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An Overview of Himalayan Bee Flora

The Hindu Kush-Himalayan (HKH) region is one of the world's richest eco-systems in terms of plant diversity. This richness is due to the great variations in climate and habitat that are found there. Although the exact number is not known, it is estimated that over 9,000 species of flowering plants could be distributed throughout different ecological regions (Collett 1971; Polunin and Stainton 1987). The bees, however, do not visit all the plants, they have particular floral preferences; they visit some plants frequently, and others they do not visit at all. Moreover, different plants produce different amounts of nectar and pollen. The plants that the bees visit to collect their food (nectar and pollen) are called bee plants or bee flora. Based on a thorough knowledge of plants that provide nectar, pollen, or both, and their relative importance, management strategies can be implemented to maintain the strength of the colonies and to maximise honey yields. This chapter reviews the available information about bee flora in the Hindu Kush-Himalayan region. It also provides information on the food of the honeybee, i.e., nectar and pollen, and the factors influencing its availability.

Existing Information on Himalayan Bee Flora

Beekeeping research in the Hindu Kush-Himalayan region is mainly focussed on honeybees and bee products. Research on plants, the primary sources of honeybee forage and bee products, has generally been neglected. There is scattered information on the honey plant resources in different countries of the region, and the focus of this research is to identify and rank the honey plants according to the quality and the quantity of nectar and pollen available from them. Isolated reports on the bee flora in different agro-ecological zones of the Hindu Kush-Himalayan region indicate that it is host to diverse bee flora; including various agricultural, horticultural, and forage crops, ornamental plants, avenue trees, wild plants, and forest trees. The sources of this information on bee plants in the HKH are field surveys and melissopalynology (i.e., identification of the pollen grains in honey). Bee scientists at various universities and research institutions in different countries of the region have, so far, identified over 1,000 bee plants. The information documented on the honey plant resources in different countries of the region is reviewed in the following sections.

Afghanistan

There is very little information about the honey plant resources of Afghanistan, though beekeeping is a traditional household activity in this country. However, the distribution of many plants described in this book extends to several hilly areas of Afghanistan. The available information shows that *Acacia* spp, *Alhagi pseudoahagi, Cassia* spp, *Robinia pseudoacacia, Gossypium* spp., *Callistemon* spp, *Eryobotryn japonica, Prunus* spp, and *Citrus* spp are important honey sources in Afghanistan (Crane 1973)

Bangladesh

Among the variety of honey plant resources found in the hill areas of Bangladesh, about 36 plants, including *Acacia* spp, *Albizia* spp, *Brassica* spp, *Citrus* spp, *Litchi chinensis, Shorea robusta, Toona* spp, and *Zizyphus* spp constitute the major nectar sources (Alam and Zannat 1980; Dewan 1980; 1984). The recent establishment of large-scale rubber plantations by the Chittagong Hill Tracts' Development Board (CHTDB) in three hill districts, i.e., Bandarban, Khagrachari, and Rangamati, will increase nectar availability and promote commercialisation of beekeeping in these hill areas.

Bhutan

There is little information recorded on the bee flora of Bhutan. However, Bhutan is the only country in the HKH where more than 70 per cent of the total land area is covered by forests and other natural vegetation. These forests have a variety of plant species that are of great value to beekeeping. Other bee flora include temperate fruits, vegetables, and agricultural crops.

China

There are more than one thousand plant species providing nectar and pollen in the Chinese Himalayas (Focke 1968; Deh-Feng and Wen-

Cheng 1981; Yue-Zhen 1984). Among these, *Astragalus* spp, *Brassica campestris*, *Citrus* spp, *Eucalyptus* spp, *Fagopyrum* spp, *Frangula* spp, *Gossypium* spp, *Lamium* spp, *Medicago* spp, *Melilotus* spp,. *Litchi chinensis*, *Robinia* spp, *Tilia* spp, *Trifolium* spp, and *Vicia sativa* are major bee plants. According to Shikui and Zaiji (1989) and Zhen-Ming *et al.* (1992), different species of *Eurya* provide important bee forage in the hill areas of southern China. These reports confirm the existence of about 80 species of *Eurya*, among which the following nine species are very important for beekeeping: *Eurya muricata*, *E. brevistyla*, *E. groffii*, *E. loguiana*, *E. alata*, *E. chinensis*, *E. hebeclados*, *E. nitida*, and *E. megatrichocarpa*. Xu (1993), in his book on nectar and pollen plants of China, described almost 543 nectar and pollen plants belonging to 109 families. Among these, 44 plants are major nectar sources and 24 are major sources of pollen. Many of these species are distributed throughout the Himalayan region of China.

