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ECTD_203

TITLE: Bees and honey in the exploitation of arid land resources

SOURCE: Chapter in: *Plants for arid lands*, Ch. 13, pp. 163-175 ed. G.E. Wickens, J.R. Goodwin, D.V. Field. London: George Allen & Unwin

DATE: 1985

PLANTS FOR ARID LANDS

Proceedings of the Kew International Conference on Economic Plants for Arid Lands held in the Jodrell Laboratory, Royal Botanic Gardens, Kew, England, 23–27 July 1984

Editors

G. E. WICKENS — *Royal Botanic Gardens, Kew, Richmond, Surrey*

J. R. GOODIN — *Texas Tech University, Lubbock, Texas, USA*

D. V. FIELD — *Royal Botanic Gardens, Kew, Richmond, Surrey*

London
GEORGE ALLEN & UNWIN
Boston Sydney

1985

12 Bees and honey in the exploitation of arid land resources

Eva Crane

International Bee Research Association (IBRA), Hill House, Gerrards Cross, Bucks SL9 0NR, UK

Introduction

My own interest in the subject of this chapter is bee-orientated, and it is necessary to explain briefly the background, and the history of IBRA's World Survey of Honey Sources (WHOS), before presenting some of the first results to come from it.

The estimated world's annual production of honey, according to official statistics, is a little short of a million tonnes, and the actual production – the amount harvested – is doubtless larger than this. Over 200 000 tonnes are exported on to the world market. The three major exporters are China, Mexico and Argentina, all of which include subtropical arid regions. Such areas can be important for honey production: when skies are clear, energy from the sun is freely transmitted to plants, and some of this energy is converted into sugar which plants secrete as nectar. If sufficient bees are present, this nectar can be converted into honey and harvested.

Areas made agriculturally unproductive by deforestation or improper farming usually become drier. But some of the plants that colonize such areas can be good honey sources, so that bees do well there. This is no new observation. Plato bemoaned the deterioration of the land by excessive farming *c.* 400 BC, in a passage in *Critias*. He referred to 'mountains in Attica which can now support nothing but bees, but which were clothed, not so very long ago, with fine trees . . . The country [then] produced boundless pasturage for cattle'.

Plants supply all the bees' food resources, i.e. nectar, honeydew and pollen, – and also the propolis they use in building their nest. Beeswax, venom and bee milk (used for feeding the young) are metabolized by adult worker bees, beeswax largely from carbohydrates in nectar and honey, and venom and bee milk largely from proteins in pollen. Immature bees cannot be reared without pollen, or an adequate pollen substitute provided by the beekeeper.

Using bees to crop the land is usually not an alternative, but an additional way of getting a harvest. And if the honey sources are plants that yield seed or fruit, the bees may increase yields by their pollinating activities.

Traditionally, honey is the harvest from bees that beekeepers work for, although some of them also harvest the various other substances mentioned above. The bees' foraging behaviour in collecting the raw materials of honey is keenly attuned to obtaining the maximum energy reward for a minimum energy expenditure. In European countries they disregard dilute nectars such as pear or plum when dandelions, with their more concentrated nectar, are growing nearby.

The pattern of bees that produce the world's honey is much more complex than anything Plato knew. As used here, the word 'bees' refers mainly to honeybees, genus *Apis*, for which there are four species; some taxonomists subdivide them, but there is no need to do so in the present context. The European hive bee, temperate-zone *Apis mellifera*, is indigenous to the Old World and has been introduced to many parts of the New World. Except in some parts of Asia, and parts of Latin America, the world's large-scale honey production is based on beekeeping with this bee. There are tropical ecotypes in Africa south of the Sahara, one of which was introduced to South America in 1956 and has spread widely there and into Central America as far as Costa Rica. In Asia, *Apis cerana* is the counterpart of tropical *Apis mellifera*; it is smaller, and generally less productive. In many countries bee-keeping with *Apis cerana* remains traditional, with fixed-comb hives, but in India especially it has been developed with modern movable-frame hives.

