BOTANICAL INVENTORY AND PHENOLOGY IN RELATION TO FORAGING BEHAVIOUR OF THE CAPE HONEYBEES (*APIS MELLIFERA CAPENSIS*) AT A SITE IN THE EASTERN CAPE, SOUTH AFRICA.

THESIS

Submitted in fulfilment of the requirements for the Degree of

MASTER OF SCIENCE, RHODES UNIVERSITY

By

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April 2003

DECLARATION

The Registrar (Academic),
Rhodes University.
Dear Sir,

I, **Admassu Adi Merti** (*Student no:* **g01m3960**) here by declare that the thesis entitled

"BOTANICAL INVENTORY AND PHENOLOGY IN RELATION TO FORAGING BEHAVIOUR OF THE CAPE HONEYBEES (*Apis mellifera capensis*) AT A SITE IN THE

EASTERN CAPE, SOUTH AFRICA"

is the result of my own investigation and research under the supervision of Mr. Peter Phillipson; and that it has not been submitted in-part or in-full for any other degree or to any other University.

Signature…….Date……

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ABSTRACT

From an apicultural point of view the Cape fynbos is under-utilised and our knowledge of its utilization by the Cape honeybees is incomplete. The key aim of this study was to test the hypothesis that the Cape honeybees utilize the fynbos species as the preferred source of nectar and pollen. Subsidiary aims included distinguishing vegetation communities in the area, identifying pollen and nectar sources, the relationship between brood population and seasonal pollen collection patterns, examining the effect of meteorological factors on pollen collection.

The study site was on Rivendell Farm within the Eastern Cape Albany district: an area of high species richness. A checklist of vascular plant species was produced revealing 97 families, 271 genera and 448 species. A classification by two-way indicator species (TWINSPAN) recognized seven vegetation communities: Forest, Bush clumps, Acacia savanna, Grassland, Grassy fynbos, Fynbos and Shrubland. Direct field observations of the foraging of Cape honeybees identified 54 nectar and pollen source plant species.

Honeybee pollen loads trapped from four colonies of hives identified 37 pollen source plants of which *Metalasia muricata*, *Eucalyptus grandis*, *Eucalyptus camaldulensis*, *Erica chamissonis*, *Helichrysum odoratissimum*, *Helichrysum anomalum*, *Crassula cultrata* and *Acacia longifolia* were the predominant pollen source plants. It was also found that 60% of pollen yield derived from fynbos vegetation. The pollen source plants came from both Cape endemic and from non-endemic species. Thus we reject the hypothesis that Cape honeybees selectively forage fynbos species as a preferred source of pollen and nectar.

The examination of the effect of temperature, wind-speed and temperature on pollen collection activity of honeybees revealed that: a temperature range of between 14°C to 26°C was optimal for pollen collection; wind speeds of up to 4m/s were conducive for pollen collection; relative humidity was found to have no significant influence on pollen collection.

Pollen collection and brood rearing patterns are positively correlated with flowering intensities, but we found in our Eastern Cape study site that brood rearing was not limited to the spring flowering season but did extend to the end of summer.

In order to determine the available nectar yield of common plant species hourly secretion of nectar volumes was measured for 24 hours to determine the variation of available nectar during different times of the day. In all nectar producing species the nectar volume was high in the early morning and declined as the day progressed. We found that the volume of available nectar was affected by prevailing temperature and humidity around the flowers.

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CHAPTER 1 INTRODUCTION

General Introduction

Southern Africa, defined as South Africa, Lesotho, Swaziland, Botswana and Namibia has rich natural resources. One important natural resource is the flora and vegetation. Southern Africa an area, which is known for its remarkable plant diversity with a high level of endemism (Adamson 1938; Cowling *et al*.1989; Gibbs Russell 1985; Goldblatt 1978). This diversity and endemism is not uniformly distributed throughout southern Africa but localized in certain regions. The Cape and the Succulent Karoo are the richest floristic regions in southern Africa with exceptional levels of diversity and endemism in comparison with similar areas elsewhere in the world.