India

Bee flora of the Indian Himalayas have been studied extensively. Saraf (1972) reported 110 plant species, including *Aesculus* spp, *Brassica* spp, *Fagopyrum* spp, *Impatiens* spp, *Plectranthus* spp, *Polygonum* spp, *Prunus* spp, and *Pyrus* spp, as important bee plants from the Kashmir Valley. Singh and Singh (1971) and Atwal and Goyal (1974) identified *Plectranthus rugous* as an important honey plant in the Kashmir and the Kullu valleys. Sharma and Raj (1985) surveyed the bee flora of the Shivalik Hills of Himachal Pradesh and their possible impact on the beekeeping industry. They have reported *Adhatoda vasica*, *Bauhinia variegata*, *Brassica campestris*, *Dalbergia sissoo*, *Ehretia* spp, *Eucalyptus* spp, *Litchi chinensis*, *Mangifera indica*, *Rosa moschata*, *Rubus* spp, *Sapindus detergens*, and *Syzygium cumini* as important bee plants of the Shivaliks. Sharma (1989) made an extensive melissopalynological and botanical survey of the honey plants of Himachal Pradesh. Her list of important honey and pollen plants includes *Brassica napus*, *Dalbergia sissoo*, *Ehretia acuminata*, *Eruca sativa*, *Eucalyptus* spp, *Fagopyrum sagittatum*, *Impatiens glandulifera*, *Malus domestica*, *Medicago sativa*, *Melilotus* spp, *Litchi chinensis*, *Plantago* spp, *Plectranthus* spp, *Prinsepia utilis*, *Prunus* spp, *Pyrus* spp, *Robinia pseudoacacia*, *Sapindus* spp, *Syzygium cumini*, *Tilia* spp, *Toona ciliata*, and *Trifolium spp.*

Analyses of the results of many surveys of bee flora in the Indian Himalayas reveal that *Allium cepa*, *Berberis* spp, *Eucalyptus* spp, *Madhuca* spp, *Litchi chinensis*, *Olea glandulifera*, *Plectranthus* spp, *Polygonum* spp, *Prunus* spp, *Pyrus* spp, *Rosa moschata, Rubus niveus, Rumex* spp, *Shorea robusta,* and *Trifolium* spp are the main honey plants in that area (Singh 1983; Singh et al. 1983; Verma 1983).

By identifying pollen in honey samples from the northeastern Indian Himalayas, Singh (1989) recorded 16 plant species as important sources of pollen and nectar. Among these, *Adhatoda* spp, *Ageratum* spp, *Helianthus* spp, *Brassica* spp, *Bauhinia* spp, *Polygonum* spp, *Clematis* spp, *Mussaenda* spp, *Wendlandia* spp, and *Solanum* spp are major sources and *Acer* spp, *Ceasalpinia* spp, *Ocimum* spp, *Litsea* spp, *Parkea* spp, and *Senecio* spp are minor sources of nectar and pollen.

Myanmar

Zmarlicki (1984) evaluated the bee flora of Myanmar. His evaluation has an added value because of the details given of the honey plant calendars of important nectar- and pollen-yielding plants. He grouped all the honey plants recorded into three groups, viz., agricultural crops, horticultural crops, and wild plants and forest trees. Agricultural crops included *Helianthus annuus, Sesamum indicum, Guizotia abyssinica, Brassica* spp, *Capsicum annum*, various cucurbitaceous plants, and *Gossypium* spp as major sources of honey. Among the horticultural plants, *Citrus* spp, *Cocos nucifera, Litchi chinensis, Prunus insitia, Zizyphus jujuba*, and *Persea gratissima* are identified as major sources of honey. The wild plants and forest trees which are major sources of nectar and pollen for bees are *Eucalyptus* spp, *Eupatorium odoratum, Leucas aspera, Leucas zeylanica, Prunus cerasoides, Salmalia malabarica,* and *Tithonia tagitifolia*.

