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**Rural Industries Research and  
Development Corporation**

# Forestry Plantations and Honeybees

RIRDC Publication No. 10/076







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# **Forestry Plantations and Honeybees**

by Doug Somerville

June 2010

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# Foreword

The Australian beekeeping industry is suffering from a decline in the available and suitable apiary sites with access to beneficial floral species. The industry has a range of availability and sustainability issues to deal with, that have the potential to have a major impact on the future viability of commercial beekeeping. Without a range of suitable flowering events for the bees to obtain their necessary nutritional requirements, the bees won't survive. This research study is designed to investigate the potential capacity of plantation forestry to contribute to the Australian honeybee floral resource base.

The report is aimed at assisting the beekeeping industry in clearly identifying the systems and issues under which they operate with a varied audience, including foresters and those with a concern for the future viability of the Australian beekeeping industry.

The key findings suggest that plantation forestry does not provide any substantial benefit to the Australian beekeeping industry. Although this is disappointing, what the report does achieve is to establish a set of guidelines that could be implemented to increase the floral resource base for the honeybee industry by favouring the planting of nectar producing plants on farms, on old mine sites and other areas requiring revegetation.

This course of action should be placed in the context that commercial honeybees are currently managed in large apiaries (80 – 140 hives) requiring significantly large areas of flowering plants (bees are able to fly 2 to 4 kms to forage). Small area plantings of favourable floral species are not likely to replace major flowering events from dominant regional floral species that are known to produce copious supplies of nectar and pollen.

The funding for this project was provided by the Honeybee Program managed by RIRDC and Industry and Investment New South Wales.

This report is an addition to RIRDC's diverse range of over 2000 research publications and it forms part of our Honeybee R&D program, which aims to improve the productivity and profitability of the Australian beekeeping industry through the organisation, funding and management of a research, development and extension program that is both stakeholder and market focused.

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**Tony Byrne**  
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## About the Author

Dr Doug Somerville is a honeybee technical specialist with the Industry and Investment New South Wales. Doug has researched and written numerous reports for the Rural Industries Research and Development Corporation including the Floral Resource Database for the NSW Apiary Industry RIRDC publication number 99/174. His PhD topic was ‘The Floral Resources of New South Wales of Primary Importance to Commercial Beekeeping’. He has an extensive and thorough knowledge of the Australian beekeeping industry and is well placed to produce this report on the subject of the value of forest plantations and honeybees.

## Acknowledgments

During the course of this study I talked to numerous commercial beekeepers in all states, including selected foresters. The sum of these discussions provided the material for this report. In particular I would like to thank Dr Rob Manning from Western Australia Agriculture, Bill Winner from Capilano Honey and Chick Robb from the Queensland DPI.

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# Executive Summary

## ***What the report is about***

The area devoted to plantation forestry has increased substantially for several decades with a significant escalation over the last decade. During this time there has also been a movement of government land tenure from that managed for forestry to that managed for national park and conservation type outcomes.

These factors have had a significant impact on the Australian commercial beekeeping industry due to the loss of usable apiary sites for commercial numbers of bee hives. The national forest plantation estate has been suggested as a floral resource that may be a future replacement for the loss of traditional sites on government owned lands. This report sets out the arguments and issues surrounding the discussion of whether forest plantations do or do not represent a valuable resource to the Australian commercial beekeeping industry.

## ***Who is the report targeted at?***

This report provides those with an interest in the future viability of the Australian beekeeping industry a list of the issues to be considered when deciding whether forest plantations provide a worthwhile floral resource. The report is also written for those involved in forest policy and conservation management to provide an overview of the management of honeybees and the criteria used by the commercial beekeeping industry when determining the value of a floral resource.

## ***Background***

The growth in areas devoted to forest plantations within Australia has not contributed significantly to the honey crop produced nationally; this is the general perception of the Australian beekeeping industry. Even so, there is a belief by some outside the beekeeping industry that forest plantations may be a valuable floral resource for honeybees. This perception is ill-founded and the risk as far as the beekeeping industry is concerned is that this view will be used to formulate government policy and lead to greater exclusion of managed honeybees from lands managed for conservation purposes.

There is also a lack of readily-available documentation/information available to growers of plantation timbers as to the other products/benefits that can be derived from various timber producing species. One of the potential outcomes for producing a report on the value of forest plantations to honeybees is to provide the criteria by which suitable species for honey and pollen production could be selected by forest managers.

## ***Aims/objectives***

- Evaluate the principal forestry species of commercial value in the plantation industry for potential use by the Australian beekeeping industry.
- Review the forest plantation management practices that may have an impact on the use of forest plantations for commercial beekeeping activity.
- Identify a suitable course of action to highlight the issue of floral resource security for the commercial beekeeping industry.
- Consider the reasons why eucalypt plantations are considered in some regions as of value to the international beekeeping industry.



## **Methods used**

There is a growing body of information on forest plantations including the distribution, markets etc for the timber produced. What is sometimes lacking is a description of the specific species and provenance of the trees selected and grown.

The species grown has a major impact on the potential value to honeybees; the age at harvesting is the next most important aspect requiring investigation. Density of trees, any insect control measures used, and policies of private and corporate plantation operators to the potential utilization of these forests for use by commercial beekeepers are all significant issues impacting on the value of plantations to commercial beekeepers.

Research strategies were initially directed at recording as much as possible about the regional distribution of plantations, species grown and age harvested from the literature available. Personnel involved with forest plantation management were contacted to obtain some of the information followed up by strategic visits to plantations.

A general request was issued to the Australian beekeeping industry to provide any information as to the utilisation of plantations, indicating frequency of visits, length of stay, purpose i.e. honey production, breeding conditions or safe location to place bee hives between honey flows.

A component of the study required an investigation overseas to ascertain the value of eucalypts to the international beekeeping industry. Presentations on the subject of forest plantations as a floral resource to honeybees were made at two international conferences in 2005 in Europe and India. These occasions were used to discuss with the various participants the circumstances that prevail around the use of planted flora as a floral resource for honeybees.

## **Results/key findings**

The study clearly identifies the structure and mechanism of the beekeeping industry and outlines the parameters by which the system operates. The need for commercial beekeepers to have a number of suitable apiary sites on a range of reliable floral species is vital for the survival of each beekeeping business.

The variability of the floral resource is discussed as it relates to the needs of honeybees under the following headings: the flowering phenology of melliferous flora, the inherent flowering pattern, tree age and flowering frequency, flower bud initiation, frequency of flowering events and distribution of flora.

To put the floral resource into perspective, the basic nutritional requirements of honeybees are provided including the protein, amino acids, fat, lipid, and minerals needed for a balanced diet. The attributes of the five major hardwood species are investigated including *Eucalyptus globulus*, *E. grandis*, *E. nitens*, *E. regnans* and *E. dunnii* from published information on the honey and pollen value of floral species. None of these species are listed or have been identified in any study as being of major importance to Australian beekeeping interests. The box and ironbark groups of eucalypts are traditionally the most prolific trees yielding nectar within Australia.

A range of plantation management practices were identified as being serious impediments to forest plantations becoming a major reliable floral resource to commercial beekeepers. These included access issues on private property, particularly the concerns for public safety in relation to the presence of honeybees and the restriction in the genetics of the plantation with the likely scenario that a mass flowering, if the plantation is allowed to mature to that stage, would be very uniform and short lived. The use of pesticides within plantations was considered a minor risk. However during the course of the investigation there were two cases reported where beekeepers were asked to remove bee hives from the proximity of a forest plantation when the application of a pesticide was required. Harvest

cycle was seen as the most restrictive practice. Hardwood plantation species are generally harvested after the rapid initial growth stage of between 8 and 15 years. There was no evidence that the primary plantation hardwood species had entered a regular flowering phase during this period.

The complexity of managing honeybees on a commercial basis within the Australian context is discussed as well as the current floral resource constraints which are creating major uncertainty for investment within the Australian beekeeping industry. The international perspective is also covered to ensure the reader has an understanding of the Australian context.

### ***Implications for relevant stakeholders***

The findings of this report emphasise one of the major constraints to the Australian beekeeping industry. Without access to floral resources there is no commercial beekeeping industry. Traditionally the major focus by industry and government has been on issues surrounding the threat of pests and disease, commodity prices and costs of production. Ultimately the availability of a range of suitable floral resources is what will determine the future shape and scope of the Australian beekeeping industry.

The beekeeping industry should not be under any illusion that plantation forestry will provide any substantial floral resources for their benefit. The plantation forestry industries could consider some of the issues discussed in this report to make their estate more beekeeping friendly if this is a desired strategy.

Government agencies and the beekeeping industry should consider other strategies to increase the extent and availability of melliferous flora within the Australian landscape, particularly the encouragement of nectar and pollen producing plants in revegetation projects. Those involved in such projects should also be conscious that the benefits may take decades to be realised. Eucalypts, in many cases, live for hundreds of years. It is generally considered by beekeepers that flowering and producing nectar in many nectar producing trees is not a regular event until the tree is in excess of 25 years old.