The other two species of *Apis* cannot be kept in hives, as their nest consists of a single comb built in the open. Honey is obtained from them by traditional honey-hunting methods. *Apis dorsata* has the largest body size of the four species. In India, and probably also in some other countries of tropical Asia, more honey is still produced from honey-hunting with *Apis dorsata* than from beekeeping with *Apis cerana*. *Apis florea*, the smallest of the species, is 'managed' to a certain extent for honey production in Oman, and elsewhere honey is harvested from wild nests.

In much of the tropics and subtropics honey is also obtained from colonies of stingless bees (Meliponini). In some regions, especially parts of Central and South America, certain species are kept in traditional hives, and can yield more honey than *Apis florea* colonies.

Historical background, and WHOS Phase I

In the present context honey sources are plants that yield nectar and/or honeydew from which bees produce honey. For historical and economic reasons most studies of them have been made on a local, subnational or national level.

In the early 1970s, when planning a comprehensive survey on honey (Crane 1975), a chapter on the world's honey plants was considered essential. There was no specialist in this subject, so I wrote the chapter, and my first task was to try to identify the most important honey sources on a world scale. Brief characteristics of 211 plant species or genera and their honeys were finally included, the selection being on a rather *ad hoc* basis. This material was augmented by a 17-page list of the best available publications on honey plants of individual countries. In Crane (1980), the same plants, with 21 important additions, were listed in relation to their world distributions. From 1975 onwards unpublished material was collected from institutions and individuals in as many countries as possible, attention being paid especially to the developing countries of the tropics and subtropics.

At several International Beekeeping Congresses discussions were initiated on the possibility of a Survey of World Honey Sources (WHOS). But in spite of much interest, and a general appreciation of the importance of the concept, no funding was available until 1979 when the International Commission for Bee Botany obtained a small subvention from its parent body, the International Union of Biological Sciences. It enabled a start to be made, and Phase I of WHOS was carried out at IBRA in 1980–1981. From published and unpublished material, 2569 plant species were recorded on multi-copy paper slips, each plant being reported as a honey source from at least one country, and some from many.

Funds for Phase I were too small to allow any publication of the results, except for a list of the 160 plant families recorded, with the number of plants species in each (Crane 1983a). Three families, Leguminosae (327), Myrtaceae (261) and Compositae (226) contributed nearly one-third of all species.

WHOS Phase II: Directory of important world honey sources

The next step was clearly to make some of our information on honey sources available. It was considered essential to prepare and store the information for publication in such a way that programmed searches could be made for honey sources that have specific characteristics. In 1982 IBRA obtained funds from the International Development Research Centre, Ottawa, for the preparation and publication of an international directory of honey sources (Crane, Walker & Day 1984). The first programmed searches, after those run for this directory, were used in preparing this Chapter.

The directory is something new in concept, in content, and in method of preparation. It identifies 467 plants, out of the preliminary selection 2569, that are reported to be major sources of the honey in a particular country or area. Some of these honey sources are geographically widespread, such as lucerne (*Medicago sativa*) and many of *Eucalyptus* species; others are confined to a single area, such as plectranthus (*Rabdosia rugosa*) which grows only on certain slopes of the western Himalayas.

The major part of the directory contains the main entries for the honey sources selected; 452 nectar-producing plants and 15 honeydew-producing plants. The information in these entries is supported by a bibliography of 820 references; almost all of them are held by IBRA, and each is coded with its library shelf mark. Table 12.1, p. 166, identifies the characteristics that were sought for each plant.

Seven lists of important honey sources with special characteristics are printed in

Table 12.1 Summary of information in main entries of the Directory.

For each plant, information (as available) is printed in the order below. Data on similar characteristics are grouped together in paragraphs or 'blocks', as shown. The 51 search fields are indicated by *.

entry number **Botanical name of plant, authority; family**
any synonyms

common names
vegetative form of plant* (tree/shrub/herb); floral description
Distribution (tropical*, subtropical*, temperate*); and where native
Habitat
Soil (salt-tolerant*). **Temperature** (damaged by frost*). **Rainfall** (drought-tolerant*)

Economic* and other uses
Food*. Fodder*. Fuel*. Timber*. Land use (hedges*, windbreaks*, shade*, afforestation*, amenity*). **Soil benefit*** (erosion control*, enrichment*). **Other uses**

Warning about the plant* e.g. toxicity of plant, including nectar, to man or animals (see also under pollen, honey), invasiveness. **Aliens to beekeepers***: difficulties in bee management, honey handling, etc.