Nepal

The bee flora of Nepal have been extensively surveyed by Kafle (1984; 1992), Maskey (1989; 1992), and Partap and Verma (1996). These surveys have found that mixed types of bee forage occur in different ecological zones of the country. Among cultivated crops, *Litchi chinensis, Psidium guajava, Citrus* spp, *Mangifera indica, Moringa oleifera, Carica papaya*, various cucurbits, *Brassica* spp, *Raphanus sativus, Punica granatum, Guizotia abyssinica, Fagopyrum esculentum, Zea mays, Malus* spp, *Pyrus* spp, *Prunus* spp, and *Abelmoschus esculentus* are important sources of both pollen and nectar. Among ornamental plants, *Althea rosea, Malva rotundifolia, Ageratum conyzoides, Aster thomsonii, Centauria cyanus, Cosmos sulphureus, Solidago longifolia, Lagerstroemia indica,* and *Delonix regia* are frequently visited in preference to other plants by bees for both pollen and nectar. Wild plants include *Aesandra butyracea, Azadirachta indica, Albizia* spp, *Sapindus mukorossi, Syzygium cumini, Terminalia belerica, T. chebula, T. tomentosa, Salmalia malabarica, Shorea robusta, Fraxinus floribunda, Plectranthus rugosus, Colquihonia coccinia, Leucosceptrum canum, Aster oblongum, Zizyphus incurva, Pyrus pashia, Eupatorium adenophorum, Innula cappa,* and *Gentiana amoena* as important bee plants. Similarly, *Rubus ellipticus, Berberis aristata, B. asiatica, Mahonia nepaulensis, Salix babylonica, Rosa sericea, Ricinus communis, Vitex negundo, Castanopsis indica, Colebrookia oppositifolia,* and *Pogostemon* spp are some of the other wild plants visited by bees.

Bauhinia spp, *Buddleia asiatica, Scheflera venulosa, Ilex excelsa, Prunus cerasoides, Madhuca latifolia*, and *Leucaena leucocephala* are fodder trees that provide nectar and pollen to bees. Similarly, *Trifolium repens* and *Cynodon dactylon* are pastures species among which honeybees are observed to forage.

Kafle's general survey of the bee flora of Kathmandu Valley produced a list of 156 plants (Kafle 1984). Among these, 44 plant species, namely, *Aesandra butyracea, Brassica* spp, *Callistemon* spp, *Castanopsis indica, Citrus* spp, *Elsholtzia fruticosa, Eucalyptus* spp, *Fagopyrum esculentum, Fraxinus floribunda, Gravillia robusta, Guizotia abyssinica, Innula cappa, Psidium guajava, Prunus cerasoides, Punica granatum*, and *Solidago longifolia*, are the major bee forages. A general survey carried out by Partap and Verma (1996) confirmed Kafle's findings and recorded the occurrence of 113 plants constituting the bee flora of the Kathmandu Valley. Similarly, melissopalynological studies of *Apis cerana* honey from Jumla recorded the occurrence of about 103 plant species constituting the bee forage sources of that region. Most important among these are *Aesculus carnea, Ageratum conyzoides, Barleria cristata, Berberis spp, Brassica spp, Castanopsis indica, Clematis spp, Elaeagnus conforta, Elsholtzia spp, Fagopyrum esculentum, Fragaria indica, Gentiana capitata, Goldfussia capitata, Guizotia abyssinica, Helianthus annuus, Impatiens spp, Indigofera spp, Innula cappa, Leucosceptrum canum, Leycestria formosa, Mahonia nepaulensis, Malus domestica, Mentha sylvestris, Nepeta nervosa, Origanum vulgare, Osbeckia nepaulensis, Persicaria posumbo, Plectranthus mollis, Plectranthus rugosus, Polypogon hydropiper, Primula spp, Prinsepia utilis, Prunus cerasoides, Pyrus communis, Pyrus pashia, Pyracantha crenulata, Rhododendron arboreum, Rosa macrophylla, Rosa sericea, Rubus diffusus, Rubus* *ellipticus, Senecio scandens, Swertia ciliata,* and *Swertia dilatata* (ICIMOD 1996).

Owing to the abundance of bee flora, three main flows of pollen and nectar occur in the Kathmandu Valley (Kafle 1984; Maskey 1989). The first, spring flow (February to March), is supported by *Callistemon lanceolatus, Eucalyptus* spp, *Fraxinus floribunda, Grevillea robusta, Trifolium repens, Bauhinia* spp, *Berberis* spp, *Leucosceptrum canum, Pyracantha crenulata,* and *Pyrus pashia*. This flow helps the bees to increase their brood rearing, resulting in numerous swarms. It also has a good impact on honey yield in subsequent seasons. The second flow comes in the period from April to May. With this flow, and the resultant impact of the preceding spring forage, beekeepers in the area have sizeable honey harvests. This flow is followed by a period of dry and dearth conditions and additionally another situation unfavourable to bees, the main rainy season. The period from September until the end of November is the third main flow season of the year. The main forage plants in this period are *Prunus cerasoides, Fagopyrum esculentum, Aesandra butyracea, Brassica campestris, Helianthus annuus, Innula cappa, Solidago longifolia,* and *Vernonia talaumifolia*. A slight variation in honey flow season is observed by Maskey (1989; 1992). She has reported that the first honey flow is contributed by the *Trifolium repens* (April-May), the second by *Brassica campestris* (November-February-March), and the third by the presence of two or more nectar and pollen sources designated as mixed' seasons (September-October).