One of the major implications of this report is that forest plantations will not replace the loss of apiary sites due to other land uses. These include the exclusion of managed bees from conserved areas and the loss of sites due to urban expansion. These factors have the potential to seriously reduce the viability of individual beekeeping operations, ultimately removing their services for the pollination of a range of agricultural and horticultural crops.

### ***Recommendations***

Plantation forestry may provide floral resources to the beekeeping industry under limited circumstances; if the floral species are prolific producers of nectar and pollen, if they flower on a regular basis, if the use of pesticides is restricted during flowering, if access is allowed, if the plantation is left to mature long enough for the trees to commence a flowering cycle.

Any policy held by any agency or authority that the plantation forest estate will provide substantial floral resources to the commercial beekeeping industry should be discarded. There is no evidence that this has or will occur in the near future.

Known floral species that produce nectar and pollen should be considered in re-vegetation and other rehabilitation projects. This should not only include larger tree species but also shrubs and understorey plants known to contribute to the overall volume of nectar and pollen available.

On-farm tree planting projects to provide shelter for livestock, protect water quality, stabilise riparian areas and provide windbreaks all provide opportunities to choose floral species that have multiple uses. Selecting reliable nectar and pollen producing flora will increase the floral resource to honeybees and provide a food source to encourage the establishment and retention of native nectarivores animals including birds, mammals and insects.

# 1. Introduction

## Value of the Beekeeping Industry to the Community

The value of the honeybee industry to the Australian economy can be measured in several ways. Honey is the obvious product of keeping honeybees. Various estimates suggest that this is worth up to \$80 million per annum (Crooks 2008), although this will vary quite significantly from year to year depending on market price fluctuations.

Australian honey has a very enviable reputation for quality on the international market. The bulk of the honey crop, possibly in excess of 80%, is harvested from native flora. Much of the remaining 20% is harvested from “agricultural” weeds such as Paterson’s curse (*Echium plantagenium*). The honey crop harvested directly from agricultural crops is small, thus the direct exposure to agricultural chemicals is very low in comparison to many other beekeeping countries.

Pests and diseases of honeybees in the Australian context do not require the extensive use of medications or chemicals, in comparison to the keeping of bees elsewhere in the world.

Australia is free of the destructive bee parasite, varroa mite (*Varroa destructor*). This parasite of honeybees, if left untreated, will kill a colony of honeybees. An extensive number of chemical treatments have been recruited by the international beekeeping community to combat this major bee pest and invariably residue issues have arisen.

The possibility of importing Australia’s honey requirements is not attractive from a food safety perspective, as an increasing volume of the world’s honey production has been implicated with a range of chemical residue incidents over the last decade. Thus, if the Australian public wish to have access to a wholesome supply of natural honey, the logical source of this product is Australia.

The use of honey for medicinal purposes has been in practice for thousands of years. Evidence suggests that the ancient Egyptians utilised honey for wound management and other ailments of people. Eastern Europeans and many Asian cultures have continued to regard honey as a medicine rather than as a sweetener. A range of research studies, including a number of PhD studies in Australia and New Zealand have ‘rediscovered’ the medicinal benefits of honey. Evidence so far suggests that some floral sources of honey have very good properties to fight external wound infections. Honey has also been identified to improve the healing process in external wounds by promoting cell growth and reducing scarring (Blair & Carter 2005).

Other products from the honeybee, including dried pollen, royal jelly, propolis and bee venom, all continue to have a following from segments of the public as products that provide some health benefits. The efficacy of these products has not received rigorous security, but the health benefits cannot be dismissed as inconsequential.

Politically the most important aspect of honeybees is their role in agricultural and natural systems as pollinators. The vast majority of flowering plants require pollen, the male gamete of a plant, to be transferred to the female receptors of the same species. There are many and varied means for this process to occur but insect pollination accounts for the bulk of the pollination events in true flowering plants. Honeybees readily visit a huge range of flowering plants in search of floral rewards in the form of nectar and pollen. In this endeavour they carry with them on their bodies large amounts of pollen. It is in the act of foraging that honeybees provide the means by which many millions of flowers are pollinated each day. Many other insects are capable of pollinating flowering plants, but none have achieved the status of the honeybee.

Internationally, honeybees (*Apis mellifera*) are recognised as the principal pollinating insect of the modern agricultural systems. In fact, various estimates suggest that well over one third of what we eat today may be attributed to honeybee pollination (Klein *et al.* 2007). The latest estimate indicates that this contribution could be worth as much as \$3.8 billion per annum to the Australian economy.

Unfortunately for beekeepers, most of this added value by honeybee pollination is not able to be realised by the Australian commercial beekeeping industry. Instead the bulk of the income, probably in excess of 90%, is obtained from honey production.

## **Structure of the Beekeeping Industry**

There are approximately 10,000 registered beekeepers in Australia, who collectively manage approximately 572,000 bee hives. The majority of these are small scale beekeepers. Approximately 1,700 beekeepers operate more than 50 bee hives, which produce in excess of 90% of the Australian honey crop (Crooks 2008).

Full time commercial beekeeping businesses typically manage 300-600 hives per operator. Many beekeeping businesses manage in excess of 1,000 bee hives, typically as multi-family businesses or employing labour.

Bee hives are managed in groups, usually determined by how many bee hives can be transported in one truck load. This group of bee hives is referred to as an apiary and may comprise between 80–140 bee hives. In some circumstances, apiaries may be smaller in number depending on local flora and areas to place apiaries. In the Tasmanian situation apiaries tend to be smaller than on the mainland.

There is a fundamental difference between beekeeping in Tasmania and mainland Australia. Beekeepers in Tasmania and many other regions of the world are migratory. They have a set pattern of movements for certain times of the year, based on annual flowering events. On the mainland of Australia a very significant proportion of the annual honey crop is harvested from eucalyptus or related species. This group of plants has a flowering pattern more in tune with rainfall events. Many eucalypt species flower once every two, three or four years. Flowering frequencies in excess of 10 years have been recorded (Law *et al* 2000). As approximately 80% of Australia's honey crop is harvested from this group of plants, it has been necessary for beekeepers to move apiaries on a nomadic basis.

## **Apiary Sites**

Not every plant that produces blossom is of value to commercial beekeeping. The reliability of the various floral species, even between sites, is considerable. This will be explained in more detail in the next chapter. Beekeepers tend to operate within a restricted zone, moving apiaries to major flowering events which provide resources for their bees that will be financially rewarding. Sometimes beekeepers have a choice of which floral species they should favour, at other times there is only one clear choice based on the reliability of that floral species. Often there are no prospects available.

Droughts have become a major issue in managing commercial beekeeping operations, with the increasing necessity to move apiaries well out of the beekeeper's normal operating zone to provide a food source for their bees. Supplementary feeding of bees has also gained some favour to make up for the natural shortfall in nectar and pollen. Unfortunately these options have major cost considerations attached. As far as supplementary feeding is concerned, the perfect protein supplement has still not been produced (Somerville 2005). If the impact of drought is widespread then the option to move bees into other regions may not be a proposition. This has occurred on several occasions in the past 10 years. Given the distribution of and competition for apiary sites between commercial beekeepers

across Australia 'spare or surplus' apiary sites may not be available outside of the beekeeper's normal zone of operation, reducing or eliminating the option of moving bee hives further afield.

Thus it is in the beekeeper's best interest to build up a portfolio of apiary sites across a range of floral species within their operational zone. Many of these sites may not be utilised for several years, but when circumstances dictate, they become a critical resource to keep each beekeeping business viable.

The value of apiary sites is influenced by a number of factors. A beekeeper may have 10 sites available to enable the placement of apiaries on a particular floral species. One of these sites may have been burnt in the last two or three years, another may have a problem with access during wet weather, yet another may be uncomfortably close to another beekeepers' site or a residential property. For whatever the reason, sites will vary in their usefulness and attractiveness to be used to place bee hives.

Due to the large number of apiary sites required, it is not feasible for the beekeeper to have ownership over their portfolio of sites. Thus, beekeepers depend on permission from the land owner or manager to place bee hives. Apiary sites can be divided into public and private sites. Access to private property is usually via a friendly agreement between the property owner and the beekeeper. The beekeeper and owner negotiate as to where on the property the owner is prepared to have bee hives situated. This relationship is often rewarded by the beekeeper providing the property owner with an amount of honey. Managing these sites can be a significant component of a beekeeping business, with the beekeeper periodically visiting all sites over the year, whether they are intended to be used that year or not. There is also a degree of competition for private property sites which can create disputes between beekeepers working within the same region.

