completely unknown by the general public and policy-makers in many Asian countries where honeybees are kept almost exclusively for honey production. In fact, pollination of crop plants by honeybees is much more important than honey production (Partap and Partap, 1997): an estimation indicates that the pollination service provided by honeybees is 40–60 times more valuable than the production of honey.

Recent surveys document that more than thirty genera of animals – consisting of hundreds of species of floral visitors – are required to pollinate the 100 or so crop plants that feed the world (Buchmann and Nabhan, 1996; Prescott-Allen and Prescott-Allen, 1990). Insects are the largest group of pollinators and honeybees are estimated to provide approximately 80 per cent of all insect pollination (Robinson *et al.*, 1989). However, there is a pollination crisis, in which both wild and managed pollinators are disappearing at alarming rates owing to habitat loss, poisoning, disease and pests (USDA-ARS, 1991).

No detailed data are available regarding changes in the numbers of honeybee colonies in most Asian countries. However, field interviews with beekeepers indicate that honeybee colonies are declining as a result of the spread of diseases and parasitic mites, exposure to pesticides and habitat loss.

Agroforestry: Concept and Major Agroforestry Systems and Practices

Various definitions of agroforestry have been proposed. However, it can be understood as the integration of trees with farming systems. It encompasses all ways that woody plants, intentionally integrated into agricultural land-use systems, provide tree products and protect, conserve, diversify and sustain vital economic, environmental, human and natural resources. It has the potential to improve agricultural productivity, diversify and increase farm income, conserve land, maintain biodiversity, and contribute to poverty reduction. Examples of major agroforestry systems are listed in Table 1.

Role of Agroforestry in Crop Pollination and Beekeeping

Agroforestry can improve and provide habitats for bees and other pollinators. As mentioned earlier, habitat loss is a major factor for declining

Table 1. Major agroforestry systems and examples of agroforestry practices

Major agroforestry systems	Example of agroforestry practices
Agrisilvicultural systems	Shifting cultivation, Taungya system, tree garden, alley farming, contour hedgerow system, multipurpose plants and crops system, windbreak, soil conservation hedge, fuelwoods and crops
Agrisilvopastoral systems	Home garden, woody hedges for browse, mulch, green manure, soil conservation
Silvopastoral systems	Fodder and crops, living fence of fodder trees and hedges, trees and shrubs on pasture
Silvopiscicultural systems(Tree fishery system)	Trees and fish farming
Agrisilvopiscicultural systems	Trees, crops, livestock and fish farming
Agripastopiscicultural system	Sericulture and fishery system
Silvo-medicinal plant farming systems	Woody plants and medicinal farming
Agrisilvo-medicinal plant farming systems	Woody plant, crops, and medicinal plants farming

Source: Nair (1987) with modifications and additions.

species and population of various pollinators, including wild honeybees and other wild bees. Removal of fence-rows, hedgerows, wild strips and fallow land has reduced forage and nesting sites for wild pollinators and honeybees. Development and promotion of agroforestry can improve now-fragmented habitats and reconstruct habitats to some extent. In agroforestry systems, large numbers of woody plants are used as windbreaks, orchards, hedgerows, riparian woods, managed woods for fuelwood, fodder and timber, multipurpose trees for soil improvement, shading, etc. Although such woodlands vary in size and plant species composition, and are not as rich in plant species as natural forests, they can contribute considerably to pollination of crop/fruit plants and wild plant species by providing and improving habitats for nesting and brooding by pollinators. This is particularly important in areas where forests are cleared and little natural vegetation is left. For example, vegetable fields with hedgerows of mixed grasses and shrubs can highly benefit pollinators. Grasses can supply pollinators with shelter and resting places.

Agroforestry systems also can improve habitats by sequestering and biodegrading excessive nutrients and pesticides from agricultural fields, and so reduce the risk of pollinator- and honeybee-poisoning. Many woody species have proved efficient in this respect. Since the replacement of pesticides will not happen quickly, intentional selection of species that biodegrade agrochemicals will be important. If the pollination issue can be taken into account during agroforestry planning and management so that habitats are intentionally provided, the role of pollinators will be greatly strengthened. There is also a need to create seminatural buffer zones around farmlands to connect farmlands with natural vegetation: agroforestry can also help here.

Agroforestry development can provide forage sources. Lack of suitable pollen and nectar plants presents a fundamental problem to wild pollinators and honeybees. Development and promotion of agroforestry can provide large expanses of forage sources for pollinators. This is particularly important for beekeeping. Almost all the horticultural plants listed by Partap (1997) as important forage sources for honeybees are targeted plants of agroforestry systems. For survival of pollinators and honeybees, there must be pollen- and nectar-producing plants that flower in sequence throughout the year. Diversified combinations of plants provide this function. For example, in Mexico, natural or planted forests are protected alongside roads and cornfields. Such forests provide resources for pollinators and honeybees, and act as fire protection for hives during the burning of cornfields (Cemas and Rico-Gray, 1991).

Agroforestry can reconstruct and improve habitats for natural enemies of pests. Approximately 70,000 pest species attack agricultural crops throughout the world (Pimentel, 1991), and almost 99 per cent of pests are controlled by natural enemy species and host-plant resistance (DeBach and Rosen, 1991). Development and promotion of agroforestry can provide, reconstruct and improve habitats for natural enemies of pests, thus reducing the need for pesticides. Extensive use of pesticides means that it is more and more difficult to locate safe sites for honeybees. Although honeybees can be moved to avoid pesticides, the death of wild pollinators may result in serious losses of key species that might cause the collapse of an ecosystem (Heywood, 1995). Another issue is economic. Pesticide application kills wild pollinators and keeps honeybees away from farmlands or orchards, as a result insect-pollinated plants have to be pollinated manually in order to achieve satisfactory yields. This increases inputs. Protecting the natural enemies of pests also reduces the amount of pesticides that have to be used which in turn reduces the risk of pollinators being killed.

Agroforestry can help to improve crop pollination. Many food, fruit and vegetable plants would benefit in quality and quantity from more thorough pollination. For example, apple trees require multiple visits by a bee to each blossom to make quality apples. Planting of various plants near or on farmlands and farm boundaries can serve as sources to attract pollinators. Because of habitat loss and changes in agricultural systems, it is necessary to investigate which plants may be grown on set-aside land, field margins or in domestic gardens, to provide alternative forage for pollinators and honeybees. While pollinating these plants, pollinators will also pollinate crops on the nearby farmland. For example, one acre of nesting habitat set aside for alkali bee can sustain sufficient female bees to pollinate 10 acres of alfalfa seed.

Conclusions and Recommendations

Pollination is a vital process for both natural and agricultural ecosystems. Animals, mainly insects including various wild and domestic bees, provide a vital role in plant pollination. Loss of nesting and roosting sites, habitat fragmentation, excessive application of pesticides and decline in forage resources are common threats to pollinators. Agroforestry encompasses diverisified land-use management practices of integrating various woody plants with food-crop plants and other cash crops. Development and promotion of agroforestry can improve, provide or reconstruct pollinators' habitats, and provide forage resources for pollinators. Agroforestry can also improve production through enhanced pollination service and reduced pest risk. Agroforestry can contribute greatly to conservation and protection of pollinators, and hence to sustainable agricultural development. The following recommendations are made for agroforestry programmes.

- General public and policy-makers should be made aware of the role played by insects including honeybees in pollination in order to protect and conserve these pollinators.
- When planning an agroforestry programme, selection of various forage plants for pollinators should be taken into consideration. Planting of different species not only protects pollinators but also reduces the chances of pests. Habitat protection and conservation should also be taken into account.
- Integrated pest management should be highly promoted in order to reduce application of pesticides.

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Chapter 57

Resource Partitioning among *Apis mellifera* and *Apis cerana* under Mid-hill Conditions of Himachal Pradesh

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Activity of the honeybee is largely governed by available bee forage and competition among bee species and other nectarivores. With the successful establishment of the exotic bee, *Apis mellifera*, competition for available food resources has arisen with the native bee, *A. cerana*. Little work appears to have been done to identify and evaluate important bee plants in relation to hive bees, although a lot of information on the bee plants of Punjab, Himachal Pradesh and Western Ghats is available (Atwal *et al.* 1970; Divan and Rao, 1971; Sharma and Raj, 1985).The present study was undertaken to find out whether bees of the two species are utilising the same floral sources or diversified ones.

Material and Methods

Studies were undertaken in the Solan area of Himachal Pradesh where beekeeping is practised with both *A. cerana* and *A. mellifera*. Observations on resource partitioning of flora by the bees were recorded by counting the number of bees per m^2 bloom (branch) area per five minutes at different day hours. Since bees visited a large number of flora during a year, the data have been tabulated for only those flora on which bee activity (of either species) was more than 2 bees/m^2/5 min. However, data for flora exclusively visited by either of the bee species are given irrespective of the number of bees.

Results and Discussion

Results are presented in Tables 1, 2 and 3.

Data presented in Table 1 reveal that *A. mellifera* and *A. cerana* shared 23 important bee flora. However, the activity of the two bee species on these flora varied to a great extent. During spring, *A. mellifera* preferred *Rubus ellipticus* (7.85 bees) and *Prunus armeniaca* (7.6 bees), whereas *A. cerana* was more active on *Malus domestica* (9.91 bees). In addition to these, *A. cerana* visited five plant species not visited by *A. mellifera* (Table 3) and similarly *A. mellifera* visited four plant species not visited by *A. cerana* (Table 2). During early summer (April–May), of the six plant species shared by the hive bees, activity of *A. mellifera* was maximum on *Eucalyptus* sp. (12.07 bees) and *Toona ciliata* (8.77 bees). *Apis cerana* foraged on these plants in good numbers but also utilised *Trigonella* to a great extent (6.17 bees).

Table 1. Comparative activity of hive bees (number of bees/m^2/5 min average of three day hours) on preferred bee flora during a year

Sr. No.	Plant	*Apis mellifera*	*Apis cerana*	Period (month)
1	*Prunus amygdalus*	2.36	2.88	2–3
2	*Rubus ellipticus*	7.85	5.26	2–3
3	*Malus domestica*	2.82	9.91	2–3
4	*Pyrus communis*	3.49	2.23	2–3
5	*Prunus persica*	5.07	3.42	2–3
6	*Prunus armeniaca*	7.60	5.52	2–3
7	*Callistemon lanceolatus*	5.67	5.62	4–5
8	*Eucalyptus hybrida*	12.07	3.96	4–5
9	*Robinia pseudoacacia*	5.48	0.82	4–5
10	*Trigonella foenumg-raecum*	3.11	6.17	4–5
11	*Brassica oleracea var. botrytis*	1.12	4.61	4–5
12	*Toona ciliata*	8.77	6.73	4–5
13	*Opuntia dellenii*	7.50	1.07	5–6
14	*Rhus wallichii*	5.21	2.94	5–6
15	*Acacia catechu*	2.65	2.39	7–8
16	*Chenopodium album*	3.40	6.37	7–8
17	*Mallotus philippinensis*	2.90	3.68	7–8
18	*Rhamnus trilquetra*	4.74	2.35	7–8
19	*Cannabis sativa*	2.40	1.03	9–10
20	*Spermadictyon suayeoleus*	1.44	8.04	10–11
21	*Tagetes minuta*	0.72	4.78	10–11
22	*Dipsacus inermis*	4.53	1.33	10–11
23	*Ocimum sanctum*	1.87	8.42	10–11

Apis mellifera, in addition, exploited six other plant species of which *Cnicus* and *Lonicera* were the most important. Later in the summer (May–June) competition was restricted to only two main flora, *Opuntia* and *Rhus wallichii*, on which *A. mellifera* predominated (respective values being 7.5 and 5.21 bees). However, *A. cerana* broadened its foraging during this period by foraging on four additional plants of which *Woodfordia fruticosa* was the most preferred (5.18 bees).

During monsoon (July–August), out of four flora shared by the hive bees, *A. cerana* was more active on *Chenopodium album* (6.37 bees), whereas *A. mellifera* foraged more on *Rhamnus triquetra* (4.74 bees). However, *A. mellifera* also foraged on six additional plant species, *Malvastrum* being the most important (3.73 bees).

During autumn (September–November), of the five shared flora, activity of *A. cerana* was greater on *Spermadictyon* (8.04 bees) and *Ocimum* (8.42 bees), whereas *A. mellifera* foraged on these flora in low numbers and had its maximum activity was on *Dipsacus* (4.53 bees). Interestingly, *A. cerana* also exploited three additional flora during this period (Table 3), activity ranging between 7.03 to 14.22 bees. This suggests that in autumn during colder climatic conditions, *A. cerana* exploited more flora than *A. mellifera*.

Table 2. Activity of *Apis mellifera* on flora not visited by *Apis cerana* during different period of the year (number of bees/m^2/5 min)

Sr. No.	Plant	No. of bees	Period
1	*Pyrus pashia*	6.58	2–3
2	*Viola tricolor*	1.99	2–3
3	*Hypericum oblongifolium*	7.81	2–3
4	*Elaeagnus umbellata*	2.70	2–3
5	*Lonicera angustifolia*	6.81	4–5
6	*Calendula offlcinalis*	5.84	4–5
7	*Trifolium repens*	5.59	4–5
8	*Centaurea cyanus*	2.51	4–5
9	*Lotus corniculata*	1.81	4–5
10	*Cnicus argyracanthus*	6.58	4–5
11	*Oenothera rosea*	1.69	7–8
12	*Datura stramonium*	0.88	7–8
13	*Oxalis corniculata*	2.21	7–8
14	*Echinops niveus*	1.29	7–8
15	*Malvastrum tricuspidatum*	3.73	7–8
16	*Myriactis nepalensis*	0.81	7–8

Table 3. Activity of *Apis cerana* on flora not visited by *Apis mellifera* during different period of the year (number of bees/m^2/5 min)

Sr. No.	Plant	No. of bees	Period
1	*Mesembryanthemum criniflorum*	–	2–3
2	*Salix tetrasperma*	1.70	2–3
3	*Wistaria sinensis*	0.73	2–3
4	*Medicago denticulata*	0.99	2–3
5	*Berberis lycium*	0.70	2–3
6	*Woodfordia fruticosa*	5.18	5–6
7	*Millettia auriculata*	0.77	5–6
8	*Sapium sebiferum*	7.55	5–6
9	*Albizia chinensis*	2.81	5–6
10	*Cynoglossum furcatum*	2.27	7–8
11	*Koelreutaria paniculata*	1.27	7–8
12	*Plectranthus rugosus*	8.59	10–11
13	*Salvia lanata*	7.03	10–11
14	*Solidago canadensis*	14.22	10–11

These observations indicate that the two hive bees share bee flora as well as show resource partitioning to some extent when in the same ecological niche. Even on shared flora, each bee species avoided competition as is evident from varying density of the two species on the flora flowering at the same time. In this manner both hive bees are reducing competition to some extent by exploring diversified flora and making it possible to co-exist. Thus the fear that one bee species could be exterminated by the other due to competition for bee flora can be set aside. Further, it must be made clear that data shown in Tables 1–3 were collected at a time when the two bee species faced competition. In the absence of competition either of the bee species may visit flora that in this study were shown not to be visited by them.

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Computer-assisted Pollen Databank: A New Method to Identify Bee Plants

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Vorwohl (1968) suggested a modern system for pollen determination in honey-pollen analyses. This key is used in a modified form on an EDV-System for Adminstration of a pollen databank and as a first step in pollen determination.

The system uses a databank of many different pollens (plants). This can be seen and used at http: //www.bfl.gv.at/institut/bienen/pollen/ndx_po.htm. Selection is made with the 'Vorwohl-key' as a help in determination (Table 1). This simplifies the work of pollen analyses.

Possible uses are scientific research (wherever pollen is of interest: bees, environmental research, plant biodiversity, botany, paleobotany,

Table 1. Vorwohl key for pollen identification

Length	Class	Breadth	N colpi	Class	Kind of colpi	Class	Exine	Class	Aggregation	Class
<=10	1	<=10	=1	1	Pore	1	psilat, faveolat, fossulat	1	=1	1
11-15	2	11-15	=2	2	Fold	2	scabrat, ferrucat, gemmat	2	=2	2
16-20	3	16-20	=3	3	Porefold	3	echinat	3	=3	3
21-25	4	21-25	=4	4	Syncolpat	4	clavat, baculat	4	=4	4
26-30	5	26-30	=5	5	Heterocolpat	5	rugulat, striat	5	=5	5
31-35	6	31-35	=6	6		6	reticulat	6	=6	6
36-40	7	36-40	=7	7		7	fenestrat	7	=7	7
41-50	8	41-50	>7	8		8		8	=8	8
>50	9	>50	0	9		9		9	>8	9

Source: Vorwohl, 1968

criminalistic, pollination, medicine, etc.); routine analyses of bee products (quality, origin, value of bee pasture, etc.); and medicine (pollen-warning system, allergy sensitisation, etc.)

Future aspects include REM-pictures and phytogeographic data; possible links to other pollen information on the internet; network databank for all interested persons (in preparation); and 'if you bring data, you can use data'.

Safety aspects include all plants having to be determined by a plant specialist named in the databank; one herbarium specimen with flowers and enough pollen for four slides (different methods) and one REM-preparation; the herbarium specimen to be deposited in an international botanical museum.

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Chapter 59

Eucalyptus in Asia: A Beekeeping Resource

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Eucalyptus species have probably been Australia's most successful export. Eucalypts have been planted in tropical, subtropical and temperate regions world-wide with estimates that plantations are likely to exceed 10 million hectares by the year 2000. Florence (1996) states that 'Eucalypts are mainly grown for pulpwood, fuelwood and charcoal, mining timber, fibreboard and essential oils'. What is often not stated in forestry-sourced references is the tremendous value eucalypts have to the beekeeping industry. Australia has average yields of 100–110 kg of honey per hive in many years. Of the 26,000 to 27,000 t produced on average per year by Australian beekeepers, about 70–80 per cent is derived from *Eucalyptus* species.

The diversity of *Eucalyptus* species accounts for the success of Australian beekeepers. Eucalypts are naturally occurring in a range of locations, extending from dry arid areas to cool alpine regions, from wet or dry temperate forests to warmer tropical regions. There are approximately 550 species of eucalypts that are endemic to Australia, of which 220 have been identified as valuable to honeybees (Lazarides and Hince, 1993).

Eucalyptus in Asia

It is estimated that 30–40 per cent of all trees planted in the tropics in recent years are of Australian origin (Vercoe, 1993). These tree species are primarily eucalypts, acacias and casuarinas. Boland (pers. comm.) of the Division of Forestry, CSIRO, Australia suggests that in 1997 the primary species of eucalypts planted in Southeast Asia are *E. camaldulensis* and *E. tereticornis* in a ratio of approximately 60: 40. An estimate of the approximate area of Australian eucalypts in plantations in Asia is given by Vercoe (1993, revised in 1996 pers. comm.) (Table 1).