Nectar rating + honeybee species
Nectar rating of a plant in a country is: **N1** = major honey source; **N2** = medium honey source; **N3** = minor honey source; **N** = honey source, importance unrated.

Apis species: ac = *A. cerana*, ad = *A. dorsata*, af = *A. florea*, am = *A. mellifera*, tm = tropical *A. mellifera*

Blooms (dates). **Nectar flow** (dates or duration). **Nectar secretion. Sugar concentration*** (low ⟨ 21%/medium 21–60%/high 61+%). **Sugar value***, mg/flower/day (low ⟨ 0.1/medium 0.1–2/high 3+). **Sugar analysis.** Other characteristics.

Honey flow
Specimen **honey yield***, kg/colony/season (high 30+/moderate ⟨ 30).
Honey potential*, kg/ha/season (high 500+/moderate ⟨ 500).

Pollen
value to bees*: high: Pl rating reported (e.g. high nutritive value to bees; produced in large quantities); pollen recorded as collected by bees; warnings – toxic pollen, sticky pollen, pollen inadequate for brood rearing

representation of grains in honey*: under-represented (⟨ 20 000 per 10 g)/over-represented (⟩100 000 per 10 g)

Honeydew
honeydew produced on plant*; honey yield from honeydew: surplus recorded either numerical or not

Table 12.1 – continued

Recommendation for propagation as a bee plant
Recommendation for planting has been published*

Honey composition
water*: low ⟨ 16/medium 16–20/high 21 (FAO max) and over; **glucose***: low ⟨ 31/medium 31–39/high 40+; **fructose***: low ⟨ 35/medium 35–42/high 43+; **sucrose***: low ⟨ 1/medium 1–4/high 5 (FAO max) and over; **reducing sugars***: low ⟨ 65 (FAO min)/high 65 and over; **ash***: low ⟨ 0.1/medium 0.1–1.0/high 1.0 (FAO max) and over; **free acids*** (meq/kg): low ⟨ 15.0/medium 15–39/high 40 (FAO max) and over; **amylase*** (Gothe): low ⟨ 3 (FAO min)/high 3 and over; **HMF*** (ppm): high 40 (EEC max) and over/low below 40 (HMF not included in FAO/WHO Codex); **fermentation** on storage*: likely/unlikely/never; **vitamins*** present; **toxicity*** any information on adverse reactions, e.g. when fed to bees; **colour**: any unusual tinges*; **Pfund*** (mm): white 0–34 (includes grades water white to white), amber 35–114 (includes grades extra light amber, to amber), dark 115+ (grade dark amber); **granulation*** complete within: ⟨ 2 wks = rapid/2–52 wks = medium/⟨ 1 yr = slow; **flavour** descriptions: bland or strong*, very sweet*, objectionable*, unusual flavour*.

the directory. The lists were made by running programmes to search the data base, using some of the 51 coded fields, e.g. Table 7b in Crane, Walker and Day (1984), identifies the 37 honey sources showing some degree of salt tolerance.

The directory also includes a separate list of 196 candidate plants, which might have been eligible for inclusion if more information had been available.

Honey sources for arid lands

Data presented below are derived from searches such as that mentioned above: all the data refer to plants in the directory, that is, plants reported to be a major honey source in one or more parts of the world.

Of the 467 plants, 77 are listed in Table 7a of the directory as drought-tolerant, including 11 that are very drought-tolerant. Of the 77, 73 are found in the directory from at least one place in the tropics and subtropics. Table 12.2, p. 168, lists 47 relevant to the arid or semi-arid tropics, and Table 12.3, p. 169, contains 58 relevant to the arid or semi-arid subtropics, plus four recorded only in temperate zones. Eleven of the 77 were new additions to Kew's SEPASAT data bank.