Many of the favoured and more reliable floral species are poorly represented on private property. Historically, public forests have been extremely important for many commercial beekeeping operations. In a 2007 survey of Australian beekeepers, 66% of all beekeeping businesses relied to some degree on public land sites to place bee hives (Crooks 2008).

Beekeepers gain access to public lands by engaging with the identified land managers. Formal agreements are normally entered into whereby the beekeeper has a defined set down site and must adhere to a range of conditions. An annual administration rental fee is charged, and this is normally renewable on an annual basis.

The following chapter sets out the evaluation of plantation forestry in Australia. The creation of the plantation estate has been primarily driven by political, ecological and economic considerations. The beekeeping industry has largely been a bystander to this national process.

## 2. Plantation Forestry in Australia

Historically, the forestry industry in Australia has been dominated by harvesting timber from native forests and woodlands. Until the 1950's very little attention was paid to planting timber species for future harvesting, when plantation forestry in Australia gained rapid momentum. This plantation forestry interest was largely driven by various state governments and primarily focussed on softwoods. This state government investment in plantations remained strong until the 1980s. Since around 1990 the plantation estate expansions have been principally driven by large private and public investment companies. This expansion has been primarily in hardwoods, with a handful of eucalypt species as the main focus.

Concurrent with the new interest by corporate Australia in investing in timber plantations, an increase in environmental awareness was occurring, including calls on governments to cease timber harvesting in native forests.

The growing public disquiet about harvesting native forests, particularly for woodchipping, became an issue requiring political attention. In 1992 all states except Tasmania signed the 'National Forest Policy Statement' with a commitment to protect all wilderness and high conservation value old-growth forests.

Public support for old-growth forest protection and particularly the growing negative sentiment towards woodchipping was evident in a News poll, published in December 1994, which showed that 80.3% of Australians wanted native forest woodchipping to stop (News poll 1994). As a result of a great deal of political activity from a diverse range of interested parties, the expansion of the national forestry plantation estate was inevitable.

The Federal and State governments initiated 46 forest enquiries – nearly half by the Federal government – during the 1970s and 1980s (Resource Assessment Commission 1991). Over those two decades Australia's native forest conservation reserves slightly more than trebled (ABARE 1991).

Before the forest controversy, from Federation to the end of the 1960s, new associated environment groups formed at an average of five a decade. Twenty five new organisations sprung up in the 1970s and that number again in the 1980s (Ajani 2007).

By the early 1970s annual softwood planting reached around 35,000 hectares, which was primarily achieved by the clearing of state owned native forests and woodlands (Leslie 1987, Uren 1972). This started to become unacceptable to the public and clearing native forests and woodlands for pine forests came under pressure. The Prime Minister of the time, Gough Whitlam, recommended the end of native forest clearing for plantation establishment in 1972. Tasmania continued to clear native forests to plant either hardwood or softwood plantations.

By the early 1990s softwood plantations generated half of Australia's sawn timber (ABARE 1993). In 1998 the Victorian government sold its tree plantations with a 99 year lease on the land. By 2000 radiata pine was the species of choice in 90% of Australia's softwood plantations, excluding Queensland where this species failed to perform due to the hotter climate (Wood 2001). Plantation mills now produce 80% of Australia's processed wood products.

In 1994 the Federal government produced a discussion paper introducing 'Regional Forest Agreements' (Commonwealth Government 1994). This paper focussed on the need to place in reserve, a cross section of representative ecosystems and forest types. The reserve criteria acceptable to all governments were not achieved until after the 1996 Federal election and after the signing of the first RFA. The implementation of regional forest agreements increased public native forest reserves by 8% (Bureau of Rural Science 2003).

Hardwood planting started tentatively in the 1980s due to the mounting timber industry unease about the environmental movement. By 1990 hardwood plantations only amounted to 96,000 ha – about 10% of Australia’s plantation estate.

In Queensland Aila Keto founded a new environmental activist group, ‘The Australian Rainforest Conservation Society’. The Society had the view that large areas of south east Queensland’s native forests with high conservation value needed immediate protection and that, ultimately, the forest-based industries needed to move out of native forests into plantations.

In 1998 in Queensland, when Mr J Beattie won office, Queensland had one of the smallest areas of conserved forests in Australia. Only 18% of Queensland’s public native forests lay in conservation reserves – compared to Tasmania where 25% of native forests were found in conservation reserves.

The Beattie government committed \$18 million to establish 500 ha of hardwood plantation and accommodated the ‘The Australian Rainforest Conservation Society’s’ wishes by legislatively guaranteeing that sawlog production on public native forests would shift to plantations over the next 25 years. By 2024, at the latest, three quarters of south east Queensland’s public native forest area would be protected from logging and presumably be managed primarily for conservation.

Three quarters of Queensland’s public forests will thus be protected in some form of conservation agreement. The governments of Western Australia and Queensland have actively shifted their forest industries out of native forests and into plantations.

Australia’s hardwood-planting boom took shape with heavily promoted, tax-minimization schemes. These schemes were based on tax advantages using negative gearing to reduce personal income tax. By 1999 it was reported that 90% of the new plantations were based on these managed investment schemes (Cummine 2000). Most were hardwood plantations for chip logs grown over a relatively short (10–18 yr) period. As softwoods grow more quickly than native hardwoods, tax minimisation, not the demand for the wood, was probably driving the increase in the hardwood plantation estate.

By the early 1990s, softwood plantations generated half of Australia’s timber. By this time plantations were providing most of Australia’s sawn timber and native forests were mainly harvested for woodchips. Commodity sawmilling companies require uniform logs, not too big and not too small for processing efficiency.

In 1997 the Federal government released its ‘Vision 2020 Plantation Strategy’ along with the National Plantation Inventory. The principal objective was to treble Australia’s plantation estate from one million hectares in 1997 to three million hectares by 2020. Since the launch of the Plantation 2020 Vision in 1997 the Australian plantation estate has increased from 1.1 to 1.90 million hectares, comprising about 883,000 ha (46%) of hardwood species, 1.01 million ha (53%) of softwood species, with a small area of mixed plantings. The plantation estate has grown in area by just under 5% per year for the last 10 years, and plantings are dominated by Australian hardwood eucalypt species. Most of Australia’s plantations are located in areas with reliable rainfall of more than 700 mm (28 inches) per year.

- Victoria and Western Australia have the largest areas of plantations.
- 86,569 ha of new plantation forests were established in 2007 comprising 76,057 ha (88%) of hardwood and 10,512 ha (12%) of softwoods
- Hardwoods now constitute over 46% of all plantations.
- Private investment through managed investment schemes is the major source of new plantations, most of which are destined for pulpwood production.

The following chapter will set out to provide evidence to illustrate the complex nature of the variability in floral rewards offered by flowering plants.

### 3. The Variability of the Floral Resources for Honeybees

The back bone of the Australian beekeeping industry is honey production, thus nectar secretion characteristics of specific floral species are of major importance to their value to beekeepers. The volume of honey produced is a factor of the honeybee population and foraging ability of each colony, combined with the availability of nectar secreted from the nectaries of flowering plants. The volume of nectar available varies from year to year, location to location, season to season, and species to species. To complicate matters, a plant which produces copious quantities of nectar in one location may fail to do so in another (Sawyer 1988).

The factors affecting nectar secretion and the sugar concentration of that nectar are many and have varying degrees of influence from species to species. The same climatic and soil fertility conditions may promote nectar secretion in one species and suppress nectar secretion in another. The influence of hereditary factors on nectar secretion is likely to be considerable. Substantial differences among varieties or clones of plants within a species have been reported for *Trifolium pratense* (Shuel 1986), *T. repens* (Shuel 1986; Jakobsen and Kristjansson 1994), *Medicago sativa* (Shuel 1986; Morthorpe *et al.* 1989) and *Brassica napus* (Szabo 1982; Mohr and Jay 1990; Kevan *et al.* 1991). A study of three Australian plant species—*Dampiera stricta*, *Goodenia bellidifolia* and *Aotus ericoides* suggested that nectarivores were likely to encounter variability in nectar rewards regardless of which plant species they utilised for nectar (Zimmerman *et al.* 1987).

The rate of nectar secretion varies considerably though out the day, probably due to variation in temperature and insolation. Jakobsen and Kristjansson (1994) found that the optimum day time temperature for nectar secretion was higher when *Trifolium repens* plants were exposed to low night temperatures, presumably a result of decreased night respiration. Different plant species within the same genus may have quite different environmental requirements for nectar production. For example, *Eucalyptus melliodora* yields nectar best when there are hot nights and still conditions, while *E. albens* requires frosty nights. Some *Eucalyptus* species yield nectar best during showery weather, while other *Eucalyptus* species cease producing nectar when rain occurs on the blossom (Clemson 1985).