India

Eucalypts were brought to India by the British in about 1843 to provide a reliable fuel supply.

Table 1. Australian *Eucalyptus* spp. in Asia

Country	*Eucalyptus* plantation area (ha)
India	4,800,000
Indonesia	80,000
Malaysia	8,000
Myanmar	25,000
Nepal	5,000
Pakistan	28,500
Philippines	10,000
China	670,000
Sri Lanka	45,000
Taiwan	3,500
Thailand	62,000
Vietnam	245,000
Total	**5,982,000**

They were planted in the Nilgiri Hills where growth rates of 6–7.5 m from seed in only eight months were reported. It was reported in 1876 that large supplies of mainly *E. globulus* were imported. Apparently the introduction was not widely successful. The major species in India is *E. tereticornis*. *Eucalyptus resinifera, E. camaldulensis, E. citriodora, E. viminalis* and *E. robusta* have also been planted (Zacharin, 1978).

Sri Lanka
By 1873 the total area planted was about 8300 ha, chiefly with *E. camaldulensis, E. grandis, E. citriodora* and *E. microcarpa* (Zacharin, 1978). By 1993 this figure had risen to 45,000 ha (Vercoe, 1993). Punchihewa (1994) writes on beekeeping in Sri Lanka and refers to *Apis dorsata* colonies migrating on to *Eucalyptus* species mainly red gum from July until October each year. Punchihewa (1994) refers to management of bees pre- and post-eucalypt flows, but does not state the species. Red gum may refer to a number of species but is probably either *E. camaldulensis* or *E. tereticornis*. Fernando (1980) also refers to *Eucalyptus* species as a melliferous floral resource in Sri Lanka.

Nepal
Some limited plantings of eucalypts have been reported in and around Kathmandu, but in other parts of the country only odd trees occur. The main species that have been reported to do well include *E. camaldulensis, E. grandis* and *E. tereticornis* (Zacharin, 1978). There is potential to investigate eucalypt species that are more suited to alpine climates than those species thus far reported in Nepal. Examples include *E. regnans, E. delegatensis* and *E. pauciflora*.

Pakistan
Eucalypts were introduced in 1867 and a large number of species have been tried. However, only 1000 ha had been planted up to 1978. The main species being *E. camaldulensis, E. tereticornis, E. microtheca* and *E. citriodora* (Zacharin, 1978). The area of eucalypts in plantations had grown to 28,500 ha in 1993 (Vercoe, 1993).

China
Between 1894 and 1896 eucalypts were introduced to south China from Italy. The earliest species was *E. globulus* then came *E. camaldulensis, E. tereticornis, E. citriodora* and *E. robusta*. Eucalypts were noted by Zacharin (1978) to be well spread across the country, with plantings between agricultural crops and along railway lines. In the 1970s, experimental plantings of *E. regnans, E. delegatensis, E. melliodora, E. viminalis, E. amygdalina* and *E. obliqua* were instigated (Zacharin, 1978). Florence (1996) reported that some 600,000 ha of eucalypt plantations in south China have been based mainly on *E. exserta* and *E. citriodora*, with *E. globulus* in the 'cooler' subtropical areas. Many of these plantations were reported to be below optimum for wood production.

Hong Kong
Species such as *E. grandis, E tereticornis, E. robusta* and *E. pilularis* are reported to grow well in the New Territories, although there are no large areas planted (Zacharin, 1978). There are no significant plantings of eucalypts in Hong Kong.

Japan
In 1954 the government of Japan officially adopted eucalypts for reafforestation. *Eucalyptus globulus* is the most common species, although there are many other plantings of eucalypt species mainly as single trees (Zacharin, 1978). There are no significant plantations recorded.

Singapore
Only specimen trees of about 14 eucalypts have been planted in the botanic gardens (Zacharin, 1978). The size of Singapore does not permit substantial plantings of forest species.

Malaysia
Eucalyptus deglupta and *E. robusta* were regarded as the most common species planted in 1978, with some areas of *E. grandis* (Zacharin, 1978). *Eucalyptus deglupta* originates from Indonesia.

Table 2. Honey and pollen values of *Eucalyptus* spp. grown in Asia

Eucalyptus species	Value for honey	Average honey yields per hive (kg)	Value for pollen
E. amygdalina	-	-	-
E. camaldulensis	High	30–50	High
E. citriodora	Medium	20	Low
E. decaisneana	-	-	-
E. deglupta	-	-	-
E. delegatensis	Medium-High	20–30	High
E. exserta	Low	10–20	Medium
E. globulus	Medium	20	High
E. grandis	Low	10	Medium
E. melliodora	Medium-High	10–60	Nil
E. microcarpa	Low	10	Low
E. microtheca	Medium-High	10–30	High
E. obliqua	Low-Medium	10	Low-Medium
E. paniculata	High	30–160	Nil
E. pilularis	Medium	0–30	Medium
E. regnans	Low	-	High
E. resinifera	Low-Medium	10–30	Medium
E. robusta	Low-Medium	10–20	Medium
E. saligna	Medium-High	20–40	High
E. tereticornis	Low-Medium	20	Medium
E. urophylla	-	-	-
E. viminalis	Low-Medium	30	Medium-High

Note: - = no information available.

Indonesia

There are three native species of eucalypt. *Eucalyptus alba* occurs at lower altitudes in Timor and surrounding islands; *E. decaisneana* is distributed over the mountains of Timor and adjacent islands; *E. deglupta* occurs on both the lowlands and mountainous regions of Sulawesi and the Moluccans (Zacharin, 1978).

Honey and Pollen Values of *Eucalyptus* spp. Grown in Asia

Table 2 indicates the relative values for honey and pollen of eucalypts mentioned in this paper to be growing in Asia as they relate to management of honeybees under Australian conditions. The average honey yield per hive is what beekeepers, under Australian conditions, may extract under reasonable conditions.

Of the two *Eucalyptus* species that dominate most plantings in Southeast Asia, *E. tereticornis* is regarded as a support species in most of its indigenous range. *Eucalyptus camaldulensis* has the widest distribution of any eucalypt in Australia. The value of this species to beekeeping varies across its distribution. Generally, honeybees do well working this species with both honey and good-quality pollen being gathered. Australian beekeepers prefer this species to be periodically flooded, particularly in spring with flowering occurring over the summer (Somerville and Thompson, 1995).

Eucalyptus paniculata and *E. melliodora* are important honey-producing species in Australia, but their pollen is not collected in any significant quantities by honeybees. Management considerations regarding nutritional requirements of the colony have to be implemented when contemplating working a honey-flow from these species.

Discussion

Beekeeping world-wide relies on a diverse range of honey- and pollen-yielding flora. Frequently knowledge of the available flora is limited. Eucalypts are often mentioned as being of value as a melliferous resource in many countries. Difficulties arise in utilising these flora when species are not specified. The necessity of authors of beekeeping literature to state the actual eucalypt species is important when relative values for honey and pollen production are considered. Eucalypt species have been largely selected for plantings based on their growth habits as they relate to timber production and their potential for beekeeping has often been overlooked. Given that it is possible for the value of beekeeping products, harvested from some eucalypt species, to exceed the value of timber products it is worth suggesting that relative values for honey production should be a consideration by reafforestation organisations and foresters when planting trees for other purposes.

In Australia it is possible that the value of the honey crop, derived from *E. paniculata* on the north coast forests of New South Wales, exceeds the value of timber in many locations (Somerville, 1998). This is also recognised in Queensland where *E. polyanthermos* and *E. caleyi* are not harvested for timber owing to their major contribution to honey production in the region (Moncur and Kleinschmidt, 1992).

The box/ironbark and stringybark group of eucalypts is under-represented in plantings throughout Asia, whereas this group provides the majority of the honey crop in Australia (Somerville and Moncur, 1997): *E. melliodora, E. albens, E. paniculata, E. crebra, E. melanophloia, E. sideroxylon, E. microcarpa, E. fibrosa* and *E. caleyi*. Other important eucalypts to the Australian beekeeping industry are given in Table 3.

It should be noted that only two species in this table appear in the table of eucalypts growing in Asia. The time of year these trees flower varies according to individual species and location; also under Australian conditions flowerings may only occur every two to four years with many eucalypt species. It is normal practise for Australian beekeepers to move honeybees from one flowering eucalypt to the next, as one finishes flowering and another begins. A knowledge of the relative flowering periods is essential to plan the movement of colonies.

Not all *Eucalyptus* are the same in regard to honey and pollen production. Their main function could be as a build-up plant, i.e. providing sufficient pollen and nectar for the colony to breed and strengthen in numbers prior to a more reliable honey source flowering or hives being used for crop pollination.

The quantity and characteristics of honey obtained from eucalypt nectar also varies with species. Honey produced may vary from a light

Table 3. Honey and pollen values of some important *Eucalyptus* species in Australia

Eucalyptus species	Value for honey	Average honey yields per hive	Value for pollen
E. albens	High	30–50	Medium
E. caleyi	High	30–50	Nil
E. calophylla	High	30–80	High
E. camaldulensis	High	30–50	High
E. crebra	High	40–80	Medium
E. diversicolor	High	40–100	Low
E. macrorhyncha	High	40–60	Medium-High
E. maculata	High	30–80	High
E. marginata	High	20–60	High
E. melanophloia	High	50–70	Medium
E. melliodora	High	30–80	Nil
E. microtheca	High	30–50	High
E. muelleriana	High	20–60	High
E. ochrophloia	High	30–50	Low
E. paniculata	High	30–160	Nil
E. pauciflora	Medium-High	40–50	High
E. redunca	High	20–60	Medium
E. sideroxylon	High	30–80	Nil

P-fund reading of 5–10 mm to a darker colour of P-fund of 90–110 mm depending on the species. Eucalypt species also vary in their reliability regarding yields. In a recent study of the value of forested lands within New South Wales, average honey yields for the top-producing eucalypts varied from 10 kg per hive to 162 kg per hive (Somerville, 1998).

Some eucalypt species planted in other countries have performed better in relation to their honey-producing capacity than in their indigenous locations. An example of this is *E. grandis* that is not a highly regarded source of honey in Australia, but is a major source of honey in South Africa.

Given the wide diversity of *Eucalyptus*, it is possible to select from a range of species that benefit beekeeping activity and forestry objectives for all climatic areas of Asia. Gathering information on honey and pollen production of eucalypts currently growing throughout Asia would be important in determining suitable species considered for reafforestation projects. Honey and pollen values of species growing in their native Australian environment should be considered when selecting species that will not only meet the desired criteria for timber and other wood-related products, but also benefit local family beekeeping operations adjacent to such tree plantings throughout Asia.

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Part 7
Experiences in Beekeeping Extension

Chapter 60

Beekeeping Needs of Farming Communities in the Hindu Kush-Himalayan Region

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Farming communities in the north-western Himalayas have a rich tradition of beekeeping with the Asian honeybee, *Apis cerana,* in wall hives. During surveys, a large number of wall hives (2–11) per farmhouse were observed. However, only 43.8 % were colonised. Interactions with farmers revealed that there were now fewer *A. cerana* swarms coming from the forests so occupancy had gone down. Modern beekeeping with *A. cerana* in Indian Standard Institution wooden hives had limited success because of the inherent traits of the bees to swarm and abscond. Farmers could not afford to invest large sums in the purchase of hives only to find that the bees had deserted. It is necessary to provide technology that fits a low-investment profile but has the benefit of scientific methods. Since the wall hive is already available and farmers are familiar with it, a technology was developed using this as a base. The scientific concept of movable frames was hybridised with the traditional structure to form the modernised wall hive.

Material and Methods

The traditional wall hive is a cavity left in a wall when a house is constructed. It is the thickness

Beekeeping in Pakistan: present status and economics

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Some 30,000–35,000 *Apis cerana* colonies occur in 4 types of traditional and 12 types of low-cost hives. A small number are in Langstroth hives in some government institutions for research and teaching. Commercial beekeeping has almost dispensed with this bee because of its non-profitability. *Apis dorsata* and *A. florea* have suffered pesticide losses mostly in cotton- and sugarcane-growing areas, being reduced to 40,000–50,000 colonies and about 12,000–15,000 colonies respectively. However, *A. florea* is safer in parts of the desert (Thar and Cholistan) and in coastal areas especially in mangrove (*Aincennia alba*) forests. American Foul Brood, first recorded in 1997, destroyed about 300 *A. mellifera* colonies in private apiaries. Some 6000 people were trained in modern bee management. Adoptation of *A. mellifera* (more than 90,000 colonies) has increased honey production: average 4 kg/colony/annum from *A. cerana* in 1982 to about 21 kg/colony/annum in 1996 from *A. mellifera*, overall production from 250 t in 1982 to more than 1800 t in 1997. 'Sidder' honey export (more than 210 t in 1996 sold locally at US$ 9–10 per kg) has increased net income of about 11,000 beekeepers by 5–10 times. Small bee-farming units are being set up in collaboration with national/international institutions.

of the wall and varies in dimensions in different regions of the Hindu Kush-Himalayas (Verma *et al.*,1997). It has an entrance on the outside for the bees and is closed on the inside usually with a plank of wood plastered with mud.

The method followed for modernisation of a wall hive is given below.

- The hive was opened by removing the mud-plastered board covering its back (Fig. 1).
- The dimensions (height, breadth and depth) of the wall recess were recorded (Fig. 2).
- Wooden frames of the requisite size and with a proper intercomb distance were made on the spot (Fig. 3).
- Bees were smoked to expose the combs.
- Combs were cut from their attachment one by one with a knife (Fig. 4).
- While cutting, each comb was gently supported and placed flat on a wire gauze mounted on a frame provided with a handle, this helped in preventing the comb from falling and also protected the developing brood and adhering bees.
- During this operation bees were highly disturbed. Sometimes they came out of the hive in large numbers and started clustering on the wall outside. In order to settle the bees, and to save the queen and receive incoming foragers, an empty box with a small opening was temporarily placed just inside the hive entrance.
- Honeycombs were separated (Fig. 5).
- Combs with brood, pollen and honey were cut in such a way as to separate the upper sealed honey from the lower brood areas.
- Brood comb was immediately mounted on a frame and supported with wire (Fig. 6).
- The wall recess was thoroughly cleaned to remove pseudoscorpions, mites, wax moth, beetles, ants, and other robbers and scavengers.
- Then two supports for the frames were inserted and fixed at the top of each side wall of the recess (Fig. 7).

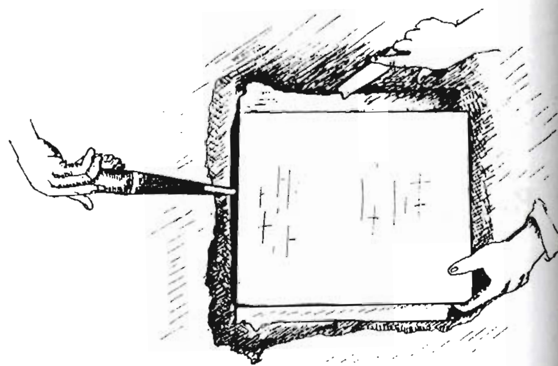

Fig. 1. Opening a traditional wall hive

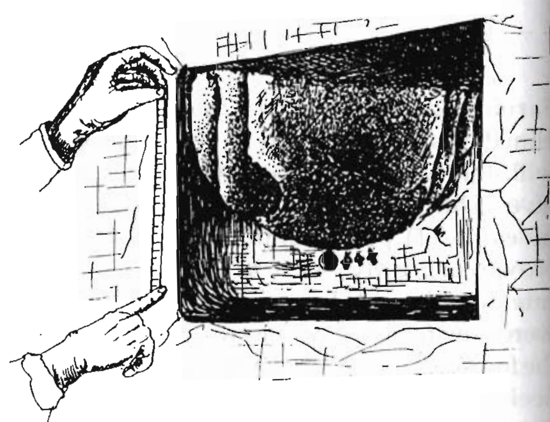

Fig. 2. Taking dimensions of the wall hive

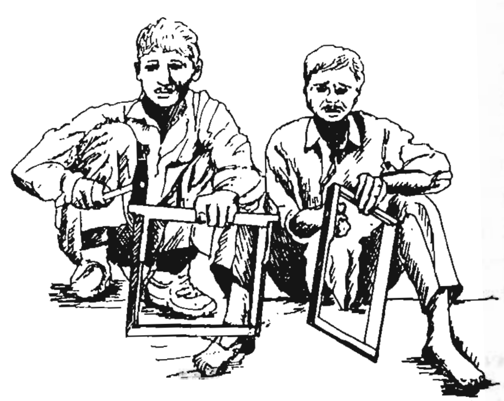

Fig. 3. Making precise movable comb frames on the spot

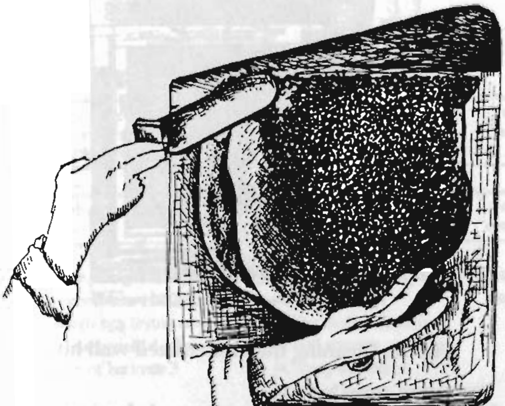

Fig. 4. Cutting the combs from the top

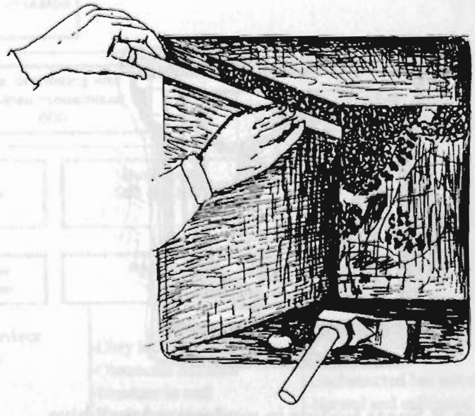

Fig. 7. Inserting ledges for holding comb frames

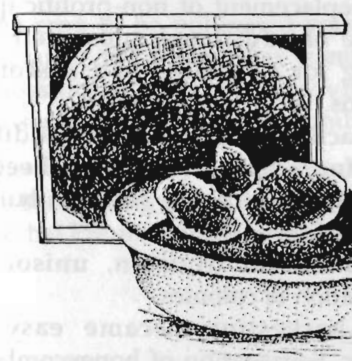

Fig. 5. Segregation of honey and brood portions of the comb

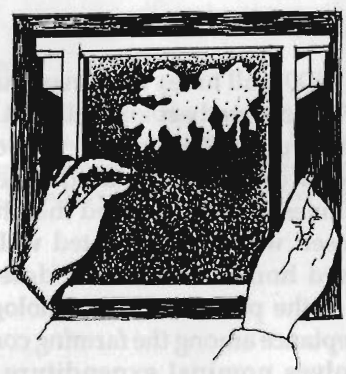

Fig. 8. Settling the bees in the modernized wall hive

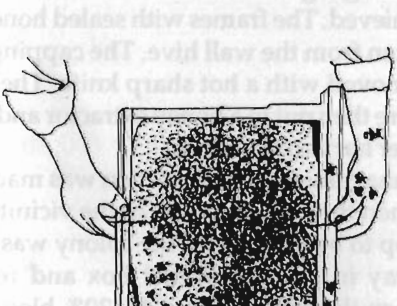

Fig. 6. Mounting brood combs on movable frames

- Comb frames were introduced on to the supports one by one and the bees settled back on to the combs (Fig. 8).
- Care was taken to complete the process in as short a time as possible to prevent chilling and loss of brood.
- Additional manipulations – segregating wax moth-infested combs, giving fresh comb-foundation sheets, wiping off honey spilled in the recess and reducing the size of the entrance – were also done as required.
- Thick sugar syrup (1 kg of sugar dissolved in 1 litre of water) was fed to the bees to help them recover from the shock (Fig. 9).