Tables 12.2 and 12.3 identify plants that could form a useful basis for beekeeping in arid or semi-arid lands: to add substance and savour to the food, or to add to the income by the sale of honey to the poorer indigenous peoples or, at a higher economic level, to stimulate a modest beekeeping industry. Among the important world honey sources, we rated as high any yield of 30 kg/colony/year or more (from a single source). Table 12.4, p. 171, gives examples of honey yields from some of the plants in Tables 12.2 and 12.3. It shows that a fair proportion of the plants listed are among the best of the world's honey sources.

Table 12.2 Drought-tolerant plants recorded in the tropics that are important world honey sources. *very drought-tolerant, T=tree, S=shrub, H=herb.

002*	*Acacia caffra*; Leguminosae	S
005	*Acacia mellifera*; Leguminosae	S
008*	*Acacia senegal*; Leguminosae	T
009	*Acacia seyal*; Leguminosae	T
010	*Acacia tortilis*; Leguminosae	T
022	*Agave americana*; Agavaceae	H
024	*Aloe dichotoma*; Liliaceae	T
030	*Anacardium occidentale*; Anacardiaceae	T
039	*Azadirachta indica*; Meliaceae	T
066	*Caesalpinia coriaria*; Leguminosae	T
067	*Cajanus cajan*; Leguminosae	S
070	*Calliandra calothyrsus*; Leguminosae	S
078	*Cassia siamea*; Leguminosae	T
093	*Citrus limon*; Rutaceae	T
106	*Combretum celastroides*; Combretaceae	S
122	*Dalbergia sissoo*; Leguminosae	T
126	*Dialium engleranum*; Leguminosae	T
156	*Eucalyptus camaldulensis*; Myrtaceae	T
172	*Eucalyptus leucoxylon*; Myrtaceae	T
176*	*Eucalyptus melliodora*; Myrtaceae	T
180	*Eucalyptus paniculata*; Myrtaceae	T
187	*Eucalyptus sideroxylon*; Myrtaceae	T
205	*Gleditsia triacanthos*; Leguminosae	T
207	*Glycine max*; Leguminosae	H
208	*Gmelina arborea*; Verbenaceae	T
217	*Gymnopodium antigonoides*; Polygonaceae	S
221	*Helianthus annuus*; Compositae	H
237	*Ipomoea batatas*; Convolvulaceae	H
244	*Jacquemontia nodiflora*; Convolvulaceae	H
246	*Julbernardia paniculata*; Leguminosae	T
290	*Medicago sativa*; Leguminosae	H
296	*Melilotus alba*; Leguminosae	H
313	*Olea europaea subsp. africana*; Oleaceae	S
315	*Opuntia engelmanii*; Cactaceae	H
319	*Parkinsonia aculeata*; Leguminosae	T
330	*Pithecellobium dulce*; Leguminosae	T
335	*Pongamia pinnata*; Leguminosae	T
336*	*Prosopis cineraria*; Leguminosae	T
338*	*Prosopis glandulosa*; Leguminosae	T
339*	*Prosopis juliflora*; Leguminosae	T
340*	*Prosopis pallida*; Leguminosae	T
349	*Rhigozum trichotomum*; Bignoniaceae	S
397	*Tamarindus indica*; Leguminosae	T
441	*Viguiera helianthoides*; Compositae	H
448*	*Ziziphus mauritiana*; Rhamnaceae	T
452*	*Ziziphus spina-christi*; Rhamnaceae	T

Table 12.3 Drought-tolerant plants recorded in the subtropics that are important world honey sources. (4 grow exclusively in temperate zones – see end of Table, while others extend into temperate zones). *very drought-tolerant; T=tree, S=shrub, H=herb.