Corbet and Delfosse (1984) found that nectar sugars were more concentrated in *Echium plantagineum* the drier the air. A similar pattern for *Echium vulgare* was found in England. They also suggested a link between the photosynthetic rate of the plant and nectar secretion. Honeybees, from their observations, only foraged on *Echium plantagineum* when the ambient air temperatures were above 17°C.

Nectar production has been shown to peak and trough throughout a 24 hour period. The nectar flow in *Angophora hispida* was greater in the morning (Anderson *et al.* 1983). Bond and Brown (1979) showed that *Eucalyptus incrassata* produced nectar predominantly in the early morning, cold temperatures were stated as reducing nectar production in banksias (McFarland 1985). Law (1994) found no correlation between minimum night temperatures and standing crops of nectar in *Banksia integrifolia*. There seems no doubt that the primary influence on nectar secretion is related to sufficient sunlight to support high rates of photosynthesis. Long-term records of honey yields indicate the importance of clear weather. Nectar yields may be affected by the quantity of solar radiation received in the previous season (Porter 1978; Shuel 1986).

The influence of soil fertility on nectar secretion is likely to be complex. It may be reasonable to expect that nectar secretion is correlated with soil fertility. Where biomass concentrations have been established for various forests, it has been estimated that about 63% of all individuals of all species occurring in the forest were concentrated in about 9% of the area with higher nutrient levels



(Braithwaite *et al.* 1983). Nectar yield in *Fagopyrum esculentum* varied according to the nutrient mineral elements, also soil nitrogen levels were highly significant (Girnik *et al.* 1977). Soil fertility may have an influence on the frequency of flowering, particularly eucalypt species. The same floral species may yield greater quantities of nectar given the same soil moisture and hereditary influence, growing on a soil with greater levels of fertility. However, the effect of soil fertility may have a greater influence on plant growth and flower development than on nectar secretion. A few studies researching nutrient impacts on nectar yields indicate that when potassium is limited, nectar yields are poor. The effects of various mineral elements on growth are interdependent rather than independent, and the same interdependence can be expected for nectar production (Shuel 1986).

Nectar production is most likely limited by water availability. Beekeeping production records have indicated that the higher-yielding seasons were slightly wetter than average and followed a season of higher than average precipitation (Shuel 1986). Thus, physical factors as they relate to soil moisture retention and availability would have a major impact on nectar secretion. Sandy soils were reported to support superior nectar yields in *Trifolium repens* in New Zealand, except in dry years when heavier soils were better (Johnson 1946). The superior drainage in sandy soils would be expected to provide better aeration and warmer temperatures, both of which were found to favour nectar yields in *Antirrhinum majus* (Shuel and Shivas 1953).

The most appropriate method for measuring the volume of nectar available is debatable. Potential nectar yields are commonly estimated by taking nectar samples from flowers from which insects and other nectarivores have been excluded, usually by the use of cloth or glassine bag. Protected flowers secrete nectar for greater periods of time than flowers that have been pollinated. Barbier (1963) reported that flowers of *Lavandula* species quickly wilt and cease nectar secretion shortly after they have been visited by honeybees. From this it can be assumed that the flower and nectar reward have fulfilled their function, attracting a pollination agent to effect the transfer of pollen and thus the flower no longer has a requirement to secrete nectar. Thus the possibility of an over-estimation of potential nectar yields is introduced.

Sampling from unprotected flowers leads to an under-estimation of the nectar potential of a species, making it difficult to utilise such information to estimate the potential honey crops available from a given area. The factors that favour nectar secretion by individual species are well understood by experienced beekeepers, providing a very reliable source of anecdotal information on this aspect of phenology.

## Flowering Phenology of Melliferous Flora

When high yielding melliferous flora are in blossom at the same period every year, commercial apiarists would be expected to move apiaries on a calendar prescription. Unfortunately this is not the case on mainland Australia where much randomness characterises commercial apiary movements. This is because:

1. Flowering in a particular species may not be annual, especially in eucalypts.
2. The nectar flow varies greatly from year to year in an area, due to both environmental and physiological factors.
3. A species that has widespread distribution may have a regular flowering season in one part of its range but flower at a different time in another.
4. Occasionally the melliferous flora in an area may have a phenomenally heavy nectar flow.

Thus commercial beekeepers must retain a considerable elasticity in their decision making as to where to seek nectar flows. The same parameters also characterise blossom-seeking bird and bat species

(Keast 1968). Flowering frequency and flowering times are major factors in determining the value of various species as a nectar or pollen source for commercially managed honeybees. The stimulus for each event will be a combination of the genetics of the individual species, temperature, available moisture, sunlight intensity and soil fertility.

A plant must undergo vegetative growth before budding and flowering is initiated. The group of factors impacting on growth would be the same as those impacting on flowering frequency. Herbaceous plants are expected to have a regular annual growth and flowering event, whereas Australian tree species have been recorded to have a longer flowering cycle. Flowering of eucalypts can be very erratic in regards to the number of years between significant flowering events, although reported examples of this variation are few (Law *et al.* 2000).

## Inherent Flowering Pattern

In a naturally occurring ecosystem, inherent differences in response to environment dictate that not all plants of a species will bloom on exactly the same date when grown at the same location (Caprio 1966). Eldridge *et al.* (1993) reported that the time of flowering in eucalypts is strongly inherited. Within any population of eucalypts the main flowering period for individual trees may be out of phase. Such situations have been observed for *Eucalyptus deglupta*, *E. regnans* and *E. pilularis*. It has been observed that on average *E. regnans* trees flower for 43 days and the order in which individual trees flowered is consistent from one year to the next.

Published lists of flowering times (Costermans 1983; Boland *et al.* 1984; Brooker and Kleinig 1990 a,b) provide only a rough guide as flowering in natural forests will vary widely with site, with provenance, from tree to tree within species and from year to year. Provenance variation in flowering season has been observed in trials of several eucalypt species (Eldridge *et al.* 1993). A trial of *E. camaldulensis* in Zimbabwe (Mullin and Pswarayi 1990) found distinct differences between groups of provenances' in flowering season and duration.

## Tree Age and Flowering Frequency

The age of a tree may have a bearing on the frequency and intensity of flowering. Cultivated trees of *E. leucoxylon* flower as early as two years. *E. grandis* may have its first general flowering at two to three years. Some species from cooler climates, *E. diversicolor*, *E. globulus*, *E. nitens* and *E. regnans* do not flower heavily, even at wide spacing, until seven to ten years. *E. dunnii* is perhaps the slowest to start flowering with only a few trees in flower at ten years (Eldridge *et al.* 1993).

There are examples of individual eucalypts that may be 1,000 years old., *E. marginata* and *E. camaldulensis*, (Jacobs 1955). Kavanagh (1987) found that *Petaurus australis* (yellow-bellied gliders) select trees with the greatest number of flowers in which to forage for nectar. The older trees mature trees (approximately 200 years old) produced 2.2–15.5 times as many flowers as pole stage trees (approximately 25 years old). Ziegler (1993) reported that in mature rainforest in Tasmania, *Eucryphia moorei* (leatherwood trees) less than 75 years old do not flower. Trees ranging between 75 to 110 years tended to flower sparsely or moderately. Several trees did not flower in consecutive seasons in this age group. The leatherwood trees that flowered profusely for an extended time (upwards of six weeks) every year ranged in age from 102 to 237 years, although the majority were between 175 to 210 years. Older dominant leatherwood trees tended to carry a greater volume of flowers over a longer period of time than did young trees. In this case there was no evidence that the quantity of nectar correlates with the age of the tree.

## Flower Bud Initiation

According to Boomsma (1981) the initiation and development of flower buds is said to be primarily controlled by external factors which produce an internal stimulus. In temperate areas the main external factors comprise the length of day and night, and the average daily temperature. In arid areas, many species flower after soaking rains, thus moisture availability is a factor associated with the initiation of flower buds. Not all individual trees of a given species in their native habitat flower together, 50 percent of a single species may not develop flowers in a particular season.

One of the few studies of the flowering phenology of eucalypt species was conducted over a 10 year period at 23 sites observing 20 Myrtaceous tree species (Law *et al.* 2000). They studied the relationship between flowering phenology, climatic factors, environmental and disturbance variables. A number of interesting observations were made during the course of the research. The same climatic factors induced different phenological responses for different species. An 18 month extreme drought led to poor flowering in *Corymbia variegata*, *Eucalyptus acmenoides*, *E. grandis*, *E. resinifera* and *Lophostemon confertus*, whereas the remaining 15 species continued to bud and flower. Surprisingly, across all species combined, the poorest period of flowering was coincident with the years of highest rainfall. This may indicate that rainfall in previous years has a larger influence on flowering than the year in which flowering occurs.