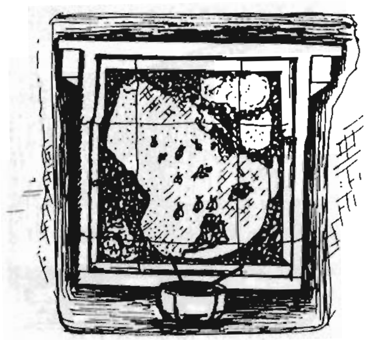

Fig. 9. Sugar feeding in modernized wall hive

Fig. 10. Cleaning the modernized wall hive

- The wooden cover was replaced and the wall hive was closed by plastering with mud.

Results and Discussion

A total of 1500 wall hives were manipulated. Of these 700 were already colonised with bees, 600 were unoccupied and 100 were newly constructed according to standard dimensions of *A. cerana* hives. It was observed that the bees in the colonised wall hives adapted well to their modernised home and did not desert under pressure of the process. The technology found quick acceptance among the farming community as it involves nominal expenditure and the farmer could make the requisite modifications himself. The modernised wall hive provided the following benefits.

- The modernisation process caused little burden to the beekeepers' pocket. The entire improved structure involved an expenditure of US $1–2 (Rs 50–60) for wooden frames, nails, wire and labour per wall hive.
- It offered a situation for scientifically managing a honeybee colony.
- The movable frames could be taken out and the colony observed for health, bee strength and food storage.
- The hive interior could be cleaned to keep off wax moth, scavengers and robbers (Fig. 10).
- In time of dearth of forage and during winter the colony could be managed by providing sugar feeding.
- Modernisation facilitated checking of the queen, replacement of non-prolific queen, presence of additional queen cells, and checking for swarming and absconding conditions.
- It also facilitated provision of additional combs and comb-foundation sheets for increasing space during strength build-up and honey flow.
- It provided for division, unison and manipulation of colonies.
- Honey harvesting became easy and economic. Segregation of honeycombs and efficient extraction of hygienic honey without damaging brood and bees was easily achieved. The frames with sealed honey were taken from the wall hive. The cappings were removed with a hot sharp knife. The frames were then put in a honey extractor and reused after harvesting honey.
- Management for pollination was made easy. When the wall hive was in the vicinity of the crop to be pollinated, the colony was moved away in an improvised box and returned when the crop reached 15–20% blossoming. This management checked bees from exploring flora other than the desired crop and pollination was more complete. When

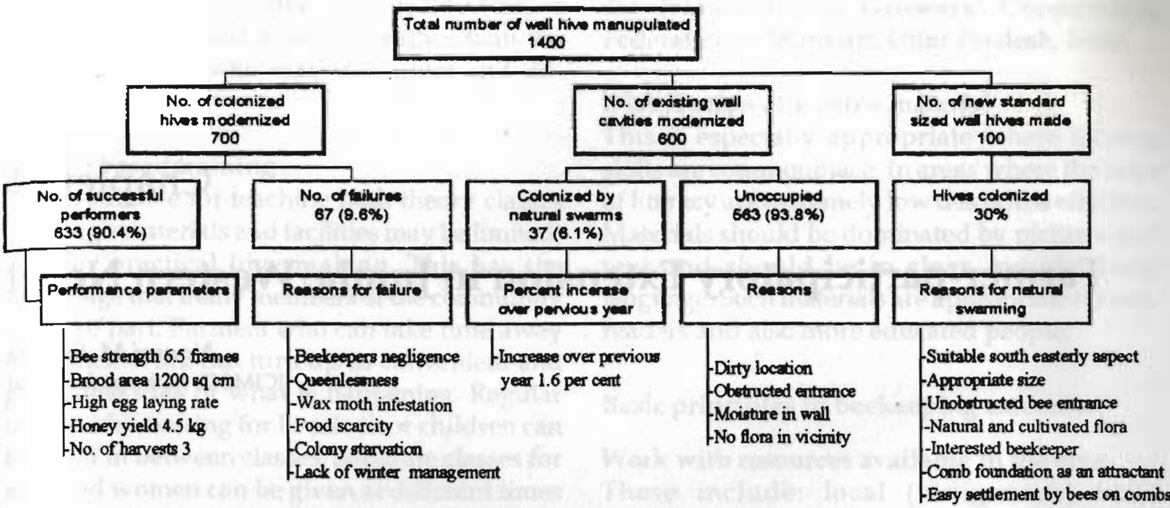

Fig. 11. Success story of modernized wall hives

the crop to be pollinated was located at a distance, the colony was transferred to the blossoming crop in improvised package boxes that could hold the comb frames.

The success story of the installation of this novel beekeeping technology in the mid-hills of Himachal Pradesh, India, is depicted in Fig. 11.

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Chapter 61

Farmer-participatory Extension in Jumla, Western Nepal

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Extension work is crucial to the successful and appropriate promotion of beekeeping in rural areas. Hence it is necessary that the Asian Apicultural Association (AAA) formulate guidelines about extension and how it may be executed appropriately in the Asian context. The issues raised in this paper have been compiled on the basis of the author's experience in beekeeping development in the remote mountain area of Jumla, Nepal. Whilst many of these issues will be general throughout Asia, others may relate only to the remote, traditional and resource-poor situation of this case study. The aim of this paper is to formulate a model on the basis of this case study.

The reasons for choosing Jumla as the site for methodological research are as follows.

- The *Apis cerana* bees in Jumla are larger and probably higher honey-yielding than other Himalayan strains.
- A strong tradition of beekeeping exists in Jumla.
- Beekeeping has a comparative advantage in the high altitudes of Jumla where rice cannot be grown.
- Honey and wax are traditionally important components of the society's (barter) economy.
- Forage resources for bees are good.
- The remoteness of Jumla and lack of land for cultivation leads to extreme poverty. Beekeeping as a means of income and improved nutrition needs to be tested as an option.

A working definition of extension in beekeeping could be as follows: transfer of beekeeping (technical) skills and knowledge, usually from beekeeping 'specialists' to 'learners' through visits to people in their own communities/homes. Learners are often men and women farmers but may also be potential new extension workers. Specialists may be bee scientists, extension workers and/or farmers.

Methods of Beekeeping Extension

Several methods used in combination make for a good extension programme. These are as follows:

Classroom based training

This is suitable for teaching beekeeping theory and bee biology, and can be held in local or district agricultural training centres. This method suffers from the fact that selection of farmers participating in training is difficult and can be a source of conflict within village communities.

Often the most vocal rather than the most active farmers are selected to attend, rather than the most interested who may stay quiet and unnoticed.

Village based training

This is suitable for teaching both theory classes (although materials and facilities may be limited) and for practical hive making. This has the advantage that many members of the community can take part. Farmers who can take time away from their work can turn up as convenient and gain some idea of what is happening. Regular tasks such as caring for livestock or children can be fitted in between classes. Separate classes for men and women can be given at different times of day depending on participants' daily routines. Also, trainers can gain better understanding of the village situation and what may be appropriate answers there.

Practical classes and/or demonstrations

These are useful especially in demonstration apiaries and with lead farmers. It is essential for beekeeping manipulations and colony management training.

Extension visits

Including advisory services, and on-the-spot practical problem-solving with demonstrations. These are essential to follow-up training, to investigate what problems are being experienced and to explore potential answers.

Farmer field trips

Usually these should be to lead farmers in the same area/district, but may also be beneficial between different areas, especially taking farmers from less developed areas into more developed ones. Where funding is available and there is similarity of language and beekeeping conditions, exchange visits of farmers (even between neighouring countries) may also be worthwhile. Such an exchange will be taking place between the Jumla farmers of the Himalayan Beekeepers' Association and those of the National Tree Growers' Cooperative Federation in Munsiari, Uttar Pradesh, India.

Distribution of written material

This is especially appropriate where literacy skills are commonplace. In areas where the rates of literacy are extremely low this is less effective. Materials should be dominated by pictures and text and should be in clear, simple, local language. Such materials are appropriate for new readers and also more educated people.

Basic principles in beekeeping extension

Work with resources available in the area

These include: local (indigenous) bees; traditional technology and knowledge; locally available materials; local people.

Why use indigenous honeybees? Local indigenous honeybees are the most suitable for use in almost all situations in beekeeping development. This is because imported honeybees spread exotic diseases that cannot be controlled. They are often not ecologically suited to their new environment and are expensive to buy. They require higher inputs than more wild-natured local bees. Inappropriate introductions of exotic bees, which are usually not screened for bee diseases, can have disastrous results. Jumla provides us with an example. In the early 1990s, *Apis mellifera* was introduced to Jumla by a beekeeping technician employed by an NGO to improve beekeeping in the district through training and extension. By 1994, these *A. mellifera* were seen to be highly infested with European Foul Brood (EFB) (Pecchacker, pers. comm.). By 1995, when I started working in Jumla, EFB in combination with the older Thai Sac Brood Virus Disease (TSBV) was wiping out the local bee population. In 1996, most colonies in the project's apiary at the Karnali Technical School died and yet more died in village communities. Samples taken in 1996 showed confirmed levels of EFB. In 1997, TSBV was hardly found at all, but EFB continued to destroy colonies throughout the district and is still affecting colonies now.

Although we cannot go back in time and test what would have happened if *A. mellifera* had not been introduced, there is strong evidence to suggest that the disease entered Jumla with the European bee. EFB is non-indigenous to *A. cerana* and is unlikely to have spread from it.

Why use traditional (indigenous) knowledge and technology? Local traditional beekeepers know their own bees and beekeeping conditions better than most outsider 'specialists', especially more than foreigners who do not speak the local language. However apparently 'primitive' local techniques in beekeeping may appear, extensionists must realise that these methods have developed over time for a reason and cannot be simply dismissed and replaced with 'modern' methods. Change takes time, and the more traditional and less developed the society, the longer it takes. Illiterate people with no experience outside their own district are slow to accept new ideas and usually need to be convinced that something will work before accepting it. Also, just as plant genetic resources need to be conserved for potential application in the future, beekeeping indigenous knowledge needs to be accessed and documented in order to avoid the loss of valuable techniques that could be applied in the future or in other problem areas.

Accessing of indigenous knowledge. Time and effort is needed to access indigenous knowledge but this is also a means of building trust between the farmer and the extensionist. The best means of access is by looking, learning and joining in with traditional practices and by informal interviews about these practices whilst staying with farmers in their homes or gathering in small groups. Such activities are particularly easy if 'participant-observation' methodology is adopted. This means adoption of local customs, dress and behaviours by the outsider extension worker. Participatory rural appraisal (PRA), and participatory learning and action (PLA) can also be used as a means of accessing knowledge, by making charts and calendars about traditional beekeeping activities and how they relate to other agricultural practices, income sources and male/female workloads.

Adapting and using indigenous knowledge. Having studied the traditional hives in use and those preferred by farmers, appropriate beehives are often best produced by adapting the local model. This usually involves the conversion from fixed to moveable combs. In areas where there is availability of planed wood, nails, wire and so on, it may be appropriate to use 'modern' frame hives, but in many cases in remote parts of the world, top-bar hives are more practicable.

Improvement of traditional techniques through use of appropriate technology. Appropriate technology means technology that is suited to local working conditions and resources available. This will vary from place to place. For example, in Jumla, the Jumla log top-bar hive is most appropriate, whereas in lower-altitude, more-heavily-deforested areas, such hives are inappropriate. Here, mud, brick or straw hives may be appropriate instead.

Allow recipients of extension to participate in the process of developing beekeeping

Participatory planning. Initially, this means that the extensionist should ask farmers what they feel and what they want while using PRA, PLA or participant-observation methods. Once it is established that farmers are happy to participate in a beekeeping programme, a process of farmer-participatory planning should be embarked upon to decide how the programme should be organized. If appropriate technology is required, then action-research involving farmers should be embarked upon to develop it. Also, indigenous knowledge from the area should be accessed and documented for incorporation with new methods that the extension programme brings in.

Who should be the target of extension? Selection of farmer-recipients of beekeeping extension is a challenge. General guidelines may include targeting those who have traditional experience in beekeeping, those who are particularly interested and already active in traditional methods, and those for whom beekeeping holds a comparative advantage economically. Because of the advantages of beekeeping in terms of being low-input, not requiring land and not being time-consuming, beekeeping may also be appropriate for disadvantaged groups such as landless people (e.g., low castes in Jumla) and women.

Group work. Having decided to work with a particular target category, beekeeper groups need to be formed in order to organize activities, and share experience and ideas. Groups should be in 'pocket areas' that can become centres of beekeeping expertise and resources for surrounding areas. These groups benefit from belonging to district-level beekeepers' associations. Groups need to feel that they own the programme in their community and that the outputs are for their benefit, otherwise the extension effort will fail. Allowing beekeeping groups to make decisions and take responsibility is crucial to effective group functioning and for motivation.

Farmer-to-farmer. Having formed groups and given training to farmers, the most skilled and interested should be used to teach other farmers in their area. Farmers share local dialect and understanding and are comfortable with the village situation in which they have to conduct extension activities. Because fellow farmers understand each other's problems, there is likely to more trust between the 'extensionist' and 'learner'. Really effective farmer-to-farmer approaches are perhaps the only sustainable answer to building long-term extension programmes in beekeeping in rural areas.

Marketing activities. Co-operatives that are part of, or the same as, an area's beekeepers' associations are a good means of co-ordinating marketing activities. Facilitation of marketing can be crucial if significant income is to be generated from beekeeping. Processing of hive products and manufacture of value-added products also needs organizing in order to increase potential benefits to the local beekeepers or beekeepers' association.

Cultural Sensitivity

Several rules of thumb apply to 'outsiders' who act as extension workers both foreigners and those from outside the target area. These are summarised as follows.

- Respect local traditions and taboos.
- Dress appropriately – this means that modest, non-extravagant clothes that do not emphasise the differences (e.g., in wealth and educational status) between extensionist and farmer are essential. Clothes that are viewed as highly fashionable or that are unfamiliar to the local community may be a means of alienating farmers.
- Learn the local language or dialect whenever possible. If time does not allow, make an effort to learn some greetings and basic small talk.
- Pay respect to local experts rather than assuming that you know more than them.
- Promote the concept of mutual learning. Listen to them and ask them about what they know as well as sharing your ideas/ knowledge.
- Ask permission before opening or touching hives, before taking photographs and so on.
- Share time, space and perhaps also food with farmers. Generation of a good relationship between the extensionist and farmer is crucial to extension success.
- Join in with what is happening. Relax and be yourself with the farmers.

Sustainability

Issues of sustainability must be addressed and re-addressed throughout the extension programme. All too often, whilst outside funding is available, it is tempting to solve problems through spending money, but if such extravagance cannot be sustained later then such expenditure should be considered carefully. Extensionists need to ask themselves the following.

- Who takes over after the programme?

- Where will materials and resources come from later?
- Are there any environmental issues at stake (e.g., forest use)?
- Do farmers feel that they own the programme?

Outputs of Extension

Potential outputs of extension can be listed as follows.

- Knowledge transfer and sharing/generation of new knowledge.
- Income generation from beekeeping.
- Livelihood improvement from beekeeping. This is particularly important in remote areas where honey is a luxury to be kept for festivals and religious ceremonies, and where it can be used as a medicine. Beeswax products can also have medicinal and other social and environmental benefits.
- Organization of farmers.
- Motivation.
- Empowerment of farmers (and in the case of farmer-to-farmer approach, of extensionists too).
- Development of new appropriate technologies (through adaptation of indigenous knowledge).

Examples of Potential Applications of PRA Tools

Questions about how, whether, why and how to operate extension programmes and the tools that can be used to address them are listed in the table below.

When to meet farmers, hold training and other activities?	Seasonal calendar Daily routine
Who are the beekeepers, where do they live, where are their hives, their hive-making and floral resources, and crops needing pollination?	Social map Resource map
What is the relative economic importance of beekeeping?	Preference ranking of beekeeping versus other activities and matrix analysis of the results
What local beekeeping practices are in use and when are they important?	Seasonal calendar Flow charts
What are the main forage species? How are honey yields, colony numbers and other parameters changing?	Forage calendar Time lines or trends
Are there gender issues to be considered?	Separate PRA activities for women and men, and comparison of views

The Beekeeping Extension Programme in Jumla

The extension programme described here developed from an action-research project in appropriate beehive design and indigenous knowledge. In 1994, experts from Austria introduced a straw hive to the Karnali Technical School (KTS) and Jumla farmers. A year later in 1995, when a follow-up visit was made to the district, it was found that the straw hives were generally not being accepted and that the few in use suffered from problems in management. Hence, hive-testing was begun in July 1995, establishing experimental hives of five designs at KTS. The hives under test include the traditional cylindrical horizontal log hive; a log top-bar hive modified from the traditional hive; a square cross-section log top-bar hive or 'Jumla' hive; the Austrian straw hive (with frames or top bars); and the wooden Newton hive with frames.

Methods and results of these experiments and results of indigenous knowledge research are given in other papers in these proceedings.

In April/May 1996, examples of the hives under test were also distributed to four farmers' groups of different castes in different eco-zones of the district to test their acceptability to farmers and workability in village beekeeping conditions. The groups were given training in hive making and in beekeeping theory and practice, with the intention that these farmers would then be able to teach beekeeping in their neighbouring villages. It was planned that the farmers would divide colonies from those given by the programme and that a proportion of the resulting new colonies could be used to start new beekeeping groups in the area.