Pakistan

There are some 900 plant species known to constitute the bee flora of Pakistan (Ahmad 1992; Muzaffar 1992; Shahid 1992). Most of these are minor sources of pollen and nectar; some plants produce large quantities of pollen and nectar but are not abundant in the area. According to Muzaffar (1992), honey production is dependent upon a few plant species that yield nectar and pollen abundantly and which are sufficiently common. Among these, *Medicago sativa, Trifolium* spp, *Citrus* spp, *Gossypium* spp, *Prosopis* spp, *Acacia modesta,* and *Plectranthus* spp are major sources of commercial honey. Ahmad (1984) reported 30 plant species, including *Acacia modesta, Albizia lebbek, Antigonon leptopus, Calliandra calothyrsus, Cedrela toona, Epilobium angustifolium, Eriobotrya japonica, Eucalyptus albens, E. camaldulensis, E. citriodora, E. grandis, E. melliodora, Gleditisia triacanthes, Grevillea robusta, Haematoxylon campechianum, Lamium album, Melilotus alba,* *Medicago arboreum*, *Medicago falcata*, *Plectranthus rugosus*, *Prosopis juliflora*, *Prunus* spp, *Pyrus spp*, *Robinia pseudoacacia*, *Rosemarinus officinalis*, *Sapindus mucorossi*, *Terminalia chebula*, *Trifolium* spp, *Vitex negundo*, and *Zizyphus spina-christi*, as promising honey plants and recommended them for afforestation on erodible lands, in degraded landscapes, and on agricultural farms. In addition to the above-mentioned plant species, he also reported *Brassica campestris* and *Gossypium* spp as important bee plants in Pakistan.

Shahid and Qayyum (1977) listed 122 bee plants found in the North West Frontier Province (NWFP). Of these, 13 plant species, including *Acacia modesta*, *Adhatoda vasica*, *Brassica* spp, *Citrus* spp, *Dalbergia sissoo*, *Eriobotrya japonica*, *Eucalyptus* spp, *Malus sylvestris*, *Medicago sativa*, *Phoenix* spp, *Plectranthus rugous*, *Psidium guajava*, *Trifolium alexandrinum*, *Zea mays*, and *Zizyphus jujuba*, were recorded as major sources for the production of surplus honey, with five major honey flows per year at different localities in the province. They also recommended the migration of bee colonies at appropriate times to different places to facilitate maximum honey yields. Makhdoomi and Chohan (1980) also surveyed the bee flora of the NWFP and West Punjab and identified *Plectranthus rugosus*, *Eriobotrya japonica*, *Eucalyptus* spp, *Adhatoda vasica*, *Acacia modesta*, *Cedrela toona*, *Trifolium alexandrinum*, and *Medicago sativa* as major nectar sources. Manzoor and Mohammed (1980) identified *Helianthus annuus* as an important honey plant in Pakistan.

The foregoing review of literature reveals that bee scientists in the countries of the Hindu Kush-Himalayas have made great efforts to identify and rank the bee flora according to the quality and quantity of nectar and pollen produced. However, this information needs to be compiled in order to provide comprehensive data on bee flora of the Hindu Kush-Himalayas. The Directory of World Honey Sources (Crane et al. 1984) is one example of such an undertaking. These authors compiled the work carried out by many bee scientists and described 453 plant species which are important sources of honey in 144 countries, including all the countries in the Himalayan region except Bhutan. The Directory, however, covers only those plants in the HKH which are major sources of honey; it does not describe other important plant species that provide enough nectar and pollen for the survival of bee colonies during dearth periods and which are, thus, very important for beekeeping. Verma (1990) reviewed the work carried out on the bee flora of the HKH region and devoted a chapter to honey plant resources in his book on 'Beekeeping in Integrated Mountain Development'. He listed the important nectar and pollen plants of the region. Yet, detailed data about each one of the potential honey plants in the HKH are lacking.

Information on important bee flora in the HKH *per se* has not yet been compiled, especially in a form that would be of practical use to bee entrepreneurs and firms. Many beekeepers, extension workers, and NGOs need specific information which answers questions such as:

1) which are the important bee plants in a particular agro-ecological zone?
2) how can bee plants be identified?
3) what plants should be grown to increase the beekeeping potential of a given area?
4) during plantation, what should be the considerations in the bee-keeping context? and
5) how can one find the plant source of an unknown honey?