A very important finding of the research of Law *et al.* (2000), which supports beekeeper observations, is that larger trees, in this case *Corymbia variegata*, flowered more frequently than medium sized trees (large: every 2.3 years; medium: every 5.9 years). There was also a trend in this direction for *E. pilularis*, *E. tereticornis*, *E. grandis*, *E. saligna* and *E. propinqua*. Most species of eucalypts are not thought to seed well, and therefore rarely flower well until they are at least 20–30 years old (Cremer *et al.* 1978). Mature forests of *E. regnans* produced 4.5 times as many flowers per tree than regrowth trees (Ashton 1975). Increasing flower numbers per tree on *C. gummifera* on the South Coast of NSW was positively correlated with increasing tree diameter (Goldingay 1990).

The factors which elicit the flowering response in any one species are presumably day length and temperature, or probably a combination of both (Beardsell *et al.* 1993). Flower induction in *E. lansdowneana* was influenced by the timing and duration of low temperatures, solar radiation and plant age (Moncur 1992).

Altitude had a significant influence on bud initiation and flowering times of a tallowwood-blue gum forest type. Flowering and seed fall of similar species at elevations of 250m-365m preceded flowering and seed fall at elevations of 550m-365m by one to two months, while at elevations of 850m-900m the flowering and seed fall was preceded by a similar period (Van Loon 1966).

## Frequency of Flowering Events

Beekeeping literature frequently refers to eucalypt species flowering on a two, three or four year cycle (Goodacre 1947; Clemson 1985). Law *et al.* (2000) indicated that on one site three melliferous species, *Angophora floribunda*, *E. acmenoides* and *E. saligna* failed to flower for a 10 year period, even though these species flowered on other sites during the same time period. In the same study, annual flower abundance was found to correlate with previous seasonal conditions. Prolific flowering followed a wet spring for *C. gummifera*, *E. pilularis* and *E. robusta*. The reverse was found for *E. grandis*, *E. siderophloia* and *Lophostemon confertus* which flowered profusely after a dry spring. Flower abundance for *E. propinqua* correlated with a previously dry winter and summer. These observations support the theory that each species behaves differently in relation to floral phenology in response to various climatic variables. The concept of a regular two, three or four year flowering cycle is not supported. Rather a combination of factors need to be met in order for flowering to be initiated. Normally a rest period is required, followed by the right combination of climatic events to suit each individual species before bud initiation occurs, followed by flowering. It is apparent that

each species is unique, in relation to bud initiation and flowering. Observations by experienced beekeepers over many years provide an exceptional pool of knowledge as to what triggers are important for flowering in individual melliferous species, and the flowering behaviour of various species in each geographic region.

## **Distribution of Melliferous Flora**

The distribution of any particular floral species will be dependent on climatic factors including minimum and maximum temperatures, frost occurrence, humidity, cloud cover or solar radiation, rainfall, soil water availability and physical factors including soil structure and soil fertility (Boland *et al.* 1984). Each species has its own set of optimal parameters which will impact on its geographic distribution. Some species will have a very defined set of criteria within which they can grow, whereas other species will have a broader set of criteria which allows the species to have a wider geographic distribution. Both categories are likely to include beneficial melliferous species, although not necessarily across their entire growing range.

Thus a beekeeper needs to develop an in-depth knowledge of the characteristics of the floral species that may benefit their honeybee colonies. To use this information to sustain a profitable beekeeping business, the beekeeper must have a working knowledge of the nutritional requirements of honeybees and the limitations imposed by the floral rewards associated with specific flowering events. The next chapter provides a basic understanding of these requirements.

## 4. Honeybee Nutritional Requirements

As a colony increases in size, the number of worker bees surplus to those required to attend larvae and queen requirements are available for foraging activities. The larger this surplus, the greater the colony's ability to forage for pollen and nectar and the greater potential for larger honey yields. In field trials, Kleinschmidt *et al.* (1974) measured the production of honey from colonies with significant population differences. Colonies averaging 50,000 bees produced 4.2 kg of honey per day, whereas colonies with a population of 35,000 bees produced 2.2 kg per day on a warm-weather honey flow. The effect of nutrition on birth and death rate, body crude protein levels and body weight influenced the colony population and honey production.

### Pollen

Honeybees require a range of elements to satisfy their nutritional requirements for normal growth and development. These elements include proteins (amino acids), carbohydrates, minerals, fats (lipids), vitamins and water. Pollen normally satisfies the dietary requirements for proteins, minerals, fats and vitamins. The proteins are composed of a series of amino acids, ten of which have been identified as being essential for honeybee nutritional requirements (deGroot 1953) (refer to Table 1).

Pollen, either stored or freshly gathered, is required for the feeding of larvae and young nurse bees up to the age of 15 to 18 days. The largest amount of pollen is consumed by three to six day old adult worker bees during spring breeding conditions, extending to nine day old worker bees during summer (Zherebkin 1965).

Fresh pollen is still regarded as the most ideal source of nutrition for honeybees compared to stored pollen and artificial pollen supplements. Haydak (1961) demonstrated that fresh pollen was 100% effective in stimulating the development of the hypopharyngeal glands in worker bees, whereas pollen stored at room temperature for one year had decreased its stimulating effect by 76%. Pollen stored for two years failed to initiate brood food gland development.

The quantity of pollen a colony consumes largely depends on the availability of pollen to foraging worker bees and the demands from the colony in the form of developing larvae and young adult honeybees. Doull (1974) suggested that on average, 125 mg of pollen was consumed for every larvae reared in the colony. A strong colony which may produce 200,000 worker bees in a year will require at least 25 kg of pollen annually. Doull also suggests this is an under-estimate for it does not take into consideration the pollen consumed by adult worker bees in the production of beeswax. Doull did not include the amount of pollen young adult worker bees consumed from when they hatch until two weeks of age, after which they largely consume only carbohydrate. Thus, a productive colony could have a need for 50 kg of pollen per year.

### Protein

Ample protein promotes a high birth rate and long-lived worker bees, whereas protein deficient conditions minimise the birth levels and length of life of adult honeybees (Kleinschmidt and Kondos 1977). Kleinschmidt and Kondos (1976) concluded that pollens with less than 20% crude protein could not satisfy colony requirements for optimum production. They indicated that for every 10 grams of protein required by the colony, it was necessary for 48 grams of pollen containing 30% crude protein to be consumed. If the protein content of pollen was reduced from 30% to 20%, the colony would be forced to increase its pollen consumption from 48 grams to 72 grams in an attempt to maintain satisfactory levels of production. They also indicated that a strong colony would require about 55 kg of pollen per year and if the quality of pollen decreased, then a colony would have to increase the consumption of pollen to make up for the reduction in nutrient content of the pollen.

Adequate protein also has a major role in the rearing of drone bees. Nguyen (1999) found that drones with higher body protein levels reached sexual maturity earlier than those with lower body protein levels, and that drones fed adequate protein produced higher numbers of spermatozoa than those fed low protein diets. This has significant ramifications for the rearing and supply of mated queen bees for sale to beekeepers. Drone mother colonies should have access to high quality pollen, or the provision of protein supplements, to ensure dietary deficiencies are not placed on the colonies rearing drones for mating with virgin queens.

## Amino Acids

Ten amino acids have been demonstrated by deGroot (1953) as being essential for honeybee nutrition (Table 1). If a pollen source is lacking in one or more of these essential amino acids, then the quantity of pollen consumed would need to be increased to obtain the quantities of the amino acids required. Pollens with low protein levels would expose honeybees to more severe amino acid deficiencies. Low levels of protein and essential amino acid would be more of a problem to a colony when there are reduced quantities of pollen stored in combs around the brood and only low volumes of pollen available in the field. A colony will require less pollen with a high protein content and all the essential amino acids at or above deGroot's recommended minimum levels, than it would if the protein content was lower or deficient in one or more amino acids.

**Table 1 Essential amino acids for satisfactory honeybee nutrition (deGroot 1953)**

Essential amino acids	Bee requirements <i>g/16g N</i>
Threonine	3.0
Valine	4.0
Methionine	1.5
Isoleucine	4.0
Leucine	4.5
Phenylalanine	1.5
Histidine	1.5
Lysine	3.0
Arginine	3.0
Tryptophan	1.0

## Fat/Lipids

Fat refers to lipids which include fatty acids, sterols and phospholipids. It is thought that fatty acids are necessary components of the phospholipids which play an important role in the structural integrity and function of cellular membranes of insects (Dadd 1973). Under normal conditions, any lipid requirement is satisfied by the consumption of pollen (Herbert 1992). Research conducted by Herbert and Shimanuki (1981) indicated that the sterols cholesterol or 24-methylenecholesterol supported brood rearing when included with diet supplements, compared to other diet mixes. They concluded that either cholesterol or 24-methylenecholesterol should be the sterols incorporated in dietary studies. However a diet of unsupplemented lactalbumin yeast containing 0.01% indigenous cholesterol, when supplemented with cholesterol (0.1% dry weight) did not increase brood rearing, which lead the researchers to believe that 0.01% level must have satisfied the requirements for brood rearing (Herbert and Shimanuki 1981).