At the same time as the beekeeping groups were established (spring 1996), brood diseases including Thai Sac Brood Virus and European Foul Brood, reached epidemic proportions causing the loss of most colonies in the KTS apiary, village demonstration apiaries and farmers own traditional hives. Beekeepers' morale and enthusiasm waned and the programme looked doomed to fail. The Jumla Beekeeping Project staff investigated medicines for the disease and management techniques to control it and in May 1997, a farmer-trainers' training in 'Disease management and extension' was held. At this training, lead farmers from the four original beekeepers' groups were chosen and were given detailed training in how to recognise bee brood diseases and in disease management, as well as basic beekeeping and extension methods.

From this training the best trainers were selected and sent into the field to conduct a questionnaire survey about bee disease and traditional beekeeping methods. They conducted PRA exercises and gave classes on bee disease, beeswax processing including candle- and medicinal cream-making and promoted the use of top-bar hives, particularly the 'Jumla' hive. The results of the questionnaire survey are presented below and also in papers on beeswax processing and indigenous knowledge presented in these proceedings.

The employment of the farmer-trainers by the Jumla Beekeeping Project was empowering and motivating for farmers, as well as a most effective mechanism for reaching out to beekeepers throughout the district. Local farmer-trainers have a number of advantages compared to government extension workers or development agency workers from outside the area. They speak the same dialect as farmers (the Jumli language is quite distinct from Nepali of the plains and Kathmandu valley). They are not particularly uncomfortable in field conditions which outsiders find difficult, and there is less suspicion and potential for bad feelings generated by wealth, education and cultural imbalances.

Within a few months, they were organizing the rebuilding of the previously inactive district beekeepers' association into a new farmer-led NGO called the Himalayan Beekeepers' Association (or HIBA), Jumla. This organization, now registered as an NGO, is actively forming new beekeepers' groups, providing training in hive-making and beekeeping, and attempting to assist with disease control. Since the training of farmer-trainers in May 1997, village-based training in beekeeping and/or hive making have been conducted. Many new village beekeepers' groups have been formed and farmers throughout the district have received extension visits concerning harvesting and quality of honey, beeswax processing and marketing, beehive sanitation and disease control, and other aspects of beekeeping.

From March 1998, with funding assistance from the Jumla Beekeeping Project, HIBA is establishing Beekeeping Information Centres in villages of seven areas of the district, focusing on the remoter and higher altitudes where beekeeping has a comparative advantage over cultivation and also a strong traditional basis. Each of these centres will be staffed by one full-time male farmer-trainer from March to September 1998. He will establish Jumla hives and traditional hives at the centre and also distribute hives to the most active farmers' group. Two demonstration apiaries will be established in each area that will be used for training and demonstration purposes and as potential banks of queens or nucleus colonies.

Although currently, many of its activities are sponsored by the Jumla Beekeeping Project, the intention is that HIBA will develop over the coming years into a strong farmer-led self-financing organization. It is hoped that the co-operative marketing of honey, beeswax and value-added products, in collaboration with another local NGO called Surya Social Service Society, will enable the financing of a minimal training and extension service in beekeeping. However, if HIBA succeeds in the coming years to create village centres of beekeeping expertise it might prove unnecessary to operate intensive extension programmes of the kind described above. Hopefully, by working together with agricultural development office extension workers in the future a sustainable and effective service in beekeeping can be established.

Promoting beekeeping amongst women is a huge challenge in Jumla. Women are interested in learning about beekeeping but a gender imbalance in workload means that women have little free time to either learn or practice beekeeping. They are busy from morning to night in household chores, child-care and agricultural work, and hence it is difficult for them to make time for beekeeping training and for extension workers to meet them. The biggest barrier to their participation is the inability of women to speak out or even enter a group if men are present coupled with their lack of education. If someone comes to the village, it is assumed by all that they will want to speak to the men since they are more often the educated ones and the spokesperson for the family. In order to reach out to women, women farmer-trainers have also been trained. Five women are employed in making extension visits and running training to encourage women's participation. Separate classes and discussions are held with women. For women extension workers, however, it is not so easy to enter a village and walk around staying in different places without causing gossip. In Jumla culture, it is generally unacceptable for a woman to travel about especially in the company of a man who is not her father, brother or husband. Hence, future programmes intend to use the women trainers more to give five- to seven-day training in one place rather than in occasional extension visits. These women will also visit the beekeeping information centres and make contact with women in the field, but will not go on long field trips that require staying in a different place each day. It is hoped that as the bee population becomes resistant to disease colonies will become available for women's groups.

Chapter 62

Role of Micro-enterprises in Providing Inputs for Sustainable Beekeeping Development

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The objective of the study is to create awareness among those engaged in planning and implementing beekeeping projects regarding the transfer of beekeeping technology and know-how, and the integration of local micro-enterprises (the so-called 'informal sector') for production of beekeeping inputs, in order to ensure sustainability.

Methods

API-Promo/GTZ analysed 35 beekeeping projects, beekeeping activities and beekeeping components of integrated projects carried out by aid organisations during the past 20 years in countries of Africa, Latin America and Asia. For this purpose, project documents and literature were examined, people interviewed and projects visited.

Findings

About 75 per cent of the evaluated projects had a little or no impact on the local beekeeping industry (35 per cent failed totally). Most projects worked well as long as experts or volunteers were in place. In most cases this changed immediately after their departure or when the project was phased out. Among the many reasons identified for the failure of projects, the following are of special interest.

- Sector policies at the national level: In most countries, governments show little interest in supporting the beekeeping industry.
- Feasibility studies: Traditional beekeeping systems, their importance in the rural economy, and their social value were not profoundly analysed.
- Project planning: Bees and beekeeping techniques were the main focal points instead of the people and their potentials, capability and interest for beekeeping.
- Economic viability: The profit margins people might earn through beekeeping were highly overestimated. Natural resources and absorbing capacity of markets were not properly analysed.
- Time horizons of projects and back-stopping: time for implementation was too short, and monitoring and follow-up was not done properly.
- Professionality of supporting agencies: In most cases, extensionists were not practical

beekeepers, but theoreticians and modernists. This resulted in low confidence among rural people and ineffective extension services.

- Technology and know-how transfer: Most projects assumed that existing traditional systems were not predisposed to developing the industry, and concentrated mainly on changing them in a short time and with big steps. The level of applied appropriate technology was extremely low.
- Factor costs: Inputs used to develop the industry were expensive, non-appropriate and not available at the village level.

The last two points are important, and are illustrated by the following example related to problems linked with the introduction of the top-bar hive. Most conceptionalists of projects are convinced that the top-bar hive solves many problems related to traditional beekeeping and honey-hunting for all groups and individuals in all developing countries. For them, the top-bar hive is simple in design (low technology) and handling, and has almost all the advantages necessary for good management and sustainable beekeeping. The costs are, in their eyes, low. As a consequence, most projects promote top-bar hive technology. However, the reality is different and often overlooked. In most cases, honey-hunters and traditional beekeepers

- are not interested in intensive management of hives
- are not capable of handling the top-bar hive
- want to earn money from bees and honey with a minimum of work and risk
- avoid spending money on inputs of any kind preferring to make their own hives or barter for them
- are individualists and risk minimisers who do not like to depend on others and do not like to expose their assets to strangers
- are afraid of theft and vandalism of hives that are not hung up in trees or watched carefully
- know that bees can become aggressive and dangerous
- depend very much on social acceptance for what they do including beekeeping.

When top-bar-hive projects started, in most cases it was soon recognised that fabrication of top-bar hives could only be done by well-equipped carpenters. To profit from cost reduction when producing large numbers of hives, manufacturing was given to large companies normally located in towns. To provide beekeepers with the necessary inputs, a 'hive tourism' and credit system had to be started. As most farmers have no means of buying and transporting hives, most were taken by project vehicles from the manufacturer to the beekeeper. When projects were phased out, in many cases credits were not repaid, revolving funds stopped working, new hives were not bought and broken ones not repaired.

Conclusion

To avoid project failure due to high-input costs and non-appropriate technologies and to guarantee a high level of sustainability the following should be considered.

- Traditional beekeeping systems and the technical skills of the people should be studied more profoundly before a project starts.
- Resource persons, familiar with rural socio-economic conditions and development, should be consulted.
- Beekeepers, honey-hunters and newcomers to beekeeping should receive different training and equipment according to their problems, capabilities and resources.
- As soon as possible, local people should be trained as trainers and project conductors, the project must become their own project. People from implementation agencies should only act in the background as facilitators.
- Integration of the rural micro-industries in producing equipment that cannot be made by beekeepers should be emphasised. For

this, training of carpenters, blacksmiths, tailors, pottery makers, etc. should be part of the project.

- Simple and easy-to-handle technologies that require minimum maintainance should dominate.
- Locally available materials, and modern materials liked by people as well as by bees (for example, cement, plastic, metal, iron sheets, etc.), and materials suitable for storing honey (recycled bottles, jars, plastic bags, etc.) should be integrated if input costs allow.
- Hives must be installed where bee pastures are best and where bees like to live to guarantee high occupation rate, high yields and a minimum of absconding.
- Hive products (comb honey, bottled honey, wax, pollen, etc.) should be used to satisfy the local market first before other markets are addressed.

If these points are respected before and during project implementation, people will be mobilised to keep bees. It is important that people are successful from the start at owning bees, and producing and selling honey. If they are convinced that beekeeping fits them, they will become beekeepers, and the development of techniques, management methods and the integration of environmental aspects will follow automatically.

Chapter 63

IBRA's Role in Educating People about Beekeeping

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For thousands of years humans have hunted for honey. They have robbed wild bees and in doing so have often destroyed the creatures that brought the golden harvest. Sadly, this is not all in the past; it still goes on today. What is more wild bees often have their habitats destroyed by farming methods and suffer the ultimate destruction of being smoked out or killed for the short-term gain of one honey collection. A remedy for this situation lies in education. It is obvious that honey-hunters need to learn to be beekeepers. Farmers should also understand the necessity of maintaining a balance in the environment. Much can be achieved if children are taught about the value of bees and the need to maintain biodiversity. It is worth remembering that today's children are the next generation of beekeepers. Development is necessary but keeping an ecological balance is also essential. There is an all too simplistic equation of 'bees equal honey'. This has to be addressed through wider education on the themes of pollination and the value of other hive products. There are, it seems to me, three stages on the road to beekeeping. They are: to kill bees; to have bees; to keep bees.

To kill bees

This first stage just robs the bees of honey and takes the larval and pupal stages for food. Any bees that survive are doomed without food or a succeeding generation.

To have bees

It is a small but important step from the first stage to this stage where wild swarms are encouraged to settle in pots or bark hives. Combs are built directly on to the container so that honeycombs can be removed while brood remains. There is little understanding of the biology of bees and no management of the colony, but at least the bees survive.

To keep bees

This is true beekeeping. It only takes place when the person concerned has some understanding of bees, and can predict certain events and employ well-practised management techniques.

Beekeeping can be lucrative but it is important that the level of technology fits the local culture and knowledge. It should be achieved naturally and not by pressure. Small-scale beekeeping projects are sometimes started with moveable-frame hives. This means high investment for high potential return. However, without follow-up or input assistance full potentials are not realised. Schemes without instruction and education are doomed because advanced beekeeping equipment requires advanced beekeeping techniques. In essence, the technology should be appropriate. It can be simple and cheap, and generated locally. The main limiting factor is human: a lack of knowledge. This can be remedied by education and the sharing of information. Education materials offered should also be appropriate. The grading of material is essential: forward momentum comes step-by-step going from the known to the unknown.

It is not only beekeepers who require education. There are commercial possibilities arising from processing and marketing bee products, and from supplying equipment to the bee industry. People involved in these activities also need appropriate information. Bees aid plant pollination that results in better-quality seed set. Also reafforestation schemes could consider tree species that provide nectar, pollen and honeydew as beekeeping can be a profitable economic activity within the growing forest. Therefore, beekeeping can be useful in fruit-growing and agroforestry projects. Planners and administrators of these projects also need to have some bee-awareness.

The honeybee is probably the world's most-studied insect, and the result of much of this study can be found in the IBRA Library. Although there are a number of excellent projects run by aid agencies and local organisations that are aware of the advantages of beekeeping, they are often in isolation. Their effectiveness could be maximised through better dissemination of information and co-ordination of training. The IBRA office is constantly being approached by individuals, co-operatives, institutions and agencies for help. It would seem that IBRA could play a prime role in an education and information dissemination programme. However, sometimes it is necessary for this input to come from a higher authority. IBRA would like to establish a network for support, co-ordination and information exchange at an inter-governmental level. IBRA is in a unique position because for almost 50 years it has succeeded in establishing credentials of independent integrity that have gained world-wide respect. It could be an honest broker – free from ties to any particular interest – in the development of the beekeeping industry from small local projects to national programmes. IBRA could be not only a resource but also a catalyst for promoting sustainable economic growth and for maintaining biodiveristy in the world through a knowledge of beekeeping.

Chapter 64

Role of ICIMOD in the Promotion and Development of *Apis cerana* Beekeeping

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The primary objectives of the International Centre for Integrated Mountain Development (ICIMOD) are to help promote the development of an economically and environmentally sound mountain ecosystem and to improve the living standards of mountain populations in the Hindu Kush-Himalayan region. The Mountain Farming System Division implements the project entitled 'Promotion and development of beekeeping through the preservation of indigenous *Apis cerana*', the Asian hive bee.

Beekeeping Activities with *Apis cerana*

Apiculture is an important resource for mountain farming systems and offers specific advantages for developing sustainable agriculture. Beekeeping with the Asian hive bee, *Apis cerana*, is a traditional occupation in Nepal and parts of the region as an income-generating activity for small and marginal farmers, landless labourers, and other poorer people living at or below subsistence level. In addition, bees play an important role in the pollination of agricultural and horticultural crops and many indigenous plant species, thereby maintaining biological diversity. Nepal is rich in bee flora and there are at least four species of honeybee that might have potential for development.

With the support of the Ford Foundation, a survey made in 1988–89 to establish the status of *A. cerana* showed that the population was declining. In order to save this species from possible extinction, ICIMOD is promoting beekeeping with it. A USAID-funded programme from mid-1991 to mid-1993 on genetic diversity of *A. cerana* found the following. There was a decline in beekeeping in the Hindu Kush-Himalayan region. Computer-assisted multivariate morphometric and mitochondrial-DNA analysis revealed that *A. cerana* can be divided into three biotypes or geographical populations: *A. cerana cerana*, *A. cerana himalaya* and *A. cerana indica*. Research on pollination ecology of vegetable-seed production suggested that use of *A. cerana* as a pollinator increased yield by 40–50 % in cross-pollinated crops such as cauliflower, cabbage, radish and by 20% in self-pollinated crops such as Indian mustard and lettuce. Also behaviour and apiary management research increased productivity and efficiency of *A. cerana* bees for honey production and pollination activities.

Promotion and Development of Beekeeping through the Preservation of *Apis cerana*

The project entitled 'Promotion and development of beekeeping through the preservation of indigenous *Apis cerana*' was implemented by ICIMOD in mid-1993. The project is funded by the chancellery of Austria. ICIMOD is carrying out this project with the co-operation of Austroprojekt, Vienna, Austria. The first phase of the project from mid-1993 to 1995 focused mainly on beekeeping research. The second phase, from 1996 to 1998, focuses largely on training and extension for beekeepers and also includes beehive testing, awareness, and pollination components in four locations in Nepal namely Bhaktapur, Godawari, Jumla and Dadeldhura. The partner institutions are local NGOs. The clients are mainly farmers groups. International/intellectual support is provided by Austroprojekt Austria, Asian Apicultural Association and Apimondia.

Beekeeping Research

This component consists of research into honey-plant resources of the Hindu Kush-Himalayan region, crop pollination studies, and testing beehive types. A survey and collection of honey plants from different agro-ecological zones of the Hindu Kush-Himalayan region, preparation of pollen slides, establishment of a reference databank on pollen, and preparation of an inventory of important honey plants in the region has been carried out. The effects of *A. cerana* and *A. mellifera* on the pollination of different crops has been studied and a manual prepared. Suitable hive types for *A. cerana* for different ecological zones are being tested in Jumla (western high-hill conditions) and Godawari apiary (Kathmandu valley conditions).

A two-year study on Thai Sac Brood Virus Disease (TSBVD) of *A. cerana* in Nepal has been made in three locations: Jumla (western high hills), Kathmandu valley and surroundings (central region) and Bhojpur (eastern mid-hills). The study reveals the severity of the disease in Nepal and further confirms the decline in the population of *A. cerana*.

Beekeeping Training and Extension

Training and extension are limited to Nepal. Major focus is on training of trainers and farmers from three districts representing mid-hill, high hill and valley conditions. Support is given to farmers/beekeepers groups and also NGOs, local institutions and individual beekeepers. Training is usually provided to a group and is as practical as possible. The poor and women farmers are encouraged to attend.

The training programme covers aspects such as improved beekeeping methods, seasonal management of colonies, bee pests and diseases, movable-frame hive management, low-cost frame hives and other tools and equipment, bee pollination management, queen-rearing techniques, colony care, etc. In addition, training is also provided on the use of hive products, e.g., honey harvesting and bottling, processing of beeswax, and making of candles, hand creams, etc. Such market support encourages farmers to work with and promote *A. cerana* beekeeping in their area.

Training and extension activities are carried out with the co-operation of local NGOs. With their staff now trained, it is hoped that beekeeping will continue after the project period. As beekeeping with *A. cerana* is traditional in Nepal, the training and extension have been useful for improving techniques commonly used at household level. There has been a great demand for the support provided by the ICIMOD Beekeeping Project and there is potential for further development in Nepal and the Hindu Kush-Himalayan region with the support of international institutions such as ICIMOD and Austroprojekt, Austria.

Summary of ICIMOD Activities Concerning the Promotion and Development of *Apis cerana* Beekeeping (1990 to date)

Books

- Beekeeping in Integrated Mountain Development: Economic and Scientific Perspectives.
- Honeybees in Mountain Agriculture.
- Himalayan Honeybee *Apis cerana* as a Pollinator of Vegetable-Seed Production: An Awareness Handbook
- Bee Flora of Hindu Kush-Himalayas: Inventory and Management.
- Dictionary of Beekeeping Terms: English-Hindi-Chinese.

Discussion papers

- Managed Crop Pollination: The Missing Dimension of Mountain Agricultural Productivity.
- Crop Pollination by Farmers: Case Studies from India and China. (In progress.)

Manuals

- Pollination Management of Mountain Crops through Beekeeping: Trainers' Resource Book.
- Beekeeping Training Manual. (In progress.)

Reports (internal)

- Honey in Nepal: A Market Study.
- Study on Thai Sac Brood Virus Disease in Nepal.
- Annual Reports on *Apis cerana* Beekeeping in Bhaktapur, KNSN 1996, 1997.
- Annual Reports on *Apis cerana* Beekeeping in Dadeldhura, RUWDUC 1996,1997.
- Annual Reports on *Apis cerana* Beekeeping in Jumla, Jumla Program 1996, 1997.
- Six-monthly and Annual Project Progress Reports (July 1993 to December 1998).