001	*Acacia berlandieri*; Leguminosae	S
002	*Acacia caffra*; Leguminosae	S
004	*Acacia greggii*; Leguminosae	T
008	*Acacia senegal*; Leguminosae	T
009	*Acacia seyal*; Leguminosae	T
022	*Agave americana*; Agavaceae	H
024	*Aloe dichotoma*; Liliaceae	T
026	*Aloysia gratissima*; Verbenaceae	S
030	*Anacardium occidentale*; Anacardiaceae	T
039	*Azadirachta indica*; Meliaceae	T
066	*Caesalpinia coriaria*; Leguminosae	S
067	*Cajanus cajan*; Leguminosae	S
076*	*Carnegiea gigantea*; Cactaceae	S
078	*Cassia siamea*; Leguminosae	T
084	*Centaurea solstitialis*; Compositae	H
085	*Parkinsonia florida*; Leguminosae	T
093	*Citrus limon*; Rutaceae	T
122	*Dalbergia sissoo*; Leguminosae	T
139	*Echium lycopsis*; Boraginaceae	H
149	*Eriobotrya japonica*; Rosaceae	T
153	*Eucalyptus anceps*; Myrtaceae	T
154	*Eucalyptus caleyi*; Myrtaceae	T
156	*Eucalyptus camaldulensis*; Myrtaceae	T
158	*Eucalyptus cladocalyx*; Myrtaceae	T
160	*Eucalyptus crebra*; Myrtaceae	T
167	*Eucalyptus gomphocephala*; Myrtaceae	T
168	*Eucalyptus gracilis*; Myrtaceae	S
170	*Eucalyptus incrassata*; Myrtaceae	T
172	*Eucalyptus leucoxylon*; Myrtaceae	T
176*	*Eucalyptus melliodora*; Myrtaceae	T
178*	*Eucalyptus oleosa*; Myrtaceae	T
180	*Eucalyptus paniculata*; Myrtaceae	T
181	*Eucalyptus platypus*; Myrtaceae	T
182	*Eucalyptus polyanthemos*; Myrtaceae	T
185	*Eucalyptus rubida*; Myrtaceae	T
187	*Eucalyptus sideroxylon*; Myrtaceae	T
191	*Eucalyptus wandoo*; Myrtaceae	T
205	*Gleditsia triacanthos*; Leguminosae	T
207	*Glycine max*; Leguminosae	H
221	*Helianthus annuus*; Compositae	H
237	*Ipomoea batatas*; Convolvulaceae	H
272	*Lotus corniculatus*; Leguminosae	H
280	*Mahonia trifoliata*; Berberidaceae	S
290	*Medicago sativa*; Leguminosae	H
296	*Melilotus alba*; Leguminosae	H

able 12.3 —continued

314	*Onobrychis viciifolia*; Leguminosae	H
319	*Parkinsonia aculeata*; Leguminosae	T
330	*Pithecellobium dulce*; Leguminosae	T
335	*Pongamia pinnata*; Leguminosae	T
336*	*Prosopis cineraria*; Leguminosae	T
338*	*Prosopis glandulosa*; Leguminosae	T
340*	*Prosopis pallida*; Leguminosae	T
354	*Robinia pseudoacacia*; Leguminosae	T
397	*Tamarindus indica*; Leguminosae	H
426	*Trifolium alexandrinum*; Leguminosae	S
450	*Ziziphus nummularia*; Rhamnaceae	T
452*	*Ziziphus spina-christi*; Rhamnaceae	

Drought-tolerant plants recorded in the directory only in temperate zones that are important world honey sources.

220	*Hedysarum coronarium*; Leguminosae	H
297	*Melilotus officinalis*; Leguminosae	H
317	*Paliurus spina-christi*; Rhamnaceae	S
405	*Thymus capitatus*; Labiatae	S

The first SEPASAT Newsletter (SEPASAT 1983) stresses the problems caused by salinity, and states that an estimated 381 million hectares of arid and semi-arid lands of the world are saline. A programmed search showed that 15 of the 73 drought-tolerant important world honey sources recorded in the tropics and subtropics are also to some degree salt-tolerant (Table 12.5, p. 172). The possibility of using the dry saline areas for honey production should certainly be investigated.