Other than the requirements for cholesterol, the dietary needs of honeybees for fats or lipids are unknown. There are two other functions that appear to be possible in explaining the role of fats and lipids in pollen to honeybee nutrition. Fats in pollen would appear to act as strong attractants to foraging honeybees and certain fatty acids exhibit significant antimicrobial activity.

Singh *et al.* (1999) found that pollens with high lipid levels were preferred by foraging honeybees over pollens with lower lipid levels. The addition of either whole pollen lipids or the fraction soluble in cold acetone significantly increased the amount of dietary supplement consumed by caged honeybees. The addition of the fraction insoluble in cold acetone, or of an extract of the volatile substance in pollen, led to decreased food consumption (Nation and Robinson 1968). This indicated that the addition of fat and lipids to artificial diets may be beneficial or detrimental, depending on the composition and quantity of the individual components of the lipids. The role of lipids as phagostimulants (attractants) appears to have merit when examples of pollens with nutrient qualities low in protein but high in fat content are far more attractive to foraging honeybees (Todd and Bretherick 1942; Standifer 1966). Historically, the view has been held that the more attractive pollens have a higher food value for brood rearing, whereas in fact this was not a true indication of the actual nutrient contribution to brood rearing (Todd and Bretherick 1942). Singh and Singh (1996) suggest that *Brassica campestris* (mustard) pollen on its own may have a greater effect on improving brood production than feeding pollen from a mixture of sources not including mustard. The protein levels were average at 21.7%, although the authors regarded this as a “rich protein source”, the lipid level of 9.2% was considerably higher than reported lipid levels for other species.

Given field observations, it is very likely that increasing fat composition of pollens improves the attractiveness of pollen to foraging honeybees. Thus there are implications to the species in question, providing them with a pollination advantage.

## Minerals

Little is known about the mineral requirements of honeybees (House 1961; Herbert and Shimanuki 1981). Substantial amounts of potassium, phosphate and magnesium are required by all insects (Dadd 1973), but excessive levels of sodium, sodium chloride, and calcium have been shown to be toxic to honeybees (Nation and Robinson 1968; Herbert 1979; Horr 1998).

Various elements can be found in pollen including potassium, magnesium, calcium, sodium, iron, copper, manganese, zinc, aluminium, cadmium, chromium, lead, nickel and selenium, although many elements are only present as trace amounts (Todd and Bretherick 1942; Nation and Robinson 1971; Youssef *et al.* 1978; Day *et al.* 1990; Anderson 1997; Manning 2000). A total of 27 trace elements in pollen and honeybee larvae were reported by Grigoryan *et al.* (1971). Various references indicate that the total content of elements in pollen may vary from sample to sample. Nation and Robinson (1971) Herbert and Shimanuki (1978) reported pollen varying between 2 and 4% on a dry weight basis. Whereas Lunden (1954) reported a variation in mineral content of 1 to 7%. Honeybees reared on a synthetic diet containing various concentrations of pollen ash reared the greatest amount of brood at 0.5% to 1% ash levels (Herbert and Shimanuki 1978).

Mineral supplements designed for sheep and cattle have been fed to honeybees, but have shown to be unsatisfactory for adult honeybees (Nation and Robinson 1968; Herbert and Shimanuki 1977). These mixes lack potassium (House 1961) and contain excessive calcium and sodium (Dadd 1973).

## Overview

This chapter has briefly outlined some of the known nutritional requirements of honeybees. Based on some of this information various pollen supplements or protein supplements have been created to feed to bee hives during a shortage of natural pollen. The success of this strategy has been very mixed. There have been claims by various researchers, and primarily the companies involved in their

manufacture, that the efficiency of these supplements is high. The proof is more in the implementation by the beekeeper. A survey of 43 beekeepers suggested that one of the prime motivating forces to provide pollen supplements was for the beekeeper to feel like they were doing ‘something’ when natural pollen was short in the field (Somerville 2005). Historically bees have performed the best on natural pollen sources and this will probably be the case for some years to come, particularly given the economics of supplementary feeding.

This Chapter hasn’t covered nectar and the carbohydrate requirements of honeybees. Using sucrose sugar syrup is highly successful in providing bees with an energy source to prevent starvation and create stimulation of the colonies. Most beekeeping countries have integrated a regular sugar feeding program into their calendar of activities. In the Australian context, given our huge annual variation in flowering events and the fact that it is possible to provide honeybee colonies with a potential nectar source most of the year, sugar feeding has not become common place. With issues such as climate change and the increasing reduction in the reliability of various floral species to yield nectar when in flower, the practice of sugar feeding honeybee colonies is likely to increase, although again this will be tempered by the financial viability of beekeeping.

The following chapter outlines the floral characteristics of the principal hardwood species currently favoured in Australia where known and their possible benefit to honeybees



## 5. Evaluation of Plant Species in Plantations for Honeybees

In 2004 the publication ‘Australia’s forests at a glance’, by the Bureau of Rural Sciences, listed the principal hardwood species by area of the total of the plantation estate as *Eucalyptus globulus* 21%, *E. globulus* and *E. grandis* 2%, *E. nitens* 2%, *E. regnans* 1%, *E. dunnii* 1%, minor and unidentified hardwood 8%. The softwoods were *Pinus radiata* 49%, *P. elliotti* 5%, *P. pinaster* 3%, *P. caribaea* 4%, *Araucaria* species 3%, and other softwood species 2%.

The following is an overview of the attributes of the principle hardwood plantation species as they relate to honeybees.

### ***Eucalyptus globulus***

Referred to as blue gum or Tasmanian blue gum, this species occurs naturally on the east coast of Tasmania, on Flinders and King Islands, and on the southern coastal areas of Victoria. The main flowering period is from September to December. Besides being heavily favoured as a plantation species, blue gums have also been extensively planted in various parks and gardens across southern Australia.

As a source of honey, blue gum is listed in a Tasmanian study as providing a surplus honey crop in “some years”, flowering biannually during late October/early November. It is not apparent in the various studies of Tasmanian beekeeping practice that this species is of major importance. No mention is made of blue gum plantations providing any benefit to honeybees in Tasmania (Ayton 1981, Kleinschmidt *et al* 1990).

In Victoria “Southern blue gum” is said to flower from June to November, producing a light amber-coloured honey of fair density and good flavour. The pollen is useful for building up hives after the over wintering period (Goodman 1973).

In a study of the floral resources used by the South Australian apiary industry, there is no mention of *Eucalyptus globulus* even though there are extensive areas of this species grown in plantations in the south and east of the state (Paton *et al* 2004).

Thus *Eucalyptus globulus* could be considered, from the available published information, to have a medium level of importance in some areas of the country. No reference could be found that suggests that this species provides any significant value to commercial honeybees in a forest plantation context.

### ***Eucalyptus grandis***

Commonly referred to as flooded gum or rose gum, this tree naturally occurs on the north coast of NSW into coastal south east Queensland, extending north along the Queensland coast. Flowering period is between April and August (Boland *et al* 1992) or March to May (Blake and Roff 1988).

Flooded gum is described as flowering fairly regularly and occasionally producing a heavy honey crop, although normally only producing a small surplus honey crop. Flooded gum produces honey of poor quality, being amber in colour, strongly flavoured and having a thin density (Clemson 1985). Blake and Roff (1988) also describe the honey produced from flooded gum as having a strong, somewhat unpleasant flavour and of weak density. It granulates fairly quickly, is slatey in colour and has a soft, smooth grain.

At times a good supply of pollen can be collected, which suggests that this species can be favourable for encouraging the breeding of bees and thus expanding colony populations in preparation for hives to be moved to a more reliable nectar flow (Clemson 1985).

In a study of NSW beekeepers, 14 beekeepers listed flooded gum as a floral resource for commercial honeybees. The species was number 62 on a list of species and was only mentioned by 4.4% of the respondents (Somerville 1999). Years between flowering events ranged from two to three, with an average honey harvest from each hive of 17 kilograms. Beekeepers generally rated this species highly as a source of pollen.

A Queensland publication lists flooded gum as a minor source of honey and a medium source of pollen. Comments on flooded gum in the same publication include: 'Although this tree blossoms regularly and at times heavily, it is a shy-yielding species. A small surplus is gathered occasionally, usually in the form of a natural blend with honey from other species flowering at the same time. Good quantities of pollen are obtained and as a result beekeepers with apiaries in flooded gum localities find that colonies maintain strength during the normally adverse autumn and early winter periods' (Blake and Roff 1988).

### ***Eucalyptus nitens***

Commonly referred to as shining gum, this species has a natural range extending from the Great Dividing Range in the north of NSW into Victoria. Flowering is from January to March (Boland *et al* 1992).