International conferences/workshops

- International Expert Meeting on (*Apis cerana*) Beekeeping Development in the Hindu Kush-Himalayan Region, Kathmandu, Nepal (21-23 June 1989).
- Fourth AAA International Conference, Kathmandu, Nepal (25-27 March 1998).
- International Beekeeping Workshop on Beekeeping Extension with *Apis cerana* (23-24 March, 1998) .
- International Beekeeping Workshop on Thai Sac Brood Virus Disease of *Apis cerana* and Varroa Mites of Bees (23-24 March, 1998).

Proceedings

- Proceeding of International Expert Meeting.
- Proceedings of Fourth AAA International Conference and International Workshops (In Progress).

Papers, posters, exhibitions, videos

Around 50 papers have been published by ICIMOD alone or together with others. These are for planners, development workers, scientists, field workers and farmers. Subjects cover a wide range of issues such as genetic diversity, pollination, honey plant resources, bee behaviour, beehives, beekeeping extension and beekeeping development. ICIMOD has also participated in two poster sessions and two exhibitions at the international level and has prepared two videos.

Chapter 65

Beekeeping: Self-employment Opportunity for Mountain Women

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Woman plays a pivotal role in mountain farming communities although her status is the lowest on the socio-economic ladder. Her role in the society is not of a bread-winner although she shares the burden of earning through indigenous farm activities while performing her principal role of bearing children and looking after the family. Her physical and socio-familial needs require avenues of income-generation that do not interfere with her primary obligations but supplement the family purse. Beekeeping has the essentials of such an occupation. In mountain communities where horticulture/agriculture is the mainstay, it is all the more beneficial to involve women in beekeeping for integrated socio-economic development (Verma, 1990; Kumar, 1993).

Area of Study

Rural women who participated in horticulture training programmes at the University were the subjects of this study. Interactions with women trainees brought to light the following factors limiting women's involvement in beekeeping.

- Beekeeping and honey-hunting were regarded as a men-only activity.
- Fear of stings.
- Lack of knowledge about simple and scientific beekeeping methods.
- Lack of awareness of the benefits of integrating beekeeping into mountain farming systems.
- Many duties at home and in the field.
- Ignorance of the scale of operation.
- Lack of funds.
- No interest or time.

This attitude and the problems of mountain women were analysed. The women were made aware of the cultural, economic and ecological aspects of beekeeping. Basic information with respect to methods of beekeeping and its income potential was given to them.

Scope and Prospects

Beekeeping can fit into the busy routines of all categories of women: rural/urban, educated/illiterate, white-collar worker/farm women/

housewife, rich/poor. It opens an important avenue of income generation for the following reasons.

- Beekeeping provides a self-employment opportunity close to home. Honeybees can be easily kept a few metres from home in kitchen gardens, backyards and even house tops, balconies and verandas. A busy woman or a woman restricted by socio-cultural norms of the community does not have to go far from home or even leave her doorstep.
- It entails little work; even the most-worked women can manage five honeybee colonies. Bees are clean in their habits and do not add extra cleaning hours to a woman's daily routine. They even collect their own food. Simply check them once or twice a fortnight for stores and diseases, and they will work efficiently without you.
- Horticulture is the principal occupation of a mountain woman. Beekeeping can broaden her income avenues. Besides obtaining bee products such as honey and beeswax, she can use bee colonies for pollination of crops. Bees do not compete with agriculture/horticulture for resources but augment it. Bee pollination improves the quality as well as quantity of fruits, vegetables, flowers and seeds giving increased return for a small investment.
- It gives both an economic and moral boost. It raises a woman's status and esteem in the society and improves her general quality of life.
- If business is her interest, bees have many avenues for a woman to exploit monetary gains.
- Beekeeping helps to diversify the food base and provides a nutritious high-value food to what can be otherwise under/malnourished hill-dwelling children where beekeepers are mothers.
- Beekeeping provides a woman with out-of-door recreation that may be otherwise impossible amidst her family chores.
- Honeybees have lessons of good housekeeping, frugality and child-rearing hidden in the organisation of their commune that are well-matched to the psychological needs of a woman.
- If it is for the love of mother nature, the aesthetic value of beekeeping is unmatched in learning and enjoyment.

Diversification of Beekeeping

The honeybee industry has vast income potential for a mountain woman depending upon the extent of her involvement and the level of operation. If she plunges into it full time and on a large scale, she can extend her enterprise to other products such as beeswax, pollen, royal jelly, bee venom and package bees.

Marketing of Bee Products

Marketing of bee products is an art in itself. When woman is the producer of honey and she is also the principal consumer: she can devise a good advertisement for the regular addition of honey to the family menu. She can pass on to other women her experiences with the use of honey as a domestic remedy for numerous ailments of children and adults. Further, her artistic aptitude can go into packaging of bee products. Attractively displayed eye-catching posters can attract buyers to the doorstep. She does not have to exert much effort to find a market. Travellers who visit the hills in all seasons are always on the lookout for farm-fresh products and are easily attracted to orchard-fresh honey. Specific-source honeys such as litchi, citrus, rose and *Plectranthus* are even more attractive.

Women beekeepers can form co-operatives and societies. The co-operatives can facilitate the sale of honey, beeswax, pollen and royal jelly. This will ensure security of investment and provide a ready market throughout the year.

Low-cost Beekeeping

Scientists working in the University have developed low-cost, eco-friendly hives to help women living at or below subsistence level. Besides bringing beekeeping within the reach of marginal budgets, construction of these hives creates another employment opportunity for women. Three designs were developed (Kumar and Verma, 1996; Verma *et al.*, 1997).

Straw hive

This is made of rice straw or local grass tied to form thick sheets. The sheets are joined to form a brood chamber. A top cover forms a sloping roof to drain off water. Ten movable comb frames are provided.

Mud hive

This uses a mixture of clay and wheat husk to form the brood chamber. A thatched slopping roof is provided for a top cover. There are ten movable comb frames.

Orchard hive

This is made from waste stones or broken bricks plastered with mud. A flat piece of stone or slate forms the inner cover. Top cover is made from dry grass forming a slopping roof. The brood chamber has ten movable comb frames.

All three types of hives make use of material that are easily available in the farmer's field. They can be made at a nominal expense of US$ 1–2 and can be constructed by women themselves. Catching and hiving a swarm of the native honey bee, *Apis cerana*, in a low-cost hive can make initiation of beekeeping almost cost-free. The interest and benefits generated can be re-invested to increase the scale of operation.

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Chapter 66

Indigenous Knowledge of Beekeeping in Jumla, Western Nepal

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Apis cerana, the Asian hive bee, and its various sub-species, is threatened in Nepal and throughout Asia. Recent research (Verma, 1998) suggests that the western Nepal high-hill strain (subspecies *cerana*) found in the remote area of Jumla, is not only larger but also higher honey-yielding than other Himalayan strains. Conservation of this genetic resource is being tackled by promotion of beekeeping with it. The aim of this study has been to access indigenous knowledge from Jumla farmers in order to develop improvements to traditional beekeeping methods.

Methods

Data have been compiled with a participant-observation method by the first author, a questionnaire survey (May-July 1997) and by participatory rural appraisal (PRA) exercises.

Results

Traditional log hives and their characteristics

In Jumla, cylindrical and square cross-section hives are made of hollowed-out logs. The wall thickness is usually 5-6 cm. Preferred timber species are *Ilex dipyrena* (kharso), *Juglans regia* (okher) and *Pinus wallichii* (sallo). A good-quality hive will last for at least 25 years, so hive-making is not such a threat to the forest as it might at first seem, especially as greenwood is traditionally viewed as unsuitable.

The month of Magh (mid-January-mid-February) is an auspicious time for making hives, particularly Tuesdays in the 'Maga Jog' (a special time in astrological charts, as explained by local astrologers). The tree must be hollow or rotten on the inside with dead tops, but not fallen, since it may then be rotten on one side. The hive-maker taps a tree at the bottom with the blunt side of an axe and if a hollow sound is made it is felled. After felling, the tree is cut into hive-sized logs and the 'male' and 'female' sides of the tree are determined. These are important to traditional beekeepers because bees prefer to make their combs on 'male' wood. 'Male' wood, used for the top half of the hive, tends to be reddish and rich in resin, and is found on the side of the tree facing the sun (east/south). 'Female' wood is whiter and is found on the shady side (west/north). The rotten middle part of the tree is scraped out using an axe and 'basso', a local cutting/scraping tool. The bottom 'female' part is made thicker than the top part to form a strong, well-balanced base that will not rot quickly. A hole is positioned at the mid-point between the 'male' and 'female' wood. Once the log has been hollowed out completely, the hive body is finished. The two openings of the log are closed with circles of the right size cut out of thick hand-cut planks. These circles are plastered into the ends of the hive using cow dung or a cow dung/mud mixture.

When building square cross-section hives/wall hives, fallen trees are preferred to dead standing ones. The method of making is similar to that of the log hive, except that the log is cut into a square cross-section and then the hive is hollowed out from one side, making a box closed on three sides. The wall hive is placed in a wall when a house is being built with the open side inside the house. This (long) side is closed with a thick plank, plastered in as above.

Traditional methods of baiting hives to capture swarms

Of 302 farmers questioned, 256 farmers had a total of 2221 baited hives in the forest and in pastures on cliffs. Many had placed none, whereas the most active beekeepers had as many as 80. The mean number of baited hives per beekeeper was 8.7 hives (SE of mean 0.8), the mode zero and the median 4. When asked what they do before placing their hives in the forest, 259 farmers said that they rubbed their hives with 'gosard' (a hive-baiting substance), 20 said they used raw honey only, and 169 said that they cleaned their hives by scrubbing them inside with fresh walnut leaves screwed into a ball. Prior to rubbing the hive with walnut leaves, about 33% of farmers scorch their hives. Five farmers said that they only scorched their hives when they were new (to dry out the wood and remove rough edges) and a few said they only scorched when the hive was damp, mouldy or bad-smelling. Some claimed that scorching the hive discouraged bees from returning by spoiling the comb imprint.

The composition of 'gosard' varies from area to area: 291 farmers used honeycomb and 264 mixed it with old combs. Added ingredients to the basic mixture were mentioned as follows: 8 farmers added walnut leaves; 42 cow ghee (clarified butter); 10 wild rose flowers (*Rosa moschata*); 4 dhoopi (*Juniperus* spp.); 11 (roasted) de-husked rice; 4 (roasted) barley; 12 mustard oil; 4 cloves; and one or two farmers mentioned cumin. Old combs are often first dry-fried in a pan over a fire. Then the ingredients are ground in a large wooden mortar and mixed with honey. It is important to use entirely dry ingredients in order to avoid the 'gosard' going mouldy. It is best kept in 'booss-paa' (*Betula alnoides* bark), which is excellent as a preservative.

Traditionally, 'Magh ko Maga' and 'Shri Panchami' are auspicious days in January/February that are good for 'gosard'-making. Other good days are determined by consulting a Brahmin or local Dharmi ('shaman'). Much is made in April/May and applied to empty hives throughout the swarming season (May–July). Some continue applying it up to the second short (post-monsoon) swarming season in September. Some farmers store 'gosard' for a few years. If the smell deteriorates, it is re-made by adding fresh ingredients. If a beekeeper knows or suspects that a menstruating woman has touched the hives, a 'puja' (ritual worship) will be performed by sprinkling the hive with cow urine and reciting mantras (religious chants). It is believed that the mere touch of a menstruating women can cause bees to abscond or not reoccupy a hive.

Swarm management methods

Once drone activity is high, traditional beekeepers prepare themselves for swarm catching. Swarms are transferred to log hives by hand or using any container that is convenient for scooping up bees (e.g., small basket). If bees need to be moved from a place that is tricky for handling a local *Artemisia* species known as 'gwiepatti' or sometimes 'titepatti' (*Artemisia* *vulgaris*) is placed near the bees and rubbed to give off a strong scent. These aromatic plants are also used by some farmers to make a kind of bee veil when handling colonies that become defensive. When a colony has swarmed two or three times, the beekeeper may look for queen cells and destroy them to prevent further swarming that would weaken the colony too much.

Honey harvesting and processing methods

A smoker locally called 'kangreto' is made out of old cotton cloth tied into a roll. Some farmers use specific herbs to produce a good smoke that encourages bees to leave the combs without inducing too much disturbance. Once the bees abandon the combs, the combs are cut from the top using either a 'panyau' (rice-serving flat spoon) or a 'khukuri' (sharp knife). Bees are brushed off the combs using a small broom made of dried grasses usually dampened with water. Any bees stuck to the combs are brushed off with the small broom and cleaned on to a plate with a little water. Bees saturated with honey are cleaned in this water and are quickly washed on to a cloth and put into the sun to dry; very few bees die in the process.

Most beekeepers only cut honeycombs from one side of the hive. Some change sides every few years, whilst others believe that the queen always resides on one side and so never cut there. Some farmers separate out the best sealed honey as raw honey ('kaacho maha') for use as medicine and to sell at a high price. The remaining unsealed honey (sometimes brood combs) and older black combs are mashed up and cooked to reduce water content and preserve. The honey is cooked directly over a fire to a high temperature. Melted wax is skimmed from the surface and kept for trading with metal workers. Cooked honey ('pakkeko maha') is sold more cheaply than raw honey and is not valued as a medicine. Some believe that it angers the local gods to sell raw honey and so only sell cooked honey. 'Chiauche maha' is made from boiling down honey water that results from handling honey during extraction until it is thick and honey-like. An important guest will be fed pure raw honey, a less important guest cooked honey and an unwanted guest 'chiauche' honey.

Winter colony management

Of 269 farmers who answered questions, 229 (86%) claimed to feed their bees. The farmers'definition of feeding ranged from leaving some combs of honey back for the bees, to applying a sweet solution around the mouth of the hive in the early spring (March–April). Sugar is not produced in Jumla and is expensive since it is flown into the area. Hence natural sugar alternatives are often used for feeding bees. Foodstuffs mentioned by farmers were as follows: 157 used (usually raw) honey; 59 either cooked or raw sweet pumpkin; 50 raw sugar cane ('gude'); 31 buckwheat flour and honey 'roti' or cake (usually par-cooked); 24 sugar; 15 sugar solution; 8 apples; and 6 a decoction of a sweet turnip (locally known as 'koira ko butun') boiled down into a thick solution. Most feed in the winter between December and April. Feeding during the dearth period in the monsoon is not practised. Other food mentioned are: 'mehel ko butun' (concentrate of a sweet forest fruit) and 'chamel ko dhuto' (inner husk of rice). The latter is extracted if rice is beaten for a long time and is sweet tasting. Beekeepers sprinkle this flour on a plank leading to the hive entrance; bees collect it and presumably consume it.

The 'buckwheat-honey rotis', or 'desu' as they are locally called, form a kind of edible 'dummy board' that probably significantly increases the insulation of bees in winter. The bees chew up the candy-like substance and obtain nutrition usually leaving just the hard dark cooked surface by the end of the winter. The buckwheat itself may be medicinal to bees, especially because of its bitter properties. 'Koira ko butun' is considered medicinal to bees. It is applied around the mouth of beehives during spring (February–April) and is believed to serve as a snack for bees on their way out for the first foraging trips of the year and a medicine against 'disease' that affects bees at this time. Bees appear to cluster upon this substance and feed from it. It does not seem to induce robbing.

'Bhuko' is a high-altitude herb (*Gnaphalium* sp.) collected in autumn (September/October) and placed in hives as insulation. The bees chew up the flower heads and fluffy leaves, and farmers believe that the bees can obtain crystallised nectar and pollen from the flower-heads. Some beekeepers hide raw honey inside bunches of 'bhuko' so that bees do not stick to it while feeding. 'Pirul' (pine needles) are packed inside hives, outside the inner layer of 'bhuko', and also around the outside of hives as insulation. They do not encourage mice in the same way as straw. In some areas 'pire gass', a high-altitude grass that is hot and spicy in flavour, is also used. Some farmers enclose this insulation with flat stones or slates and at high altitudes will even build a wall enclosing the hives. This helps protect against pine martens.

Traditional methods of disease control

Jumla farmers recognise diseased bees in various ways, e.g., black and/or angry bees, absconding, bees not working, and bees inactive, hanging together by the feet. Brood disease is recognised when bees are seen throwing out dead larvae ('that look like grains of cooked rice'), by a sour smell and black combs.

The traditional method of treating disease, other than feeding with honey or 'koira ko butun' is to apply a herbal smoke, especially on Tuesdays. The constituents of this vary. Of 16 farmers interviewed who applied smoke, most used 'dhoopi' (*Juniperus* spp.). Botanical identification of other ingredients used to smoke bees is yet to be completed. Some believe that 'puja', sprinkling a teaspoonful of cow urine together with 'chuna jurro' (local herb), is effective. Hive condensation, when bees are in occupancy, is solved by wiping the wetness off and sprinkling barley flour inside the hive.

Discussion

Although the concept of fixed-comb beekeeping may seem primitive to a modern frame-hive beekeeper, there are many aspects of traditional beekeeping knowledge that may have application in modern beekeeping or in beekeeping with appropriate technology in other countries. The following points drawn from the above results warrant further investigation and testing in other areas with *A. cerana*: (i) use of 'male' wood for top-bars and 'female' wood for bee boxes; (ii) medicinal effect of buckwheat-honey cake; (ii) effect on *A. cerana* of subsisting on natural fruit sugars in dearth periods; (iii) bee-repellent properties of *Artemisia* spp.; (iv) anti-microbial properties of *Juglans regia* leaves; (v) anti-microbial and acaricidal properties of herbal smokes; and (vi) the attractiveness of 'gosard' and its various components.

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Chapter 67

Indigenous Beekeeping Techniques in Dadeldhura, Nepal

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Dadeldhura in far western Nepal is rich in bee flora and has good potential for beekeeping. According to a 1994 marketing survey, its annual honey production is 3600 kg under traditional management which is relatively high for this region of Nepal (NoFrills Consultants, 1994). The present study was carried out with the objective of documenting indigenous beekeeping techniques, beehives and bee flora. The information was gathered from beekeepers, beekeeping trainees, and the District Agricultural Development Office through interviews and office records. Various tools of participatory rural apprisal, such as semi-structured interview, transect walk, preference ranking and triangulation, were employed. Data obtained from field observation and personal experience were combined with published reports.

Bees and Beekeeping

Beekeeping is a source of additional food and income in Dadeldhura where farmers keep a few colonies of *Apis cerana* in log and wall hives. Honey is valued by local people as food and medicine, but pollen is not used and beeswax is not used to its full potential. The contribution that bees make to pollination, thus increasing yield and quality of fruits and seeds, is not understood by local people.