Categorisation of Bee Flora

In order to survive, prosper, and be productive, honeybee colonies need an adequate supply of both pollen and nectar. As stated earlier in this chapter, the plants from which bees collect pollen and nectar are called 'bee plants'. The flora of an area are characteristic of its agroclimatic conditions. For example, the flora of the plains will be different from those of the mountains. Moreover, differences in longitude, latitude, and altitude cause variations in the behaviour of the bees and plant species; climatic conditions also affect the distribution and habit of plant species. The nectar and pollen potentials of a plant species vary, depending upon the longitude, latitude, and altitude. A plant can be a major source of nectar and pollen in one area and only a minor source in another. Among these variations, altitude is the most important factor in the context of creating differences in climate and, thus, in flora. Based on the agroclimatic zones, the bee flora of the Himalayan region are categorised into three groups: **sub-tropical, sub-temperate, and temperate.**

The most widely-accepted criterion used for the categorisation of bee flora is the **type of bee food**. Plants that supply nectar abundantly but little or no pollen are considered to be **nectar or honey plants**. These nectar or honey plants are best suited for honey production. Important nectar sources of different agroclimatic zones of the Himalayan region include *Achras japota, Aesandra butyracea, Calliandra* spp, *Citrus* spp, *Gossypium* spp, *Grevillea robusta, Leucas aspera, L. zeylanica,* *Leucosceptrum canum, Medicago sativa, Melilotus alba,* and *Trifolium repens.* Plants supplying pollen but little or no nectar are called **pollen plants**. Examples are *Bidens* spp, *Cynodon dactylon, Leucaena leucocephala, Mimosa pudica, Vitis vinifera,* and *Zea mays.* Pollen plants are important in beekeeping, especially at the time of colony build-up, when bees need large amounts of protein for brood rearing. Many plants, however, provide both nectar and pollen in good amounts. These plants are called the **nectar and pollen plants**. Such plants include *Acacia arabica, Brassica* spp, *Citrus* spp, *Carthamus tinctorius, Eucalyptus* spp, *Guizotia abyssinica, Helianthus annuus, Litchi chinensis, Prunus insitia, Prunus persica,* and *Raphanus sativus.*

Nectar and pollen plants are further classified on the basis of their **nectar and pollen potentials**. Nectar and pollen potentials can be defined as the quantity of nectar or pollen produced by a crop grown on one hectare area of land (Crane *et al.* 1984). Plants that produce surplus nectar and pollen and are abundantly available in an area are **major sources** of pollen and nectar. These plants supply important annual honey flows. Plants that supply sustained annual flows of nectar and pollen used in the maintenance and development of bee colonies are **medium sources**. These plants provide a main flow under favourable ecological conditions. The third group includes plants from which honeybees do not generate surplus honey, yet the plant provides enough nectar and pollen for the bees to survive on during dearth periods. These plants are called **minor sources** of pollen and nectar and are also important for beekeeping.

Cirnu *et al.* (1976) developed another criterion for classifying bee plants based on their economic contribution to beekeeping. These authors categorised all recorded honey plants into five groups. The first group includes plants with a **very high economic contribution to beekeeping**. They are characterised by high honey potential, cover important areas in a particular country, and supply important honey flows, for example, *Helianthus annuus, Sesamum indicum, Tethonia tagetifolia,* and *Zizyphus jujuba.* The second group includes plants with a **high economic contribution to beekeeping**. These are characterised by high honey potential, cover rather large areas, and supply periodic or annual honey flows, for example, *Brassica* spp, *Citrus* spp, *Aesandra butyracea,* and *Guizotia abyssinica.* The third group includes plants with a **medium economic contribution to beekeeping**. These plants supply sustained annual maintenance flows of nectar and pollen and, in favourable ecological conditions, may even provide the main flow. The fourth group includes plants with a **low economic contribution to beekeeping**. These plants supply nectar and pollen frequently, helping to maintain bee colonies without ensuring the main flows. Lastly, the fifth group includes plants **without any economic contribution to beekeeping**. These plants supply pollen and nectar only from time to time and for short periods, covering either small areas or producing small amounts of nectar and pollen.

Other criteria for the categorisation of bee flora and those generally used for the classification of plants are: i) plant form (**trees**, **shrubs,** or **herbs**) and ii) plant habitat (**cultivated** or **wild**). The categorisation of bee flora is summarised in Table 2.1.

Table 2.1 ***Categorisation of Himalayan bee flora***

Agroclimatic zones	**Plant forms**	**Habitat**
Subtropical bee flora	Trees	Cultivated plants • *Agricultural crops*
Subtemperate bee flora	Shrubs	• *Horticultural crops* • *Forage crops*
Temperate bee flora	Herbs and annuals	• *Ornamental plants*
		Wild plants and forest trees
Bee food	**Nectar and pollen potential**	**Economic contribution**
Nectar or honey sources	Major nectar or pollen sources	Very high
Pollen sources		High
Nectar and pollen sources	Medium nectar or pollen sources	Medium
	Minor nectar or pollen sources	Low
		None

Source: Compiled by the Author

In Chapter Five, honey plants are categorised into five major groups: Agricultural Crops, Horticultural Crops, Forage Crops, Ornamental Plants, and Wild Plants and Forest Trees, in order to make this book more useful for beekeepers, beekeeping extension workers, farmers, and other private entrepreneurs.