Another reference has shining gum flowering between October and March, reaching peak flowering in summer. Flowering is normally light but with occasional heavy flowering events. The honey produced is amber in colour and of medium flavour and density. Pollen is produced in abundant quantities (Goodman, 1973). In later surveys of commercial beekeepers in NSW and Victoria, shining gum or *Eucalyptus nitens* is not recorded at all. (Somerville 1999, Goodman 2001).

### ***Eucalyptus regnans***

Commonly referred to as mountain ash, this species has a natural distribution in the mountain ranges of eastern Victoria, south west of Melbourne, plus north east and south east Tasmania. Flowering is from December through to May (Boland *et al* 1992). Generally, mountain ash has a biennial cycle of heavy and light flowering years. The flower buds appear in December–January, just over two years before flowering. The enclosed bracts are shed in the following December–January, exposing the clusters of flower buds. These buds develop on the trees for a further 15 months before flowering in autumn. Heavy losses of buds often occur (Goodman 1973). The flow of nectar can be erratic when the nectar yielded is thin, however when the nectar is denser a heavy flow usually occurs. Honey is strongly flavoured, dark and of medium density. Bees thrive on the pollen which is yielded abundantly (Goodman 1973).

A later survey of beekeepers by Goodman (2001) listed mountain ash as being of value as a source of nectar by the beekeepers in only two regions. No mention of mountain ash could be found relating to any use or value in the species by Tasmanian beekeepers (Ayton 1981, Kleinschmidt *et al* 1990).

### ***Eucalyptus dunnii***

Commonly referred to as Dunn's white gum, this species has a natural distribution restricted to north east NSW, extending just into south eastern Queensland. Flowering is from March until May (Boland *et al* 1992).

Unfortunately the name “white gum” has been used to refer to a range of eucalypt species. Thus it is difficult to categorically cite references mentioning white gum unless a degree of evidence suggests that the species is *E.dunnii*. No references were reliable enough to suggest, with any degree of accuracy, that they were referring to *E.dunnii*.

## **Other Species**

There are a range of other hardwood species that are being grown on a small scale that may provide some benefit to honeybees. Some of these may be common in local plantings such as spotted gum, Chinchilla white gum and Dunn’s white gum in south east Queensland. These species will also vary in relation to their benefits to honeybees. Only the major national hardwood species have been discussed in this chapter.

The following chapter provides a general overview of the management practices that have the potential to affect the use by beekeepers of any hardwood plantation estate, no matter what the floral species.

## 6. Plantation Management Practices

There are a number of plantation forestry management practices that have the potential to impact on the availability and value of the floral resource to the commercial beekeeping industry.

### Access

While access to private property by beekeepers is usually agreed to in an informal setting, it is not likely to be the case with access to private sites owned by large companies. Local management does not usually have the authority to grant access to third parties.

Access comes with a set of risks to both the beekeeper and the property owner. These are tolerated by individual beekeepers and farmers but are unlikely to be tolerated in a large corporation due to OH&S issues. Beekeepers, in most situations, have now taken out public liability insurance which should cover the owner of the property for any liability caused by the bees being on their land.

The fee currently charged by public land managers is, in most cases, seen as only covering the administration costs. Making a profit from the beekeeping industry by public land managers has never been a goal.

Given that there is very little to no financial incentive to allow managed bee hives access to lands managed for private forestry plantations and the fact that bees sting creating a potential occupational health and safety issue for forestry workers, also beekeepers require access 24 hours a day, 7 days a week to move apiaries into and remove them from sites, it is highly unlikely that access by commercial beekeeping operations into large agri/forestry plantations will be seen as a desirable/compatible activity by private forest companies.

### Single Species

Plantation forestry can be regarded as a crop with a long growing period. The land for the crop is selected/identified, it is then suitably prepared, planted with the desired species, the growing period is managed and eventually the trees are harvested. This high cost and high risk enterprise must maximise returns for the investments made.

Plant breeding is a common concept across all plant industries, and plantation forestry is no exception. Successful domestication and breeding of eucalypts, including hybridisation and mass clonal propagation, have led to large gains in productivity (Eldridge et al 1993).

The genetic diversity within a single species plantation is likely to be very narrow due to the intensive selection process to isolate and propagate those traits that make a particular plant economically attractive. Thus, if the trees in a particular forest plantation are allowed to grow to maturity and flowering occurs, it is extremely likely that most trees within the plantation will flower at much the same time.

In a natural forest it has been demonstrated that the same trees from a particular species will flower at approximately the same interval at each flowering event. A tree from a particular species that flowers early will always flower early. Also in a mixed forest there is likely to be a number of species in flower which could be of benefit to honeybees. Flowering weeds may be available in the early establishment of a plantation but these will become insignificant as the canopy of the plantation becomes denser.

In a plantation forestry situation where a single species is the dominant flowering event, it is unlikely that there will be many opportunities that will occur where foraging honeybees will have access to a range of other flowering species. Other species may be present and in flower but, by the very nature of plantations, competition for soil nutrients and soil water from non-crop species is often discouraged by managers of the plantation.

## **Chemical Use**

Native forestry management systems very rarely use agricultural chemicals. Plantation forestry systems on the other hand, may periodically apply fertilisers, herbicides and insecticides. Herbicides and fertilisers are likely to be used prior to planting or in the very early stages of plantation establishment. Insecticides are occasionally used to control defoliating insects in the early stages of growth. Most of these uses will not impact on honeybees working plantation forestry species when they are mature enough to flower.

During the early establishment period there may be other floral species in adjacent blocks that may be highly attractive to honeybees. Likewise, weeds amongst the planted trees in a plantation may also attract foraging bees. Use of agricultural chemicals to manage the establishment of the forest plantation in these circumstances may have a major detrimental impact on managed honeybees within the foraging area, which could be a 3 to 5 km radius of the bee hives during warm weather.

Beekeepers are usually aware of the dangers and risks associated with placing bees in or near agricultural crops. Some crops have a very high risk to managed bees, e.g. cotton, due to the frequency and toxicity of the chemicals used. Beekeepers may not be aware of the specific use of chemicals potentially harmful to honeybees in plantation forest plantations. This is an added risk not experienced when beekeepers utilise native forest or woodland ecosystems.

## **Harvest Period**

The more quickly a forest plantation can reach 'commercial' maturity, the faster a profit can be realised by the investors. Most agricultural crops have a defined growing period, if they don't receive sufficient moisture or nutrients during this period they either fail or their yields are adversely affected. A 'timber' tree crop, on the other hand, has the advantage of slowing down growth during water shortages or when growing conditions are not favourable. Having invested significant funds into growing a 'timber' crop, it is desirable to have the crop perform at its optimum. Thus, forest plantations have tended to be established in areas where the growth rates and ultimate yields for specific species are maximised.

The growth rates are calculated and harvest dates are determined on maximising the yield of wood from a given area within the shortest period possible. To achieve this, plants are spaced to shade out any non-crop species as soon as possible. Given adequate soil moisture and nutrients, growth will be rapid. A thinning harvest may be conducted within the crop rotation. Most eucalypts will be harvested at 8–12 years, depending on the type of wood required for a specific market.

The density of the planting to encourage rapid, upright growth is unlikely to promote bud initiation of most eucalypt species. During the course of this study some reports were received that indicated that the trees around the perimeter of a plantation may initiate buds and flower before harvest, suggesting a preference for reproduction where competition for light, nutrients and water is not so intense.

These are some of the obvious forest management practices and issues that will impact on the assessment of plantation forest as a floral resource for commercial beekeeping activities. The following chapter will discuss the issues highlighted in previous chapters and provide further information to draw some conclusions on the relationship of plantation forestry and honeybees.

## 7. Discussion

Whether forestry plantations can offer opportunities to commercial beekeeping interests is unclear. On analysis of the plantation forestry situation in Australia and the management strategies and style of Australian beekeeping enterprises, there is probably very little that either can contribute to the other.

### Complexity of Managing Honeybees

The introduction to this report established the patterns and behaviours of the beekeeping industry. This model has evolved as the most economic management system within the Australian environment for keeping honeybees on a commercial basis.

The need to move loads of bee hives from location to location is based on the sporadic nature of the flowering events that beekeepers rely on. This system is largely driven by rainfall events and the requirements of managing honeybees. The chapter on honeybee nutritional requirements is provided to give the reader with no or little understanding of this subject a background on what factors should be considered in maintaining a healthy colony of bees.

An apiary comprised of 80–140 bee hives is an intensive livestock system. Animal units (measured as bee hives) have to forage within a restricted area for a finite resource. The restricted area is defined by how far bees can fly economically and the geography of the location.

Beekeepers thus have adapted their management to seek out major flowering events where the floral rewards in the form of nectar and pollen adequately meet the needs of the number of colonies within those apiaries. Reducing the numbers of bee hives in some circumstances could be beneficial to the individual bee colonies, but this change of system would require greater numbers of sites and also potentially create an unprofitable beekeeping business.