Village farmers also harvest honey from other honeybee species with traditional honey-hunting methods. *Apis dorsata* migrates from the Terai in March/April and stays in low-hill areas until September. A professional honey-hunter can collect about 20 kg of honey per harvest per *A. dorsata* colony and sell it in local markets. Although *A. florea* honey is considered superior in quality and is highly priced, its production is low and limited to only a few places in low-hill areas. Some beekeepers in low-hill areas are trying to keep stingless bees, *Melipona/Trigona* spp., in their native habitat, i.e., hollowed-out logs.

Indigenous Beehives

Traditionally, *A. cerana* is kept in several types of hive made from hollowed-out logs, wall recesses, wooden pitchers and wicker baskets of *Bauhinia vahlii* leaves and bamboo strips. The most common are log hives and wall hives.

Log hive (mudheghar, dhado)

This is a simple structure made from a hollowed-out log with one or two small entrance holes and each end closed with a wooden stopper plastered in with cow dung and mud (Fig. 1). The length and diameter of horizontal log hives is usually 60–75 cm by 60–80 cm.

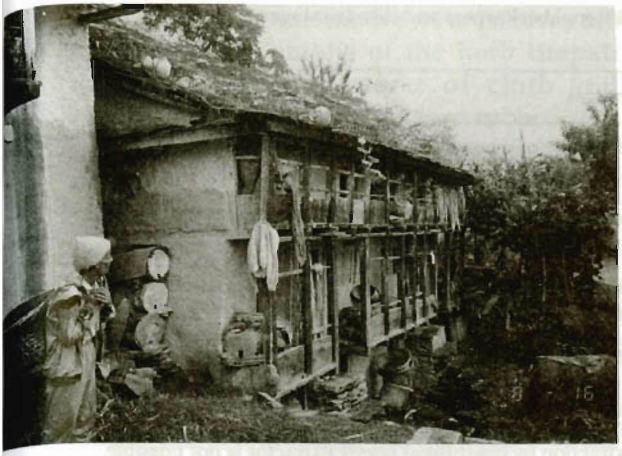

Fig. 1. Multipurpose dwelling house with traditional log hives.

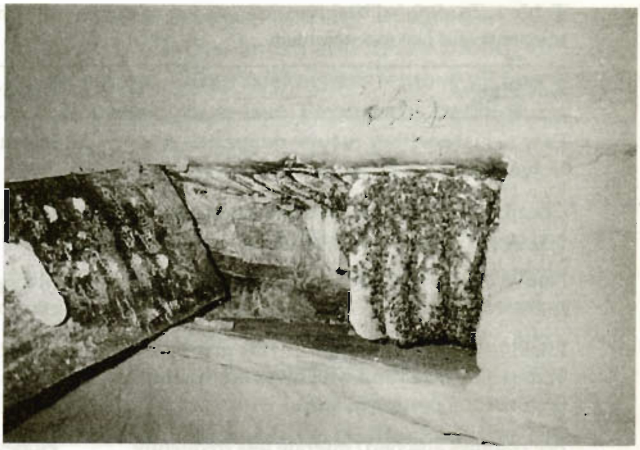

Fig. 2. Traditional wall hives showing 12 combs of which 8 combs were harvested.

Wall hive (khope ghar, jalekha)

These are either rectangular or square and vary little in dimensions (Fig. 2). A small entrance hole is located on the outside of the house. Each recess is 40–60 cm (the length from elbow to finger tips) long and 25–30 cm (one 'bitta': the span of a hand) deep. The side walls are plastered with mud and cow dung, and the floor and roof are wooden planks. Bees generally build combs on the wooden roof parallel to the entrance of the hive. The backside of the recess is closed by a wooden plank that is temporarily fixed to the house walls with a mixture of mud and cow dung. While harvesting honey, the back door is removed by scraping off the mud plaster.

These traditional beehives have been in use for hundreds of years and have been gradually improved by farmers. For farmers, they have several advantages over modern hives; however, for bee scientists and beekeeping extensionists, they also have several disadvantages (Table 1).

For rural farmers it is not a matter of right or wrong, it is a matter of practicality. For them, beekeeping depends on their technical know-how and earning capacity which are often not enough to use expensive movable-frame hives. Some farmers who receive training are willing to change from traditional techniques; however, the high cost of equipment makes it difficult for them to begin. Keeping this in mind, the International Centre for Integrated Mountain Development (ICIMOD) in collaboration with the Rural Women's Development and Unity Centre (RUWDUC) has made efforts (Fig. 3) to adapt traditional hives so that movable frames can fit into them. Hence, wall hives with moveable frames (Fig. 4) and straw hives plastered with mud and cow dung (Fig. 5) have been experimentally tested since March 1996. These hives are cheaper and provide better

Fig. 3. ICIMOD in collaboration with RUWDUC displaying different types of hives.

Table 1. Traditional beehives: advantages as expressed by traditional beekeepers and disadvantages as expressed by bee scientists and bee extensionists

Advantages	Disadvantages
Easy to make as they require no special techniques or accuracy for construction.	Increased chance of queen loss during honey harvesting.
Cheap: require little investment for log hives and no investment for wall hives.	Difficult or impossible to inspect colonies thoroughly.
Native bees are familiar with and well-adapted to these hives.	Management operations such as uniting, dividing, queen-rearing, control of laying workers are not possible.
Liked better by wild swarms. This may be because log hives and wall hives are similar to their natural nesting habitat.	Brood destroyed and adult bees killed during honey harvesting.
Bee colonies abscond/migrate less frequently from traditional hives (this may be because of less disturbance by the beekeeper).	Honey extraction by centrifugal honey extractor is not possible. Honey is extracted by squeezing the combs and contains brood extracts, parts of bee bodies, hive debris and dirt. Such honey does not fetch a good price and ferments quickly.
Less prone to attack by pine marten and other enemies because wall hives are generally 2–2.5 m above the ground and not easily accessible; log hives are hung under the eaves of houses and are thick and heavy.	

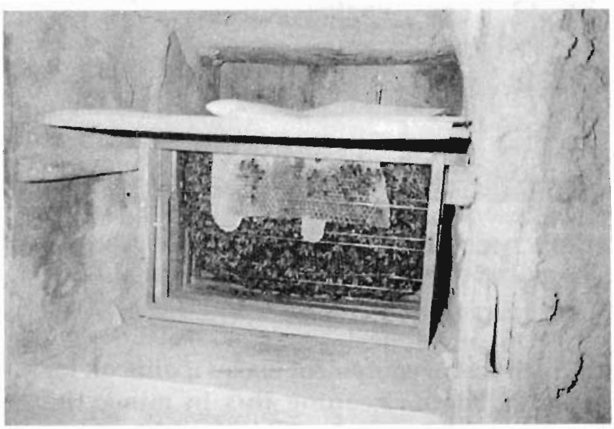

Fig. 4. Improved wall hives with movable frames

Fig. 5. Low cost movable straw frame hive plastered with mud and cow dung

insulation than Newton B wooden hives. Bee performance also seems to be better so far.

Traditional bee management techniques

Farmers in Dadeldhura consider bees as the 'symbol of fortune'. They rely more on luck than management techniques. Only a few management techniques are practised.

Catching swarms

Since there is no tradition of buying and selling bee colonies, they are collected as wild swarms. Baited log hives are placed on sunny, sheltered cliffs. To prevent wax moth and ants, hives are fumigated with smoke of the herb titepati (*Artemisia vulgaris*), pieces of cloth and dehydrated butter (ghee), and then rubbed with honeycomb. Titepati has a strong smell and insect-repellant properties (Regmi and Kama, 1988). As soon the hive is occupied, it is brought home.

To catch hived-bees as they swarm, farmers throw clouds of soil, dust, ashes or water at them and repeatedly mutter 'Basa, mauri, basa!' (Stay, bees, stay!). After catching the swarm, the wings of the queen are cut and the swarm is placed in a basket (chhapro) and kept in a dark place. In the late evening, bees are rehoused in their hive. The practice of cutting the wings of the queen greatly disadvantages the survival of secondary (donalo) or tertiary swarms (tenalo hul), since the queen leading these swarms is generally virgin and needs wings for the mating flight. In such swarms, the bees sometimes kill the queen and rejoin their parent colony; but, generally, they start worker-laying, survive 2–3 months and then die. This practice may be contributing to the decline of *A. cerana* in the region. The beekeeping programme is now successfully educating farmers about the virgin queen's need to make mating flights.

Seasonal management

Only a few entrepreneurial farmers practise seasonal management techniques. To keep bees warm, farmers in high-hill areas cover hives with rice/wheat straw or other insulating materials. If hives are too big, they put 'guwo' (dry inflorescences of *Anaphalis* spp. and *Gnaphalium* spp.) inside them and make them narrower with dummy boards of wooden planks. During the monsoon, log hives are covered with pine needles, thatch grass or plastic to protect the bees from rain.

Swarm control

Some experienced beekeepers recognise signs of swarming, especially from outside the hive. When drone (andyal) activity is high they look for queen cells (raa kothi) and drone brood, and destroy them. Other beekeepers remove all brood combs except one or two. Farmers in Dadeldhura consider the first swarm to be the best.

Pine marten control

Pine marten (*Charonia flarigula*) is a major enemy of bees in Dadeldhura. It can destroy a colony in a night and tends to return to an area having developed a taste for honey. Once attacked, colonies abscond the next day. To control pine marten, some farmers hang 'ghanti' (cow bell) in the hives. When a hive is attacked, the bell rings and the sound scares away the pine marten. Some farmers place 'seto kurro' (*Achyranthes* sp.) outside the hive. This herbaceous plant has sticky inflorescences that adhere to the body-hairs of the pine marten and may make it think that somebody is pulling at it; it thus runs away without destroying the hive.

Bee Flora and Supplementary Feeding

Traditional beekeepers know well the plants that provide nectar and pollen. Some experienced beekeepers can determine the botanical origin of unifloral honey such as chiuri (*Aesandra butyracea*), tori/rayo (*Brassica* spp.), neem (*Azadirachta indica*), suntala/mausam (*Citrus* spp.), kirmada (*Berberis asiatica*), ghangaru (*Pyracantha crenulata*), tooni (*Cedrela toona*) by tasting it. From field observation, 76 bee plants were recorded in the district (Table 2). At most times of year bees do not need to be fed; but there are occasions when supplementary or emergency feeding is required. Unfortunately, farmers in Dadeldhura do not provide this. Some beekeepers leave one or two honeycombs during harvesting for their bees. Honey is also provided once during winter and once after housing newly hived swarms. In high-hill areas, where winter is cold, bees are given a half-boiled, fully ripe, sweet variety of greater pumpkin. In some areas, fully ripened snake

Table 2. Bee Flora of Dadeldhura District

Bee Flora	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	District
AGRICULTURAL CROPS													
Brassica campestris (Mustard)	*–	*–	*–									*–	LH-HH
Brassica juncea (Indian mustard)	*–	*–	*–									*–	LH-HH
Brassica napus var. toria	*–	*–	*–										LH-HH
Brassica oleracea var. capitata		*–	*–										LH-HH
Brassica oleracea var. botrytis		*–	*–										LH-HH
Raphanus sativus (Radish)		*–	*–										LH-HH
Cucumis sativus (Cucumber)							*–	*–					LH-HH
Cucurbita maxima (Greater pumpkin)				*–	*–								LH-HH
Cucurbita pepo (Pumpkin)							*–	*–					LH-HH
Lagenaria siceraria (Bottle gourd)							*–	*–	*–				LH-HH
Daucus carota (Carrot)						*–	*–	*–					LH-HH
Trigonella sp. (Fenugreek)			*–	*–									LH-HH
Coriandrum sativum (Coriander)				*–	*–								LH
Allium cepa (Onion)						*–	*–						LH-HH
Sesamum indicum (Sesame)							*–	*–					LH-HH
Amaranthus paniculatus (Amaranth)					–	–							MH-HH
Zea mays (Maize)						–	–						LH-HH
Fagopyrum esculentum (Buckwheat)							*–	*–					MH-HH
HORTICULTURAL CROPS													
Citrus limon (Lemon)				*–	*–								LH
Citrus aurantifolia (Lemon)				*–	*–								MH-HH
Citrus reticulata (Mandarin)				*–	*–								LH
Citrus sinensis (Sweet orange)				*–	*–								LH
Citrus limetta (Sweet limetta)				*–	*–								MH
Malus domestica (Apple)				*–	*–								HH
Musa paradisica (Banana)	*	*	*	*	*	*	*	*	*	*	*	*	LH
Prunus armeniaca (Apricot)				*–	*–								HH
Prunus domestica (Plum)			*–	*–									MH-HH
Prunus persica (Peach)			*–	*–									MH-HH
Pyrus pashia (Pear)			*–	*–									MH-HH
Punica granatum (Pomegranate)					*–	*–							LH-HH
Mangifera indica (Mango)				*–	*–								LH
Juglans regia (Walnut)			–	–	–								HH
Psidium guajava (Guava)		*–	*–										LH
Carica papaya (Papaya)				*–	*–	*–							LH
FORAGE CROPS													
Trifolium spp. (Clovers)			*–	*–	*–	*–	*–						MH
Rumex spp. (Almado)							*–	*–	*–	*–	*–		MH-HH
Circium wallichi (Thistle)					*–	*–							HH
Polygonum spp.					*–	*–							LH
Oxalis corniculata								*–	*–				LH
Saccharum spp. (Tall grass)									*–	*–			LH
HEDGEROW PLANTS													
Adhatoda vasica (Basak)	*–	*–	*–	*–									LH-MH
Prinsepia utilis (Dhatelo)	*–	*–											HH
Pyracantha crenulata (Gangaru)				*–	*–								MH-HH
Yucca sativa (Adam's needle)						*–	*–						MH-HH

(Contd.)

Table 2. (Contd.)

Bee Flora	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	District
Berberis aristata (Berberis)			*-	*-									MH
Vitex negundo (Indian privet)					*-	*-							MH
Opuntia spp. (Prickly pear)				*-	*-	*-							LH-MH
ORNAMENTAL PLANTS													
Tagetus erectus									*-	*-	*-		LH-HH
Calendula arvensis (Marigold)	*-	*-											LH-MH
Aster spp. (Starworts)									*-	*-			LH-HH
Helianthus annuus (Sunflower)			*-	*-	*-								LH-MH
Rosa spp. (Garden roses)			*-	*-	*-								LH-MH
Ocimum sanctum (Tulasi)									*-	*-			LH-HH
WILD PLANTS, FOREST TREES													
Aesandra butyracea (Chiuri)									*-	*-	*-		LH
Myrica esculenta (Kafal)		*-	*-										MH-HH
Grewia optiva (Bhewal)								*-	*-				MH
Sapindus mucorossi (Soapnut tree)					*-	*-							MH
Bauhinia variegata (Koqiralo)									*-	*-			MH
Bauhinia purpurea (Geranium tree)			*-	*-									MH
Bauhinia vahlii (Camel's foot)					*-	*-							LH
Cedrela toona (Tooni)			*-	*-									MH
Azadirachta indica (Neem)			*-	*-									LH
Dalbergia sisso (Sisssoo)			*-	*-									LH
Prunus cerasoides (Wild cherry)					*-	*-							MH-HH
Phylanthes emblica (Amla)	*	*											MH
Rhododendron arboreum (Guras)			*-	*-									MH-HH
Rhododendron spp. (Setoguras)			*-	*-									HH
Salix spp. (Willow)		*-	*-										MH
Shorea robusta (Sal)			*-	*-									LH
Fragaria spp. (Wild strawberry)					*-	*-							MH
Kapium insigne (Khirro)					*-	*-							MH
Elaeagnus parvifolia (Gunyeli)		*-	*-										LH-MH
Rubus ellipticus (Raspberry)			*-	*-									LH-MH
Zanthoxylum spp. (Nepali pepper)			*-	*-									MH
Rosa spp. (Wild rose)				*-	*-	*-							LH-MH
Caesalpinia capitata (Kunyeli)			*-	*-									MH

Notes: Nectar source * ; pollen source - ;HH = high hills; MH = mid-hills; LH = low hills.

gourd is also provided. In recent years, some farmers provide 'gud' (a home-made sugarcane product).

Honey Harvesting, Processing and Uses

Harvesting period

Honey harvesting depends upon climatic conditions, forage availability and cultural considerations. In high-hill and mid-hill areas, honey is harvested twice a year during April/May and October/November. In low-hill areas, an additional harvest can be taken in chiuri (*Aesandra butyracea*) and mustard (*Brassica* spp.) blooming periods. Chiuri is considered as a major source of honey in the low hills where farmers harvest honey twice or thrice during its blooming period. Traditionally, honey is harvested on auspicious days in the lunar calendar. Generally, it is harvested during the bright half of the lunar month (shukl-pachhy), and never on Saturdays, Sundays, Tuesdays or during 'panchak' (a period when all planets are visible simultaneously) according to the lunar calendar. There are also cultural considerations determining the harvesting of hives when outsiders are present because honey is regarded as a gift from God and should not be shown to strangers. Only a few beekeepers, who do not follow cultural traditions, harvest honey whenever they like.

Harvesting technique

For harvesting honey, farmers use a smoker (hantaro) made from a piece of cloth tied into a roll. After smoking bees, they are brushed off the combs using a small broom of thatch grass (babiyo) that is usually dampened with water. Then combs are cut from the top of the hive and placed in a large-mouthed vessel (bata). Due to lack of awareness, both honey and brood combs are removed from the colony during harvesting and consequently much brood is lost. Successful training is creating awareness of how to reduce brood damage during harvesting.

Processing

Honey is generally extracted by squeezing the whole combs. Some farmers squeeze both honey and brood combs together but others separate the brood and honeycombs. Brood comb is considered to be highly nutritious and is fed to milk cattle and children. Squeezed honey is packaged in pre-used utensils especially in plastic gallons and glass bottles. Such honey has a high moisture content. It does not fetch a good price and ferments quickly. To prevent fermentation, some farmers cook their honey by direct heating. The resulting honey does not ferment but looses its nutritional and medicinal benefits. However, in recent years farmers of low-hill areas sell sealed honeycomb and receive a good price.

Uses

Honey is considered as one of the five heavenly foods, 'panchamrita' (a mixture of milk, curd, ghee, honey, sugar). In Dadeldhura, more than 90 per cent of honey is consumed directly. The remaining is used (i) to make 'addu', a sweet dish made of roasted and ground rice, til (sesame) and honey; (ii) as a medicine to cure eye disease, wounds, burns, cuts, stomach aches, gastritis, diaorrhea, colds, etc; (iii) to ease childbirth (by taking honey during the birthing period); and, (iv) as an energetic and stimulant food, etc.