Honeybee Forage: Nectar and Pollen

Nectar and pollen are the basic raw materials of the beekeeping industry. Nectar provides energy to the bees for flight, foraging, and performing other hive activities. Bees convert the excess nectar into honey and store it in the combs. Pollen is the sole source of the proteins, lipids, minerals, and vitamins needed to feed the brood and immature adult bees. The production of nectar and pollen is affected by numerous factors, and these are described in detail in the following text.

Nectar

Nectar is a water-based solution of sugars and minor amounts of numerous constituents which include proteins, amino acids, organic acids, lipids, antioxidants, dextrin, minerals, volatile oils, and enzymes (Baker and Baker 1983). The concentration of sugar in nectar at the time of collection varies from four or five per cent to more than 60 per cent. The amino acid content of nectar (0.002-4.8mg per 100mg total solids) is too low to contribute significantly to honeybee nutrition. The organic acids and volatile compounds contribute significantly to the flavour of honey.

Nectar is secreted by glands called **nectaries**. **Floral nectaries** are found in parts of the flower such as the receptacle, base and apex of the ovary, below the stamens, on the petals and sepals; or **nectaries** are **extrafloral** when found on the vegetative aerial parts, e.g., between and below the bracts, on the petiole, on the undersurface of leaves; on the leaf midrib and between the midrib, and on the main veins. Both floral and extrafloral nectaries may occur on the same plant, e.g., cotton and broad bean (Butler et al. 1972; Davis et al. 1988). More than one form of extrafloral nectary may be present; for example, cotton has extrafloral nectaries in several locations and the trumpet creeper has four extrafloral nectary systems in addition to the floral system (Elias and Gelband 1975).

Nectaries may consist of a simple group of cells with little to distinguish them from the adjacent tissue or they may be conspicuous structures, as seen in the *Poinsettia*. Often highly-developed nectaries are more richly pigmented than their adjacent tissues. Brighter green, orange-gold, yellow-gold, yellow white, or white nectaries occur in different species of *Lamium*.

Nectar is basically phloem sap which has undergone certain alterations during the secretory process. Depending upon the plant species, xylem sap may be present. The overall process includes the unloading of sap from the phloem sieve tubes, passage of the sap (sometimes called pre-nectar) from cell to cell through the subglandular tissue and secretory cells, and, finally, the expulsion of the finished nectar to the outside.

Factors Influencing Nectar Production

Factors influencing nectar production are classified into two categories:

i) internal factors, and
ii) external (environmental) factors.

These have been discussed below.

<u>Internal Factors.</u> Internal factors affecting nectar production include genetic and physiological factors and pollination and fertilization. These are reviewed by Shuel (1992).

Genetic and Physiological Factors

The potential for nectar yield is determined by heredity; the extent to which the potential is realised depends upon the environmental conditions of weather and soil. In the context of the physiology of secretion, the yield depends upon two basic factors: the secretory capacity of the nectary and the quantity of sugar delivered to it. Different varieties of various crops, for example red clover, alfalfa, white clover, cucumber, and rape seed differ substantially in the amounts of nectar secreted. This hereditary variation in nectar yield is linked to anatomical features such as the volume of nectariferous tissue, nectary size, diameter of the receptacle, and the number of nectary stomata.

Where male and female flowers are present on the same plant, their nectar yields may differ. For example, the female cucumber flower secretes more nectar than the male flower (Collison 1973). The male flowers of the banana yield several times more nectar than the female flowers, and the male flowers of the willow produce more nectar than the female flowers (Fahn 1949).

Secretory rates may differ with the age of the flower. For example, cucumber flowers produce most of their nectar on the day of anthesis, a majority of flowers produce little or none on the second day (Collison 1973), and the dandelion flower secretes on two successive mornings, with a larger yield on the second day (Szabo 1984). Amongst species which flower during the day, variations have been observed in the time of the day at which bee visits occur, which, in turn, may serve as an indicator of the rate of nectar production (Meeuse 1961).

Pollination and Fertilization

Nectar secretion is also affected by pollination and fertilization. It begins about the time the flower opens, pollen ripens, and the stigma becomes receptive. As a result of this timing, pollination is successful and leads to fertilization. Fertilization, in turn, seems to activate a feedback mechanism in the flower which switches off the secretion of nectar. The flowers of lavender, alfalfa, cucumber, and cotton quickly wilt and cease to produce nectar shortly after the bee's visit.

External (Environmental) Factors. The external factors that affect nectar production in plants are light, temperature, atmospheric humidity, and soil.