Beekeepers get their honey mainly from the plants that are growing within the bees' flight range of a home apiary; those who make their living from honey production usually take up one or both of two further options. Either to base their operations in an area with a good honey potential, and/or to migrate their bees from one honey flow to another. A third option is to grow plants as honey sources for the bees. This is not usually cost-effective in the moderate or good growing areas where most professional beekeepers live – the land is more valuable for other purposes. Whereas in arid and semi-arid areas, the yield per hectare in terms of food produced is often very low and the return from using bees to crop the land may be comparable with that obtained in other ways.

A further category of drought-tolerant honey sources warrants consideration;

Table 12.4 Some honey yields reported from drought-tolerant plants recorded in the tropics and subtropics.

Yields are quoted in kg/colony/year unless otherwise stated. 'Honey potential' is a term in Eastern Europe for the estimated weight (kg) of honey that could be obtained in the course of a season from 1 hectare of land covered with the plant, assuming optimal conditions (Crane 1975).

001 *Acacia berlandieri*, 27 in USA
004 *Acacia greggii*, 72 (also 10) in USA
010 *Acacia tortilis*, 2–3 in Oman, using *Apis florea*
022 *Agave americana*, 41 in Mexico
066 *Caesalpinia coriaria*, 'much honey in the hives in October' in the Caribbean area
070 *Calliandra calothyrsus*, 1–3 kg/colony/month in Java, Indonesia, with *Apis carana*
086 *Cicer arietinum*, 20–2.5 in Uttar Pradesh, India, with *Apis carana*
093 *Citrus limon*, 30–60 (mixed with other *Citrus* spp.) in Israel
122 *Dalbergia sissoo*, 4–9 in India, using *Apis cerana*?; 27 (mixed with honey from clovers) in Pakistan
149 *Eriobotrya japonica*, 20 in Lebanon; in Pakistan 3.6 using *Apis mellifera*, also 1 using *A. cerana*

Eucalyptus spp.:
156 *E. camaldulensis*, 55, 60 in Australia; 100–120 (mixed with honey from *E. cladocalyx*) in Morocco
158 *E. cladocalyx*, 12–25, maximum 90, in Cape, S. Africa; 100–120 (often with honey from *E. camaldulensis*) in Morocco
160 *E. crebra*, 82 in Queensland, Australia, but good yield only every 3 years
168 *E. gracilis*, mean 27–36, maximum 113, in Victoria, Australia
176 *E. melliodora*, 25, maximum 75, in Australia
178 *E. oleosa*, 54 in Victoria, Australia
180 *E. paniculata*, 100 in Australia; 50 in S. Africa
191 *E. wandoo*, 90 in Australia

205 *Gleditsia triacanthos*, honey potential 250 kg/ha in Romania
208 *Gmelina arborea*, mean 20, up to 100, in Gambia
217 *Gymnopodium antigonoides*, 136 (with *Viguiera helianthoides*), in Mexico
315 *Opuntia engelmanii*, 30 in south-west USA, best during partial drought in Texas
338 *Prosopis glandulosa*, main source in Punjab and Sind, Pakistan; mean 27, maximum 90, in Texas, USA; most flowers are produced when soil moisture is low
340 *Prosopis pallida*, 120–150, 227–363, in 2 Hawaiian islands
354 *Robinia pseudoacacia*, 8–10 kg/colony/day in Romania; honey potential up to 1600 kg/ha in eastern Europe
426 *Trifolium alexandrinum*, using *A. cerana* in Pakistan 9, also (with *T. resupinatum*) 27; 'important in Baluchistan, Punjab, Sind, NWFP'; honey potential 165 kg/ha in Bulgaria
441 *Viguiera helianthoides*, 30% of honey crop in Yucatan, Mexico.

Table 12.5 Plants recorded in the tropics and subtropics that are drought- and salt-tolerant, and important world honey sources.
This list includes plants reported to show any degree of salt tolerance.