The larger the beekeeping business, the more profitable the business tends to be (Crooks 2008). This is based on large apiaries of 80 to 140 hives. Smaller numbers of bee hives per site would amount to a very large number of apiary sites for each flowering event with an increased cost in servicing the same number of hives.

Given the current and past economic returns to Australian beekeepers, it is unlikely that a change of beekeeping management practice is likely in the foreseeable future. Thus mainland Australian beekeepers are tied to a system of nomadic beekeeping wherein large loads of bee hives are transported within their defined operational zone.

### Major Resource Constraints

As already described, access to a range of floral resource species is critical to maintaining profitability of commercial beekeeping businesses within Australia. A range of factors continue to put pressure on the availability of suitable sites to place commercial loads of bees. These include urban development, drought, fire, dieback, land clearing, risks associated with certain agricultural/horticultural crops due to toxic sprays, reduced number of favourable weed species and biocontrol programs aimed at useful honeybee plants.

Reduced access to conserved lands is a growing area of concern to the beekeeping industry. As more government-managed lands, primarily lands formerly managed by forestry departments, are incorporated into conservation category lands, and more private land is obtained to increase the conservation reserve system, the impact of policies that exclude managed honeybees could be devastating.

Ironically, beekeepers were probably one of the earlier groups within the Australian community to have and voice strong conservation values. Loss of older mature trees with excellent reputations to yield substantial honey crops was a major concern through the 1950s and into the 1970s. The beekeeping industry lost the use of vast areas of high value forest and woodlands as a result of the initial establishment of the softwood plantation industry in the 1970s. It is not feasible for beekeepers to own all their own sites on which to place bee hives. In most beekeeping businesses they will own none of the apiary sites they utilise, this is just simply not an economic proposition. Thus beekeepers have relied on access to lands at the discretion of others. As the resource base continues to decline, the remaining access to suitable sites becomes even more valuable to the beekeeping industry.

One of the most serious risks to the future viability of the Australian beekeeping industry is the loss of access to government-owned forested lands due to change in management philosophy that excludes the keeping of bees. Combined with the general reduction in suitable sites nationally, the beekeeping industry's capacity to find alternate floral resources is heavily constrained.

Forest plantations have been suggested as an alternative resource for beekeeping. Unfortunately species selection, harvest period (age of tree), density of planting and other factors such as access greatly diminish the value of the resource for commercial beekeepers.

## International Perspective

Eucalypts are essentially Australian native species except for a handful of species that naturally occur in Indonesia. The genus is comprised of over 700 species, although Australian beekeepers probably focus on just 200 species for their floral rewards to honeybees. Various species exist in a range of soil types and climatic conditions. Generally, Australian flora has evolved in an environment with poor soil fertility and erratic rainfall events.

Due to the diversity of the eucalyptus genus, there are species that will grow in just about any climatic zone, and the genus has been propagated worldwide. An estimate of over 13 million hectares of eucalypts are now under cultivation in plantations worldwide (Davidson 2005). India and Brazil have the largest areas of eucalypt plantations, estimated at 4.8 million and 3.6 million hectares respectively. Several million hectares of additional equivalent area of eucalypts are estimated to have been planted on farms and in rural areas generally as single trees or as small groups of trees in India.

Rates of growth are often much faster in the exotic locations than in the natural range. This is thought to be because of the lack of substantial pest pressure, usually increased and more reliable moisture availability, and frequently greater soil fertility.

Eucalypts are considered a floral resource for beekeeping industries in many countries. Personal enquiry during this research suggests that eucalypts also tend to be more regular and reliable in their flowering patterns in these exotic locations.

The apparent success of planting eucalypts and the indirect contribution this activity has had to the local beekeeping industries in overseas has little bearing on the situation in Australia. Many beekeeping countries operate apiaries in permanent or semi-permanent locations and only occasionally or seasonally harvest surplus honey. Average annual honey crops in many of these situations are extremely low by Australian standards, 20 to 40 kg/hive compared to the NSW average of 100 kg/hive (Somerville 2004).

The difference in species is also significant. The most reliable eucalypt species for nectar production in the Australian context are those belonging to the 'box' and 'ironbark' group. Species from the 'gum' group of eucalypts are the most popular for plantation forestry, although the red gums, including *Eucalyptus camadulensis* and *E.tereticornis* are excellent species for honeybees and are also favoured for use in plantation forestry projects in the international setting.

There are far too many variables to draw any broad conclusions as to the value of eucalypt plantations to honeybees in the international setting. Therefore, there is very little scope to compare plantation forestry within Australia as a floral resource for honeybees, as compared to any international equivalent.

## **Conclusion**

The plantation forestry industry is increasing the area planted to trees. Up until very recently this trend was unlikely to slow down. The recent demise of two of the largest public listed companies with major stakes in the forest plantation industry has created some uncertainty. Even so, plantation forestry makes a lot of sense in relation to growing the products for which there is a profitable market.

During the same period that forestry plantations have gained momentum within Australia, we have witnessed an increased pressure on the Australian beekeeping industry in relation to a severe decline in floral resources on which the industry is reliant. Providing a complete artificial supplementary diet to honeybees is not possible or economically viable. Significantly more research needs to be completed before this is likely to be achievable.

The search for alternative floral resources has occupied the thoughts of the Australian beekeeping industry and continues to be explored by the international beekeeping fraternity. The concept of purpose planted areas to benefit honeybees has been researched with limited success. Simply put, it is not economically viable to plant a specific crop purely for the benefit of a commercial honeybee enterprise.

Commercial honeybees are harvesters of the floral resources, nectar and pollen, on an opportunity basis. Nectar and pollen are limited resources. Different floral species provide different volumes of these rewards under varying circumstances. The species selected for softwood plantation forestry within Australia offers no significant value to honeybees. The hardwood species have the capacity to provide some rewards to honeybees when in flower.

The harvest rotation, density of planting and other issues discussed within this report clearly rate the hardwood plantation estate as having a very low overall value to the Australian beekeeping industry. There are likely to be localised examples of some benefit to honeybees, but generally the forest plantation estate will not replace the loss of access to native forests, loss of sites due to urban expansion, or any of the other constraints on the floral resources on which the beekeeping industry relies.



# Recommendations

1. Plantation forestry may provide floral resources to the beekeeping industry if the individual species are grown long enough to provide regular flowering events. Thus where there is a possible choice of species to be planted, the selection of a known nectar and pollen producing plant should be considered.
2. Any concept by any agency or authority that the plantation forest estate will provide substantial floral resources to the commercial beekeeping industry should be discarded. There is no evidence that this has or will occur in the foreseeable future.
3. With the growing public awareness of the need to plant trees and the increased pressure to revegetate degenerated sites, there is an opportunity for species that are known producers of nectar and pollen to be considered. This should not only include larger tree species but also shrubs and understorey plants known to contribute to the overall volume of nectar and pollen available.

This has the benefit of providing a resource to honeybees, and also to native nectarivorous animals such as sugar gliders, honey eating birds, nectar bats and a range of beneficial insects.

Degenerated sites that need rehabilitating may include mining sites, roadsides, erosion areas, landfill sites and similar sites.

4. On-farm tree planting projects to provide shelter for livestock, protect water quality, stabilise riparian areas and provide windbreaks all provide opportunities to choose floral species that have a multi-use values.

Selecting reliable nectar and pollen producing flora will increase the floral resource to honeybees and provide a food source to encourage the establishment and retention of native nectarivorous animals including birds, mammals and insects.

These plantings are likely to provide a more long term benefit to nectarvores than forest plantations which are regularly harvested. Reports from Victoria and southern NSW suggests that at least one tree species planted occasionally on farms, sugar gum (*Eucalyptus cladocalyx*) a native of South Australia, for shade and shelter for livestock has provided surplus nectar to commercial honeybees.

This course of action should be placed in the context that commercial honeybees are currently managed in large apiaries (80 – 140 hives) requiring significantly large areas of flowering plants (bees are able to fly 2 to 4 kms to forage). Small area plantings of favourable floral species are not likely to replace major flowering events from dominant regional floral species that are known to produce copious supplies of nectar and pollen.

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# Forestry Plantations and Honeybees

by Doug Somerville

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The Australian beekeeping industry is suffering from a decline in the available and suitable apiary sites with access to beneficial floral species. Without a range of suitable flowering events for the bees to obtain their necessary nutritional requirements, the bees won't survive. This research study is designed to investigate the potential capacity of plantation forestry to contribute to the Australian honeybee floral resource base.

The report is aimed at assisting the beekeeping industry in clearly identifying the systems and issues under which they operate with a varied audience, including foresters and those with a concern for the future viability of the Australian beekeeping industry.

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