Sunlight

Sunlight is of primary importance for nectar production. During flowering, it supports a high level of photosynthesis and produces more sugars. Duration of sunshine is the weather factor which is most influential in determining nectar yield in many plants, e.g., alfalfa, sainfoin, and white clover. In red clover and alsike, a close association occurs between solar energy reaching the plants in the 24-hour period immediately preceding nectar secretion and the nectar yield (Shuel 1952; 1957); and there is also a close association between hours of sunshine and the nectar yields of sainfoin and white clover (Kropakova and Haslbachova 1970). In a greenhouse, where temperature and soil conditions were favourable to secretion, daily nectar yields of red clover varied by as much as 300 per cent with fluctuations in incident solar radiation (Shuel 1952).

Temperature

Nectar production involves many individual processes within the plant, each of which is probably affected by temperature. Nectar production hus a direct correlation to air temperature. Alternation of high day and low night temperatures promotes good nectar flows. Minimum threshold temperatures for secretion have been reported for various plants.

Basswood flowers begin to secrete nectar at 18°C, bird cherry at 8°C, cherry laurel at 18°C-20°C, cucumber at 17°C-21°C, and several cultivars of soybean at 21°C (Beutler 1953; Collison 1973; Erickson 1975). There is little information on the optimum temperature range and the upper temperature limit for nectar secretion in different species. In soybean plants, nectar secretion increases progressively with an increase in daytime temperatures from 20° to 32°C. Prolonged high temperatures in the absence of adequate soil moisture adversely affect nectar production, owing to moisture stress in the plant. Under such conditions, photosynthesis and sugar transport are reduced and may cease completely (Crafts and Crisp 1971). When soil moisture is plentiful, continuous hot weather has the effect of accelerating flower development, so the nectar flow may be of shorter duration but of greater intensity.

The temperatures to which plants are exposed before flowering determine the number of flowers produced and, therefore, the nectar yield per plant. When honey crops are obtained from trees and shrubs, temperature effects, like those of sunshine, are extremely complex and difficult to predict. Nectar flows in *Eucalyptus,* for example, are influenced by the weather conditions occurring for several years preceding the honey harvest. Cool temperatures at the time of flowering favour the nectar flow (Porter 1978).

Atmospheric Humidity

Although there is no evidence that atmospheric humidity affects nectar secretion directly, it may have an indirect effect, similar to that of temperature, through its influence on the rate of water loss from the plant by transpiration. Nectar sugar yield in some plants, e.g., cotton, decreases with decreasing relative humidity, probably owing to water stress (Butler et al. 1972). The most important effect of humidity on nectar production is manifested as an inverse correlation with the concentration of solids. This effect is chiefly physical, and can be explained as follows: as nectar is secreted, it begins to exchange water molecules with the surrounding atmosphere, tending to approach an equilibrium with it, but not attaining it (Corbet et al. 1979). Unless atmospheric humidity is very high, the result will be a net loss of water molecules from the nectar and an increase in sugar concentration. The rate of increase in sugar concentration depends on humidity, air movement, temperature, and the degree to which the nectar is protected by the flower parts.

Soil Conditions

The physical condition of the soil with respect to water content, temperature, and aeration is very important in establishing the base for a honey crop. Sandy soils support good nectar yields, except in dry years when heavier soils can be superior (Johnson 1946). Several honey production records indicate that the best crops occur in slightly wetter seasons. Dry soils reduce both nectar and flower production. Water deficiency also promotes a decrease in nectar sucrose and an increase in glucose and fructose.

Soil temperature affects the number of flowers produced by the plant, as well as the amount of nectar produced by individual flowers. Less nectar is produced at a soil temperature of 16°C than at 20°C, and the yield is also reduced in soil with a water content either above or below the optimum (Shuel 1992).

Soil fertility determines both flower production and nectar secretion. Experimental evidence shows that fertilizer input, particularly of potassium and phosphorus, increases the number of flowers and nectar production in a number of crops. The best nectar yields are produced by a reasonable balance between these two elements. Leguminous plants yield good amounts of nectar when grown in calcareous soils, suggesting that calcium, magnesium, or high soil pH favour nectar secretion in leguminous crops. Application of boron to boron-deficient soils makes flowers more attractive to honeybees because of increased concentration of sugar in nectar (Holmes 1960).

Nectar and Honey Potentials

Nectar potential is the amount of nectar produced during a season by a crop in one hectare of land. A plant species is considered to be a major source of nectar if it secretes large quantities of nectar and contributes to surplus honey, or a minor source if it provides just enough nectar for the survival of bee colonies without generating surplus honey. Since honey is produced mainly from nectar, **honey potential** is the estimated weight (kg) of honey that can be obtained in the course of a season from one hectare of land covered with the plant, assuming optimal conditions (Crane 1975). Like nectar, honey potential varies from species to species and also according to climatic and soil conditions. Factors such as air temperature, humidity, and soil moisture, which affect nectar production, also affect the honey potentials of any particular plant species/

crop. As an example, the honey potentials of some common bee plants of the Hindu Kush-Himalayas are given in Table 2.2.