022 *Agave americana*; Agavaceae
067 *Cajanus cajan*; Leguminosae
122 *Dalbergia sissoo*; Leguminosae
156 *Eucalyptus camaldulensis*; Myrtaceae
167 *Eucalyptus gomphocephala*; Myrtaceae
180 *Eucalyptus paniculata*; Myrtaceae
205 *Gleditsia triacanthos*; Leguminosae
221 *Helianthus annuus*; Compositae
272 *Lotus corniculatus*; Leguminosae
319 *Parkinsonia aculeata*; Leguminosae
330 *Pithecellobium dulce*; Leguminosae
335 *Pongamia pinnata*; Leguminosae
336 *Prosopis cineraria*; Leguminosae
340 *Prosopis pallida*; Leguminosae
426 *Trifolium alexandrinum*; Leguminosae

Table 12.6 Drought-tolerant plants recorded in the tropics and subtropics that are specifically recommended for planting to increase honey production. All have other economic uses.

039 *Azadirachta indica*; Meliaceae
070 *Calliandra calothyrsus*; Leguminosae
122 *Dalbergia sissoo*; Leguminosae
156 *Eucalyptus camaldulensis*; Myrtaceae
158 *Eucalyptus cladocalyx*; Myrtaceae
160 *Eucalyptus crebra*; Myrtaceae
167 *Eucalyptus gomphocephala*; Myrtaceae
172 *Eucalyptus leucoxylon*; Myrtaceae
176 *Eucalyptus melliodora*; Myrtaceae
180 *Eucalyptus paniculata*; Myrtaceae
181 *Eucalyptus platypus*; Myrtaceae
182 *Eucalyptus polyanthemos*; Myrtaceae
185 *Eucalyptus rubida*; Myrtaceae
187 *Eucalyptus sideroxylon*; Myrtaceae
221 *Helianthus annuus*; Compositae
290 *Medicago sativa*; Leguminosae
296 *Melilotus alba*; Leguminosae
330 *Pithecellobium dulce*; Leguminosae
354 *Robinia pseudoacacia*; Leguminosae

those that have other economic uses than honey production. Of the 73 drought tolerant honey sources under discussion, 67 are known to have economic uses; Table 12.6 lists 19 of them that are specifically recommended for planting.

It is important when making recommendations for planting, to know if any of the plants being assessed have potentially undesirable characteristics of which users should be aware. In the directory two types of such characteristics are indicated. A warning is given, e.g., entries 039, 070 and 354 can be invasive under some conditions, and for 158 and 354 whose leaves may be toxic to animals (see Tables 12.2 & 12.3). An alert to beekeepers is also given where appropriate, e.g. if a plant yields no pollen, or pollen that is inadequate for brood rearing, colonies working it may dwindle and die. The beekeeper must therefore check whether other pollen sources are available and, if not, feed pollen substitutes. A number of *Eucalyptus* species have this characteristic, including 6 of the 17 listed in Tables 12.2 and 12.3, entries 168, 172, 176, 180, 182 and 187.

Some nectar flows, that from *Helianthus annuus* (221) for example, seem to stimulate swarming in colonies. Other plants, that are very good honey sources, flower so early in the reproductive cycle of the honeybee colony that the bee population is too small to take full advantage of the nectar available, unless the beekeeper follows special management procedures. This situation is usually a result of the introduction of a crop plant whose growth cycle and flowering are out of phase with the local growth cycle. Autumn-sown oilseed rape (*Brassica napus* var. *oleifera* (060)) is a well known example, and *Robinia pseudoacacia* (354) in eastern Europe is another.

Beekeepers face a different type of problem if the honey from a particular plant granulates (crystallizes) very rapidly. If granulation occurs within a few days, while the honey is still in the hive, the honey cannot be extracted from the combs. Honey from *Eucalyptus paniculata* (180) in Table 12.6 is reported to granulate in the hive in cold weather, and that from *E. polyanthemos* (182) is reported to be 'difficult to extract'.

Information on honey composition is known for only 108 out of the 467 plants listed in the directory, and 77 (71%) of these are temperate-zone plants. We hope that honey chemists will take note of this imbalance and extend their studies to more of the tropical and subtropical honeys.