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Chapter 68

Traditional Beekeeping with *Apis cerana* in Kullu Valley of Himachal Pradesh

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Indigenous methods of keeping bee colonies in log and wall hives are still common in Kullu valley despite the fact that modern beekeeping started here in 1934. Traditional beekeeping requires little investment in terms of cost of hives and bees. Hives are prepared from available local materials and bees generally settle in such hives during swarming. A survey conducted in 32 villages revealed that most farmers still keep bees in self-made log and wall hives. In total, 507 hives were found occupied by *A. cerana* of which 250 were wall hives, 197 log hives and only 60 modern hives (Langstroth and ISI hives). Every village had several farmer-cum-beekeepers each with two to many colonies.

Bees are kept in traditional hives made from wood of *Pinus wallichiana* (kail) and *Picea smithiana* (rai). The hives are either log hives, box hives or wall hives. Log hives (dhindhor) are made by hollowing out the trunk of a tree. They have an entrance at the front and are closed at the back by a wooden plank sealed with a paste of cow dung (Fig. 1). They are kept vertical in a verandah or on the roof of a house. Ordinary box hives (marham) without frames are prepared from wooden planks. They are kept either horizontal or vertical (Fig. 2) in a verandah or in

Fig. 1: Log hive (wooden plank removed to show the colony)

Fig. 2: Box hives (without frames)

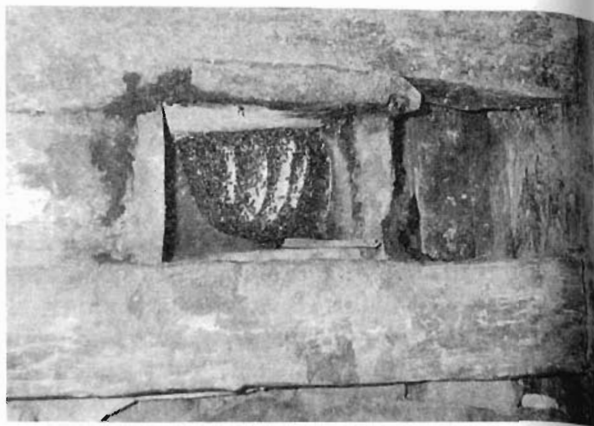

Fig. 4: Inner view of wall hive

Fig. 3: Three log hives and, on the right, a wall hive constructed between layers of stone and wood. (Swarm-catching basket and big spoon for collecting bees can be seen on top of the log hive on the extreme left)

Fig. 5: Log hives placed on hilly gradient for catching swarms

the open. Wall hives are built at the time of construction in recesses in the walls of a house between the layers of stone and wood (Fig. 3). The entrance is a triangular opening on the outside. On the inside, a wooden plank is used to close the hive and allows for handling of the bees for honey extraction (Fig. 4).

To catch swarms, beekeepers throw dust or water on flying swarms and, after they have settled, transfer them to swarm-catching baskets with a big spoon. In remote areas such as Jana empty log hives are placed in a protected place on steep hilly gradients for catching natural swarms (Fig. 5). Once occupied by bees, these hives are then taken back to the village by the owner.

Sealed honey is harvested (Fig. 6) twice a year during summer (June) and winter (November). For this, bees are driven out by smoke produced by burning cow-dung cake on a plate or big spoon. Honeycombs are harvested along with brood. Generally old combs are harvested and 2-4 new combs are left for the bees depending upon the season. Colonies generally yield 2–5 kg

Fig. 6: Harvesting of honey from log hive

of honey per year, however, 10 kg of honey/log hive was harvested at Baragaon during winter. Honey is squeezed through cloth. The beeswax is discarded as a waste product.

Colonies in log and box hives are rented to orchardists for pollination but many combs are damaged during transportation. It has also been observed that bees in these hives have less tendency to abscond, which is otherwise a major problem with *A. cerana*.

Kullu valley has great potential for beekeeping with *A. cerana*. In this area there is a scarcity of bee colonies required for pollination of fruit crops such as apple. There is an urgent need to develop a programme to encourage traditional beekeeping for income generation and for increasing the number of *A. cerana* colonies available for pollination.

Beekeeping in Nepal: Problems and Potentials

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In Nepal, use of honeybees ranges from honey-hunting of *Apis laboriosa* and *A. dorsata* by rural tribes who plunder honey and wax causing great damage to colonies, through traditional beekeeping with *A. cerana* practised by rural farmers, to modern beekeeping with *A. cerana* and *A. mellifera*. In remote rural areas, hollow logs and wall cavities are mostly used to hive bees. Top-bar log hives and frame hives are used by trained beekeepers who also practise simple seasonal management. Diversified vegetation and rich bee flora is abundant in the mid-hills of Nepal, so beekeeping has great potential. However, the indigenous *Apis cerana* bee is not well domesticated and beekeepers face problems of absconding, frequent queen loss, quick emergence of laying workers, high swarming tendency and small honey yields. Honey in Nepal can be classified according to bee species (*A. dorsata, A. laboriosa, A. florea, A. cerana, A. mellifera, Melipona* and *Trigona*), seasons and bee flora. However, the lack of standardisation of honey quality has created problems in reliability and popularity with consumers. Thai Sac Brood Virus and European Foul Brood are major prevalent diseases; *Vespa* spp. and pine marten are devastating predators (Anon., 1990 a, 1990 b; Baidhya *et al.*, 1997; Bhattarai, 1992). Although various agricultural and horticultural crops cultivated in Nepal require bee pollination, so far there is little use is made of honeybees for crop pollination. In contrast to *A. cerana*, traits such as higher yields of honey, and low absconding and swarming rates have made *A. mellifera* popular among innovative beekeepers. However, *Varroa* and *Vespa* problems, and higher economic investments are major constraints, and seasonal management procedures need to be developed.

In Nepal beekeeping can be useful both as an income-generating activity for rural beekeepers and as an industry for earning foreign currency. Breeding *A. cerana* with desirable traits and improving mother stocks, finding better precautions and dealing with disease and enemies, determining zonation of *A. cerana* and *A. mellifera* beekeeping, conserving bee biodiversity and honeybee flora, and utilising bees for pollination are main priorities. Increasing interest by farmers in beekeeping has put greater emphasis on solving these problems. Training of trainers and farmers (beekeepers) is essential for improving beekeeping in Nepal. The government's Bee Development Section and non-governmental organisations conduct beekeeping training programmes for leader farmers. Bee Development Section runs hive construction training for carpenters and trainers' training for technicians.

Honeybee Species: Future Potentials

At least five honeybee species exist in Nepal; four are native species—*A. florea, A. dorsata, A. laboriosa* and *A. cerana*—and *A. mellifera* is introduced. In subtropical parts of the country, *Melipona* spp. and *Trigona* spp. are also found. *Apis cerana* is kept and found naturally throughout subtemperate to subtropical regions, thus, providing tremendous genetic and technical potential for scientific research. *Apis mellifera* has been recently introduced but constraints such as heavy investment, greater susceptibility to disease and pests, and lack of resistance to natural enemies has stimulated work to improve *A. cerana* stock. Selection and breeding of *A. cerana* for desirable traits can make beekeeping with this species more viable and sustainable.

Honeybee Flora and Pollination Potentials

Diverse climatic conditions across the country provide various bee flora in tremendous quantity. Nevertheless increased deforestation and heavy use of chemicals in agriculture has resulted in the decline of both wild and domesticated bee colonies. In the Kathmandu valley, three main flows of nectar and pollen occur: the first spring flow lasts from February to early April supported by *Eucalyptus* spp., *Fraxinus floribunda, Grevillea robusta, Bauhinia purpurea, Citrus* spp., *Dyospyrus* sp., *Prunus* spp., *Pyrus* sp., *Trifolium* spp., *Abelmoschus esculentus, Brassica* spp. and *Eugenia* sp. This is followed by a short flow from April-May supported by *Zizyphus* sp., *Brassica* sp., *Solanun* sp., *Cedrela toona* and *Lonicera* sp. Then follows by a short period of dryness and so dearth before the start of the rainy season, which is also unfavorable. The third season is autumn that lasts from September to November. Main plants flowering in this period are *Prunus cerasoides, Eleucine coracana, Fagopyrum esculentum, Aesandra butyracea, Innula cappa,* and *Solidago longifolia*. Autumn is followed by a cold winter. In five districts (Kavre, Sindhuli, Nawal Parasi, Rautahat and Arghakhanchi) out of 849 farmers questioned, many (49%) replied that *Aesandra butyracea* is the major flora for honeybee especially in hilly districts, and *Nyctanthes arbortristis* is dominant in the Terai (plains) (Baidhya *et al.*, 1997). Mustard (*Brassica* spp.), litchi (*Litchi* spp.) and buckwheat (*Fagopyrum esculentum*) are also important sources (Anon., 1990 a, 1990 b). Some plants such as *Aesculus indica, Papaver* sp., *Euphorbia royleana, Lyonia ovalifolia, Maesa chisea, Pieris formosa* and *Rhododendron cinnabarinum* are suspected of yielding toxic nectar. Such honey seems to be non-toxic to bees but toxic to human beings (Kafle, 1984).

Status of Beekeeping

Apis cerana bees have a high tendency of migration and absconding creating problems for beekeepers (Baidhya *et al* 1997). The life cycle of *A. cerana* bees in Kathmandu is as follows. This scheme is approximate and may differ according to the situation and place. Life of bees is affected by bee flora availability and climate, especially rainfall and temperature (Bhattarai, 1992).

January	Winter and rest period; bees go out during daytime. Not many bee plants are flowering but incoming nectar and pollen is sufficient to keep the queen laying eggs.
February	More bee flora available, more activity by bees. Brood nest grows faster and first drone cells can be found.
March/April	Swarming season; good nectar and pollen flow. Honey production may be from 5-10 kg per hive (Baidhya *et al.*, 1997).
May/June	Gradual decrease of flow and death of drones. Absconding common (Baidhya *et al.*, 1997).
July/August	Rainy season. Bees go out between showers and even store honey. Brood nest remains constant.
September	Increased activity; building of drone cells.
October	Swarming season but less than in March. Change of queens without swarming is also possible (supersedure). Good nectar flow.
November	Eviction/slaughtering of drones.
December	Winter and rest period. Bees fly during daytime. Brood rest remains small, but egg-laying continues at a minimum.

Most of beekeepers do not have the opportunity to be trained. Over ninety per cent of farmers interviewed were untrained but interested in attending training programmes. Main sources of training for farmers are governmental (Bee Development Section, Godwari), non-governmental organisations, and farmers' traditions and own experience (Anon., 1990a, 1990b; Baidhya *et al.*, 1997). Women are equally interested in beekeeping training programmes.

Problems and Potentials

Domesticated bees as well as wild bees such as *A. dorsata* and *A. laboriosa* are facing worse environmental conditions and are in need of conservation. The number of wild colonies is declining in Nepal. Main causes of colony decline include the following.

Deforestation

In Nepal deforestation is causing the loss of flowering plants, bee flora and natural vegetation. This leads from highly diverse natural ecosystems to far less diverse (often monocultures) agro-ecosystems. The scarcity of bee pasture due to deforestation not only leads to decline in colony numbers but also creates 'stress condition' for living bee colonies and increases their vulnerability to pests and diseases, and hunting (Verma, 1993).

Honey-hunting and human predation

In Nepal traditional honey-hunting is carried out by certain communities to earn a livelihood. It results in the destruction of bee colonies and also the development of undesirable traits such as absconding or swarming. Since many of these absconding or swarming colonies have the propensity to return to the same nesting site each year, they are subjected to repeated harmful destruction (Bishop, 1992). If honey-hunters are trained to keep bees properly or harvest honey without damaging colonies, or given alternative means of earning livelihood through training programmes, the degree of damage caused by honey-hunting can be diminished.

Diseases and enemies

Thai Sac Brood Virus Disease killed 90–95% of *A. cerana* colonies in Nepal between 1980 and 1984. Around 5 % seemed to be resistant and the number of colonies has increased since then (Crane, 1992; Rana *et al.*, 1986, 1987; Verma, 1993). Recently European Foul Brood has badly affected *A. cerana* colonies in the Kathmandu Valley (Verma, 1993). The mites, *Acarapis woodi, Varroa jacobsoni, Neocypholaelaps, Tropilaelaps* sp. and *Pyemotes naferi* have been reported on *A. cerana*. Acarine disease poses a serious problem (Verma, 1987). Wasps (especially *Vespa* spp.) and hornets are serious predators of *A. cerana* although, because of its evasive shivering and shimmering behaviour, it can resist attack by wasps better than *A. mellifera*. Two species of wax moth, *Galleria mellonella* and *Achroia grisella*, are serious pests of *A. cerana* as this species does not collect propolis to guard against attack by moths.

Pesticide damage

In developing countries such as Nepal, honeybees face high risk of pesticide application, often through farmer ignorance. Unlike in developed countries, as well as limited know-how there is also lack of legislation to regulate the use of pesticides. Integrated pest management technologies are not prevalent. They could protect bees from the harmful effects of broad-spectrum biocides. Major pesticides used are Metacid, Nuvan and Thiodan/Decis (Baidhya *et al.*, 1997).

Impact of exotic *Apis mellifera*

Despite the higher initial investment and problems of local pests and diseases, the importation and propagation of exotic *A. mellifera*, for better economic returns in terms of higher honey production and efficient pollination services, is constantly increasing and replacing *A. cerana* beekeeping in Nepal. The two species frequently rob each other (Verma, 1993), and when kept together intermating produced lethal offspring that caused failure of their coexistence (Verma, 1993). The transfer of parasites and diseases from one species to another is another problem: *Varroa jacobsoni* can coexist with and cause no serious harm to *A. cerana*, but proves a serious pest to *A. mellifera* that conversely can transfer new diseases to *A. cerana*.

Apis cerana bees used in Nepal are still wild in nature and need a great deal of attention for stock improvement. The greater tendency of absconding and swarming, fighting and robbing, frequent queenlessness, quick emergence of worker layers, susceptible to stress and low honey yields are the main drawbacks (Anon., 1990 a, 1990b; Baidhya *et al.*, 1997). Colonies of *A. cerana* in Nepal are highly susceptible to threats by natural enemies and environmental degradation or adverse conditions. Stock improvement to select races for reduced absconding behaviour is a priority. Furthermore, should such selection be attempted, a queen-breeding station for large-scale distribution of queens would be required.

The lack of appropriate technology for indigenous *A. cerana* as well as skilled technicians needs attention. Apart from abundant natural resources suitable for honey production in Nepal, honeybees can also be exploited for pollination of agricultural crops (Kevan, 1993). Pollination programmes can be united with crop, fruit and seed production programmes. The transfer of technology to farmers is only assured through practical training programmes that in turn require training infrastructures and manpower development. To cope with supply-and-demand problems of beekeeping equipment and implements, apiary resource centres have been developed in parts of Nepal. These centres are useful for helping to solve technical problems and for carrying out laboratory work. They can also be used as gene pools for selection and breeding of colonies with desirable traits. They provide training and extension to farmers and trainers enhancing local participation.

Policy Guidelines

In Nepal there is lack of legislation regarding bees, bee equipment and honey, and it is difficult to enforce existing legislation. For conservation of bees, discouraging honey-hunting, the heavy use of chemical sprays, and deforestation are the main areas to be taken into account. Legislation regarding importation of bees or beekeeping equipment, honey or hazardous chemicals must be developed and adopted. Beekeeping zones should be specified to avoid competition and/ or problem transmission between *A. mellifera* and *A. cerana*. Standardisation of honey and legislation to discourage honey adulteration should be strictly followed (Crane, 1992).

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Chapter 70

Sustainable Beekeeping Development in Karnataka

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Karnataka is a large coastal state in south-west India. Good forage sources for bees are found throughout the region. Best are the forested areas of the Western Ghats providing excellent forage and habitat for bees. The coastal strip is also good with coconut and soap-nut providing major nectar flows. The plains of north-eastern districts support intensive agriculture, especially sunflower, and offer excellent potential for beekeeping. Periods of nectar flow vary throughout the state. Many of the major food crops provide useful pollen and/or nectar forage, and include coffee, areca nut and coconut, maize, pulses, sunflower, fruits and vegetables.

The Karnataka Government's department with responsibility for beekeeping is the Directorate of Industries and Commerce (DIC). In 1994, DIC requested FAO (United Nations Food and Agriculture Organisation) for assistance to promote apiculture as a source of income generation amongst landless farmers. In previous years beekeeping with the indigenous honeybee *Apis cerana* had become difficult due to a virus disease. It was proposed that one way to overcome this difficulty was to introduce the European honeybee, *A. mellifera*, and promote its use amongst landless farmers. In 1996 FAO agreed to support a Technical Co-operation Programme to assist with beekeeping in the state, providing funds for DIC's proposal entitled 'Beekeeping for landless farmers in Karnataka State'. When the project commenced in December 1996, an important priority was that

Honey sources and beekeeping prospects in Bangalore district

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Survey and identification of plants of apicultural importance were carried out during 1993–96 in Bangalore district, Karnataka, India. The area is rich in both agricultural and non-agricultural flora. The availability of many diversified bee flora greatly supports large-scale beekeeping in Bangalore district. The survey revealed that there were 19 nectar plants, 101 pollen plants, and 166 both pollen and nectar plants. A floral calendar was devised. Results indicate that the time and duration of flowering of bee flora were highly variable. The floral calendar suggests that Bangalore district is potentially rich in bee flora and has good honey potential. Data on beekeeping and bee-management practices in Bangalore district suggest that beekeeping is underdeveloped and unproductive. Factors responsible for poor beekeeping practice, and a strategy to encourage beekeeping are discussed.

activities should be sustainable: beekeeping must be feasible and self-supporting, not reliant on external support.

Analysis of the Beekeeping Situation

Personnel and administration

Apiculture falls within the jurisdiction of DIC. There are over 130 apiculture staff, five Beekeeping Training Centres and many further apiary sites. Each centre has staff with full-time responsibility for apiculture, and additional technical staff.

Training, extension and information provision

Apiculture staff have received training in apiculture, but this is mainly theoretical. Every government apiary lacks a practical demonstration of beekeeping. Consequently training given by extension staff focuses on theory rather than practical skills.

The state offers assistance to beekeepers in terms of provision of training, usually including a stipend, bee boxes (either free of charge or subsidised) and tool kits (hive tool, smoker, veil, etc.). Bees are not usually provided; the new beekeeper collects them from the wild. There are seven schemes funded by the state offering this type of assistance. They are implemented through Zilla Panchayats (local government). There are also Government of India schemes.

Great efforts have been made to help people start beekeeping, but there is no follow-up assistance because practical beekeeping skills are lacking and extension staff do not have access to transport or appropriate allowances. Lack of technical information is a serious constraint. World-wide beekeeping is becoming more difficult as bees and their diseases are introduced to new areas. International research is moving rapidly, and Karnataka beekeepers must not be isolated from opportunities to stay abreast with developments.