Pollen

Pollen is a key element in pollinator-flower relationships. As discussed earlier (page 23), it is essential for honeybee nutrition and provides pro-

Table 2.2 **Honey Potential of Common Bee Plants in the Hindu Kush-Himalayan Region**

Plant species	Honey Potential (kg/ha)	Remarks/Factors
Brassica campestris	50-100	Needs good irrigation
Eucalyptus spp	1000-1500	Varies with age and size of the tree
Litchi chinensis	500-1000	Healthy plants
Dalbergia sissoo	200-300	Requires good rains during winter
Syzygium cumini	200-300	Large, healthy trees
Azadirachta indica	100-200	Large, healthy trees
Cedrela toona	300-500	Uniform plantations and age of trees
Sapindus mukorossi	300-500	Uniform plantations and age of trees
Berberis spp	100-300	Thick bushes
Terminalia chebula	100-300	Healthy trees and uniform plantations
Prunus armeniaca	100-300	Uniform plantations and healthy trees
Malus domestica	15-20	Requires plentiful rains during winter
Trifolium alexandrinum	300-500	Requires good irrigation
Gossypium spp	100-300	Healthy crop, good irrigation
Robinia pseudoacacia	500-1000	Requires plenty of soil moisture
Acacia catechu	100-300	Requires plentiful rains before flowering and light rain during flowering
Trifolium repens	200-500	Requires good irrigation and soil moisture
Plectranthus spp	500-1000	Requires plentiful rain during rainy season and good soil moisture
Prunus cerasoides	100-300	Requires good soil moisture
Brassica napus	300-500	Requires good irrigation
Helianthus annuus	100-200	Requires good irrigation

Source: Joshi 1992

teins, lipids, minerals, and vitamins that the honeybees feed the and immature adult bees (Gary 1992).

Biologically, nectar and pollen are in different categories; nectar is a product of secretory activities, but pollen grain is an integral part of the plant, a spore, also called a microspore or male gametophyte. In flowering plants, pollen is produced in four pollen sacs in the anthers. Each pollen sac contains numerous pollen mother cells which undergo meiotic cell division to produce haploid pollen grains (microspores). These pollen grains are released by the dehiscence, e.g., opening of the anthers.

The time of the day at which pollen is released is a species' characteristic. Some plants, such as sunflower and rape seed, release pollen early in the morning, whereas others, e.g., broadbeans do so in the late afternoon. Depending upon the time of pollen release, angiosperms are divided into six categories (Percival 1955). In the flowers of some plants, pollen is released continuously throughout the day. The amount of pollen released in flowers of the same species varies widely depending upon the age of the plant. In some plants, e.g., black currants and maize, pollen release takes place almost simultaneously in the stamens of all flowers, whereas in other plants it extends over a period of hours, and a few plants, e.g., raspberries release pollen over a period of several days.

Pollen from different plant species differs greatly in nutritive value and attractiveness to bees. Pollen is classified **as highly nutritious, nutritious, fair, and poor,** depending upon the evaluation of pollen sources on the basis of their efficiency in supporting development of hypopharyngeal glands and fat bodies. Pollen from fruit trees, willows, maize, and clover is among the best, dandelion pollen ranks second, and the pollen of pine and other conifers is the poorest. In tests based on the brood produced per unit of diet consumed, differences were found even among closely-related plant species (Loper and Berdel 1980). From the results of various feeding tests, it appears that the amino acid balance is a major determinant in the nutritional efficiency of pollen. Mixed pollen usually seems to be preferred by bees to a single source.

Factors Influencing Pollen Collection by Honeybees

Pollen collection by honeybees appears to be influenced by a number of factors, both internal and external to the colony (Shuel 1992). The colony's need for protein is important. The presence of unsealed brood stimulates pollen foraging (Free 1967; Barker 1971), and the foraging is intense during population build-up in spring (Free 1967; Barker 1971). The absence of unsealed brood inhibits pollen foraging.

Among the external factors influencing pollen collection, the temperature is most important. In England, a positive correlation exists between daily maximum air temperatures and the number of pollen loads collected by honeybees (Synge 1947). This is mainly because a high temperature accelerates dehiscence of the anthers, whereas a low temperature delays dehiscence by retarding the pollen ripening process. The minimum temperature for dehiscence varies with the species and may be quite low for those which flower in spring, e.g., the anthers of apple have been observed to dehisce at 5°C (Percival 1955).