The future of the WHOS programme: satellite directories and Phase III (data bank)

IBRA intends to use further search programmes to prepare satellite directories of selective entries on honey sources that have certain important characteristics, e.g. drought-tolerant plants that give especially high honey yields are of great interest for semi-arid parts of the world. Details to be published about each of the plants would include, for example, botanical and ecological information, economic uses, honey-producing capability, and experience in propagation specifically for honey production. We should welcome suggestions as to satellite directories likely to be in greatest demand and although commissioned searches for specific information can be made, no funds are available at present for a free service.

We can also use search programmes to show which data are lacking, and thus where new research should be focussed. Programmes that involve the growing of good honey plants can be monitored, and areas of the world where a specific plant might be especially profitable can be identified.

IBRA regards the survey of the world honey sources as a continuing project. Storage of the information on discs allows the future addition of further data for plants included in the directory. It will also allow the upgrading of some of the candidate plants to the status of a full entry, as information becomes available.

The 40 000 plant species visited by bees are too numerous to be absorbed into the present honey-oriented project; they must be left for environmentalists to

document. The aim of IBRA is to use the information bank primarily in ways that will advance apiculture in different parts of the world, especially in developing countries.

Pollination of arid land crops

Another project, the preparation of a pollination directory for world crops (Crane & Walker 1984), has been funded by the New Zealand Ministry of Foreign Affairs, and the book will be published by IBRA. It is on a much simpler level than the directory of honey sources (Crane, Walker & Day 1984), and is intended especially for use by crop growers in developing countries. It will contain a single sequence of 400–500 entries under common name of crop, with an index of botanical names. Each entry gives brief details, as available, of the uses and distribution of the crop, and of the plant's floral structure and pollination mechanism. Pollinating agents are identified where possible; where there are difficulties in ensuring adequate pollination these are set out and recommendations made for overcoming them. For many insect-pollinated crops the most practical action is to take hives of bees to the crop, the number of hives per hectare depending on the crop. The isolation distance required for production of 'certified' seed is also quoted where applicable.

Many crops are among the important world honey sources, and about 100 of those in the pollination directory (Crane & Walker 1984) are cross-indexed to entries in the honey sources directory (Crane, Walker & Day 1984). For these, the use of bees may give a dual benefit; a honey harvest and increased crop yields.

Conclusions

The use of bees to crop food resources can provide a harvest additional to that for which plant crops are primarily grown. Moreover the primary harvest from many insect-pollinated crops is increased in quantity and quality by the presence of foraging bees. Beekeeping at an appropriate technological level, low, intermediate or high, can add usefully to food and income in developing countries of the tropics and subtropics. Furthermore beekeeping can be undertaken by men, women and children, on a part-time or full-time basis.

The above statements are generally accepted but constraints to the most effective use of beekeeping still need to be studied quantitatively. One constraint has certainly been a lack of knowledge about plants that are important honey sources in different habitats in the tropics and subtropics. The 'Directory of important world honey sources' now helps to remove this particular constraint.

In the context of the Conference, 73 important honey sources in the arid and semi-arid lands of the tropics and subtropics are identified, 67 of which are recorded as having other economic uses. They are examined from various points of view: degree of drought-tolerance; habit (tree, shrub, herb); distribution (tropics, subtropics); salt-tolerance coupled with drought-tolerance (15 plants); recommendation to plant for honey production (19 plants). These 19 plants are of special interest because other uses of arid land may give such poor yields of food, fodder or timber, etc. that the yield from beekeeping may be more profitable.

It is considered most important that, in future work, information related to bee and honey production should be linked with broader plant data bases for developing countries. IBRA is certainly willing to take responsibility for this specialized aspect of such work, provided funds can be found to support it.

Acknowledgements

I much appreciate assistance from the Royal Botanic Gardens, Kew with plant taxonomy and other matters, and especially Dr G E Wickens's interest in WHOS as a potential component of SEPASAT. I take this opportunity also to pay special tribute to my colleagues Penelope Walker and Rosemary Day for their valuable contributions to the project.

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