Apicultural practices

An important finding of an analysis of the existing beekeeping situation was that 50–90 % of all honey is collected from wild colonies of the rock bee, *Apis dorsata*. This fact is not revealed in official documents (DIC, 1996). Honey-hunters, who collect from the wild, are barely regarded by extension staff as part of the 'apicultural community'. In interviews, honey-hunters said they received no assistance from the extension service. One of their main problems is in gaining access to state forests. Auctions are conducted to sell the rights for honey-hunting, and this can make the activity non-economic. It also means that honey-hunters are forced to be secretive.

Keeping colonies of *A. cerana* in wooden movable-frame hives, known here as 'box hives', is the style of beekeeping that has been promoted within India for the past 80 years. All official documents and beekeeping programmes relate to this style of apiculture. A typical harvest from *A. cerana* in box hives in Karnataka is 5–8 kg per year. However some beekeepers routinely obtain yields of 20 kg or more (Olsson, 1995).

Before box hives were introduced, *A. cerana* was kept in clay hives and log hives. These methods are still used although it is difficult to know to what extent they are practised. The extension service is so focused on box hives that staff seem reluctant to admit, or perhaps are not aware of, the continued existence of other methods. One beekeepers' co-operative estimated that 25 % of their 1724 shareholders still use traditional hives. Traditional hives yield 3–5 kg of honey per year. These yields are low relative to those potentially obtainable from frame hives. However, many beekeepers in Karnataka harvest similar amounts of honey from their frame hives as they could have harvested from much cheaper clay hives. A beekeeper could have 20 clay hives for the cost of one box hive. The economy, simplicity and sustainability of traditional methods should not be underestimated. The low-cost of simple methods is likely to make them more economical on a small-scale than more sophisticated beekeeping. There could be a market for honeycombs produced by simple beekeeping. Well-presented and marketed as a pure, traditional product they could achieve a premium price.

Frame-hive beekeeping has been promoted in Karnataka within only the last 20 years or so. It is understandable that there are still relatively few people with skill in managing bees to their full potential in these hives. Further training and information materials are needed for apicultural staff, extension workers and beekeepers. *Apis mellifera*, the European honeybee, has been brought to Karnataka. The total number of *A. mellifera* colonies is probably less than 1000. These stocks have been obtained from various other Indian states (Punjab, Haryana). Many of these colonies are small, docile and easy to handle.

Marketing of Honey and Beeswax

Poor marketing is a major constraint. A rapid way to assist honey-hunters and beekeepers would be to ensure they derive more profit from their products.

Impact of Thai Sac Brood Virus Disease (TSBVD)

This is a disease caused by a virus that kills the brood of *A. cerana*, and ultimately leads to colony death. TSBVD was first identified in Karnataka in 1992. Official documentation states that '75–90 % of bee colonies in the southern parts of Karnataka have been wiped out' (DIC, 1996). However it is not clear how these figures have been derived. It is difficult to assess the actual impact of TSBVD for the following reasons.

- Until 1995 beekeepers were paid Rs 50 compensation for every colony lost to TSBVD. There was therefore an incentive to state that colonies had been lost.
- One of the effects of TSBVD is that it causes the colony to abscond. However there are many other factors that will cause *A. cerana* to abscond. Many trainees have been given boxes and bees, but do not have the practical skills to manage them. When the colonies are stressed in one way or another the bees will abscond. Yet all absconding colonies are said to have TSBVD. During field visits it was evident that skilled beekeepers had more colonies than unskilled, who claimed to have lost all their colonies because of TSBVD. Even among extension workers, TSBVD has become a useful excuse for every colony absconding due to lack of proper care.
- There is no field survey of numbers of colonies before and after the arrival of TSBVD.

Disease-tolerant colonies are now appearing. Extension staff have no programme to identify and increase stock from such colonies, and therefore increasing colony numbers has been slow. Extension staff and beekeepers are unaware of management methods that enable *A. cerana* beekeeping to continue in the presence of TSBVD. Overseas training for a few trainers, provision of relevant literature, and the development of an effective extension programme could help people to manage *A. cerana* and alleviate problems caused by the disease. There is a shortage of *A. cerana* colonies. In general neither extension staff nor beekeepers have the skills to make sufficient increase in bee stocks from native bees. Extension staff cannot practise queen-rearing. This means that recovery from TSBVD has been slower than necessary.

Pesticides

It is likely that honeybee populations are being seriously harmed by pesticides used extensively in Karnataka. Farmers and beekeepers need to know ways of avoiding pesticide-killing of bees. Policy is needed to provide compensation for beekeepers whose colonies are destroyed in this way. However the most effective way to prevent harm to bees is to increase awareness amongst both farmers and beekeepers, and increase communication between interested groups.

Other honeybee diseases

The present disease situation in Karnataka, compared with much of the rest of the world, is actually good. Many common bee diseases have not yet been recorded and seem not to be present. Policy and awareness are needed to maintain this situation. European Foul Brood Disease, caused by the bacterium *Melissococcus pluton*, is currently reported in introduced *A. mellifera*.

Introduction of *Apis mellifera*

It was proposed that the present project should focus on the introduction of *A. mellifera*. However, this should only be done if it will generate more income for a significant number of the poor people that this project aims to assist. The following reasons mitigate against its introduction.

Survival of Apis mellifera

The DIC imported 90 colonies of *A. mellifera* in March 1996. Some of these have died already, and those surviving are in a weak state. None has so far generated honey surpluses greater than can be obtained from *A. cerana*. This beekeeping cannot be promoted to farmers until feasibility is established and management methods are well determined.

Support service

The extension service is at present unable to deliver the additional technical skills, and cope with the additional problems presented by beekeeping with *A. mellifera*.

Economics

Given correct management it may be possible to keep *A. mellifera* in such a way that significant quantities of honey and beeswax are generated (especially in north-eastern districts). The input costs will be greater because *A. mellifera* is an exotic species from a temperate climate, and will require more resources (time, treatment against endemic diseases and predators). It is already well-known from other Asian countries that beekeeping with *A. mellifera* can be more productive than with *A. cerana* only when practised on a large-scale. Since the aim of this project is to assist landless farmers, introduction of *A. mellifera* is unlikely to be of assistance to this sector.

Disease

Apis mellifera will present new problems for extension staff and beekeepers: (a) because of indigenous diseases to which it will be susceptible; and, (b) because of new diseases it may introduce. Sadly some of the colonies already in the state have brought in European Foul Brood Disease. This is typical of the increasingly complex disease situation that will accompany introduced *A. mellifera*.

Existing constraints

The proposal to introduce *A. mellifera* aims to increase income generation by increasing honey production. Yet shortage of honey is not seen as a constraint to the industry: plenty of low-cost honey is available from honey-hunting. Constraints to the current apiculture industry are the effect of TSBVD, pesticides, and poor marketing of products. None of these constraints will be addressed or alleviated by the introduction of *A. mellifera*.

Environmental issues

Evidence from other regions of Asia suggests that large-scale introduction of *A. mellifera*, where high populations of this species are maintained by beekeepers, can lead to loss of indigenous bee species. As well as the inevitable competition for food resources, there are also the risks of disease introduction, especially viruses. Loss of honeybee species leads to loss of pollination of plant species, and therefore loss of diversity. All of these concerns suggest that great caution must be exercised in the introduction of *A. mellifera*. Numerous scientific apiculture meetings have passed resolutions to this effect.

Beekeepers' needs

There is no strong request arising from beekeepers to introduce *A. mellifera*, and indeed many state that they do not want the exotic species. Some beekeepers have observed that it does not thrive. They have noticed that during the rainy period it ceases foraging while *A. cerana* continues, also that it is more susceptible to predators. It is mainly extension staff who have heard that *A. mellifera* is a 'better bee' and quote honey production of 30 kg per colony. This is stated without consideration of whether lack of honey production is a limiting factor.

Considering all of the above, there seem to be no compelling reasons for further introduction and promotion of *A. mellifera* in Karnataka at present. A more worthwhile use of project funds is to address the underlying reasons that led to the proposal to introduce *A. mellifera*.

In summary, constraints to beekeeping can be summarised as follows: lack of technical skills; lack of technical information; marketing; diseases; shortage of *A. cerana* colonies available to farmers; pesticides; and access to forests.

Project Activities

The best assistance with long-term benefit is to make beekeeping a worthwhile, profitable activity. The project is endeavouring to achieve this by alleviating the constraints listed above.

Research

As a start it is recommended that the University of Bangalore establishes a functioning demonstration apiary with at least 50 *A. cerana* colonies. Using these bees the National Expert can begin to provide practical advice to beekeepers on economic beekeeping, prevention of absconding and overcoming the recurring effects of TSBVD.

Training

DIC personnel responsible for apiculture and agricultural extension workers need practical apiculture training. Important aspects include the management of *A. cerana*, TSBVD control, colony multiplication, and ways of generating income from the products of apiculture. DIC staff are being given opportunities to see other successful beekeeping practises and be kept up-to-date in their field. They are participating in training courses at the Bee Development Research Centre in Vietnam, and in courses in beekeeping and queen-rearing in *A. cerana* run by the Central Bee Research and Training Institute, Pune. Following this, a Training of Trainers Programme is being organised for all apiculture training staff.

Extension

Extension must provide practical skills. The project is establishing seven strong, functioning demonstration apiaries, and maintaining high populations of bees for supply to farmers. It is also providing information and equipment to beekeeping centres to assist with their extension efforts. Excellent methods for beekeeping extension must be developed and evaluated. Following the Training of Trainers programme, a new extension programme will be devised.

Policy

Policy must be determined and implemented concerning the importation of bees, disease control, honey marketing, access to forests, and pesticide use.

Development of the industry

Efforts will be made to increase populations of *A. cerana*. Apiculturalists will be encouraged to generate more income by selling their honey in more profitable ways. Honey-hunters should be assisted by the extension service and by support for their industry.

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Chapter 71

Beekeeping in Bangladesh

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Beekeeping has long been practiced in Bangladesh. In early times it could be classified as bee hunting. It was done mainly for honey collection and is still found today. Efforts to keep bees in wooden hives probably started at the time of the Gandhian self-reliant movement in the 1940s. Prior to this people kept bees in logs, clay pots or similar methods.

In the 1970s interest in beekeeping began to increase. Beekeeping activities were started by the Government's Small and Cottage Industries Corporation and by non-governmental organisations. In 1977, an apiculture programme was financed by the Canadian Government and after a pilot period of research, training and extension it was decided that a comprehensive programme of scientific beekeeping could be developed. To provide administrative and institutional support, the Bangladesh Institute of Apiculture (BIA) was formed in 1981. BIA is a non-governmental organisation that focuses on research followed by dissemination of information.

Bees in Bangladesh

There are four species of honeybee indigenous to Bangladesh: *Apis dorsata, A. cerana, A. florea* and *Trigona iridipennis*. Among the four species *A. cerana* is the most suitable for beekeeping. It is readily available and well adapted to local conditions. *Apis cerana indica*, although wild, is easy to handle. It is a multi-combed bee with honey production per colony recorded at 2–3 kg every 10–15 days during honey flow. *Apis dorsata*, locally called Rock bee or 'pahari moumachi', is important in honey production (5–20 kg per colony). Most honey available in Bangladesh comes from *A. dorsata* colonies.

Bee Plants and Honey Production

Although Bangladesh is largely a rice-cultivating country, there is enough vegetation in many areas well suited as bee forage. In the intensively agricultural areas, litchi, jackfruit, lemon, *Acacia*, *Albizzia* and other leguminous trees, coconut, date, drumstick, blackberry, mango, palm nut, jambura, *Eucalyptus*, papaya, pomelo, wood-apple, banana, guava, and other fruit and shade trees are good sources of nectar and pollen. Besides these, there are huge areas cultivated for mustard, cucumbers, melons, peppers and various pulses. Litchi and mustard are important sources of honey. Bees use mustard as a source during colony build-up. One full extraction of honey measured 3 kg per colony 20 days after supering. Honey-flow season starts in late

September lasts until April/May. Average honey production is 10–20 kg per colony per year. Highest production so far recorded was 35 kg from one colony in four months (November, December, March, April). In the present market, pure honey can be sold at Tk 150 per kg earning Tk 1500–3000 per colony per year.

Extension of Beekeeping

The main objective of BIA is to introduce beekeeping to the rural poor to help them earn additional income and to pollinate agricultural and horticultural crops. We have achieved significant success in introducing beekeeping through training and extension, research and marketing. We have also formed Beekeepers' Associations for practicing beekeepers trained by BIA as model honey-producing centres. Organising Beekeepers' Associations is extremely important to BIA as they are the local-level production groups and the focus of all the Institute's activities. After completing training, beekeepers join an association that assists them with equipment and provides follow-up. Under the guidance of the Research and Demonstration Centre of a particular area, the Beekeepers' Association controls the activities of its beekeepers so that there are disciplined and organised groups with high standards in rural areas.

Chapter 72

Improvement of *Apis cerana* Beekeeping Using the ICIMOD Bee Project as an Example

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The native Asian hive bee, *Apis cerana*, is resistant to *Varroa* and *Tropilaelaps* mites and other predators. This means that *A. cerana* honey can be an unpolluted health food. This bee is well adapted to its flora and climate and, along with other Asian bee species, is a good pollinator of native Asian flora. It is also a 'low-cost' bee as it requires no medication or sugar feeding and uses traditional hives. However, it has the disadvantages of a lower productivity than *A. mellifera*, and heavy colony losses from Thai Sac Brood Virus Disease and a high swarming/ absconding tendency.

Improvements in *A. cerana* beekeeping have to focus on three important steps.

Improvement of Technical Equipment

A moveable-frame hive in a self-made system with local materials is essential. The ICIMOD

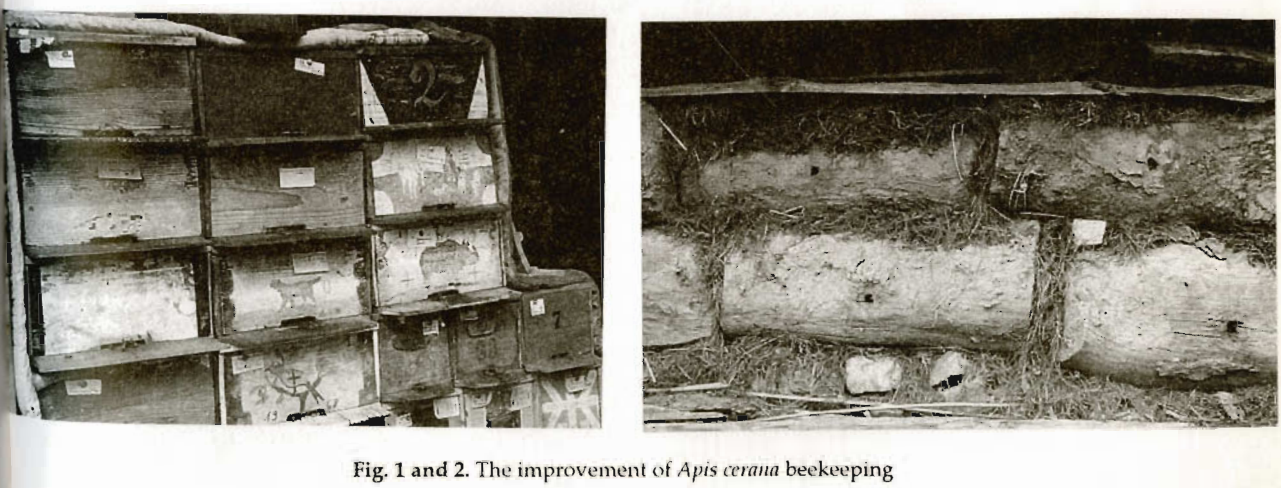

Fig. 1 and 2. The improvement of *Apis cerana* beekeeping

Beekeeping Project uses a straw hive with moveable frames in a completely self-made form. This is the most important step.

Improvement of the Bee

Effective queen-rearing and selection need modern equipment and colony management. Figures 1–2 show that *A. cerana* 1998 is still at the same economic stage as *A. mellifera* 1900. World-wide *A. mellifera* has a much higher productivity than *A. cerana* because of higher technical standards used in *mellifera* beekeeping and an effective response to selection over the last 50–100 years.

Training for Beekeepers

Training and accompanying scientific work are necessary in all project areas. A booklet, video films and slide shows have been made as training resources by the project. Other activities include practical things such as pollen traps, candle making, wax melting, etc.

About the book

Asian Bees and Beekeeping: Progress of Research and Development presents an overview of research and development on bees and beekeeping in Asia, and highlights the issues related to conservation and management of the Asian hive bee, *Apis cerana*. This book is an outcome of the Fourth Asian Apicultural Association (AAA) International Conference organized by AAA and ICIMOD in Kathmandu, Nepal, from March 23-28, 1998. It contains over 150 presentations reflecting beekeeping research and development issues in over 24 countries, and is organised into seventy-two chapters. New frontiers in bee biology research, covering diverse topics such as evaluation and selection of *Apis cerana* populations and the effect of synthetic queen pheromones on behaviour and honey production of *Apis cerana* and *Apis mellifera* are covered. Recent findings on bee diseases and pest control and innovations in apiary management are explained. A section on production, processing, properties, and marketing of different bee products - honey, beeswax, royal jelly, and propolis - has been provided. In addition, new advances in crop pollination research through beekeeping and experiences in extension, covering topics ranging from beekeeping needs and extension methodology in the hill and mountain areas to the role of various research and development institutions in promoting sustainable beekeeping, are given in detail.

International Centre for Integrated Mountain Development (ICIMOD) is the first international Centre in the field of integrated mountain development. Founded out of widespread recognition of environmental degradation of mountain habitats and the increasing poverty of mountain communities, ICIMOD is concerned with the search for more effective development responses to promote the sustained well being of mountain people. The Centre was established in 1983 and commenced professional activities in 1984. Though international in its concerns, ICIMOD focusses on the specific, complex and the practical problems of the Hindu Kush-Himalayan region, which covers all or part of eight Sovereign States. ICIMOD serves as a multidisciplinary documentation Centre on integrated mountain development; a focal point for mobilisation, conduct and co-ordination of applied and problem-solving research activities; a focal point for training on integrated mountain development, with special emphasis on the assessment on training needs and development of relevant training materials based directly on field case studies; and a consultative Centre providing expert services on mountain development and resource management. At present, ICIMOD is running a four-year programme on 'Indigenous honeybees of the Himalayas: A community-based approach to maintaining bio-diversity and enhancing farm productivity'.

Asian Apicultural Association (AAA) devotes itself to address the issues related to Asian beekeeping. Established in 1992, AAA networks with scientists and development workers interested in Asian bees and beekeeping. The main objective of AAA is to promote the exchange of scientific and general information relating to honeybee sciences and apiculture in Asia and to encourage international cooperation in the study of problems of common interest. Although, so far, AAA is not a big organization, it encourages research on the biology and management of honeybee species found in Asia. In order to share knowledge and information, AAA organizes a conference every two years. The first conference that led to the founding of the organization took place in 1992 in Bangkok, Thailand.

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