The flora of southern Africa comprises 23,404 vascular plant species (Arnold & De Wet 1993) of which at least 80% are endemic (Gibbs Russell 1985 & Goldblatt 1978). South Africa contains the greatest part of this diversity, and it is the only country in the world to totally contain one of the world's six Floral Kingdoms, the Cape Floral Kingdom, which comprises one third of South Africa's plant species (Low & Rebelo 1996), and possibly comprises the world's most botanically rich habitat with higher plant diversity than many tropical rainforest areas (Cowling *et al*. 1992).

South Africa comprises many different vegetation types. The vegetation of South Africa was described by Acocks (1953) and classified into 70 veld types based on agricultural and farming potential. Forty years later, Rutherford and Westfall (1994) mapped the vegetation types by biome and classified them into seven biomes on the basis of dominant and co-dominant growth forms. These are the Grassland, Savanna, Succulent and Nama Karroo, Forest, Fynbos and Desert biomes. Low and Rebelo (1996) added a Thicket biome, which had been earlier, described by Cowling (1984) and Lubke *et al*. (1986) (Fig 1.1).

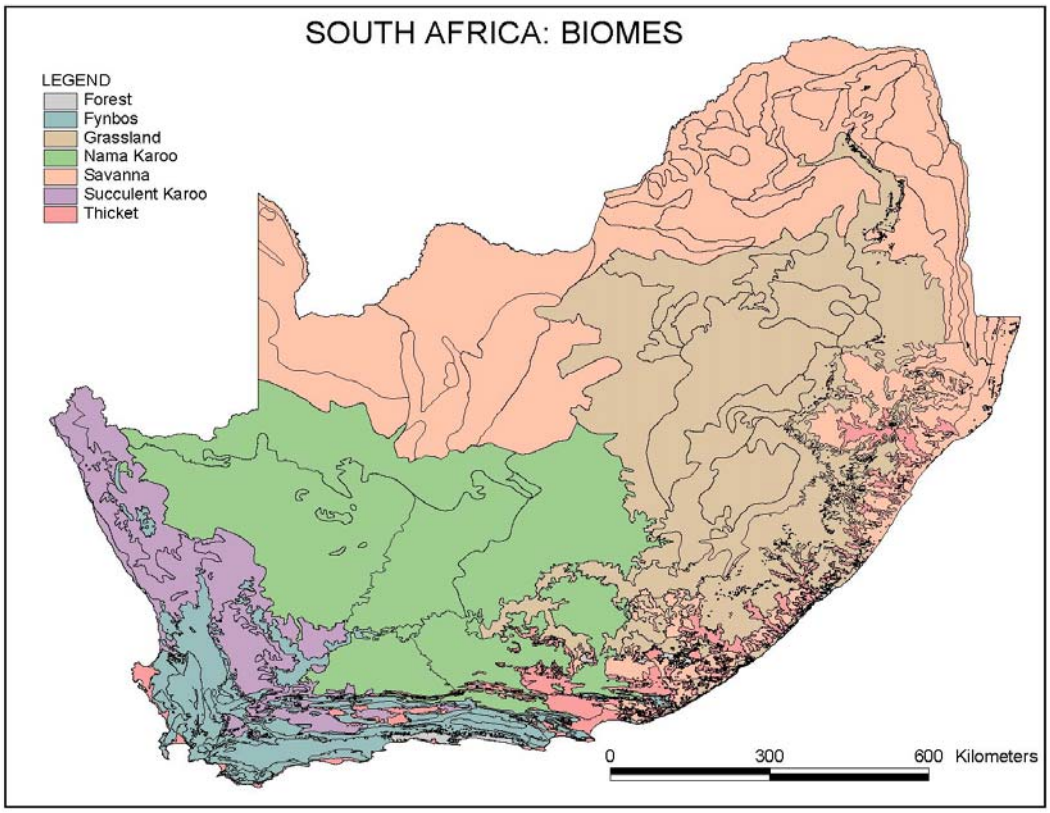

Figure 1.1 The major vegetation biomes of South Africa (Low & Rebelo 1996).

1.1.1 Phytochorological regions of Southern Africa

Phytochorology is defined as the study of the distribution of taxa, floristic regions and their evolutionary history (White 1983). In southern Africa, there are five phytochoria (White 1983).

I. The Afromontane archipelago-like regional centre of endemism is formed as an archipelago or island over the southern Africa. The major vegetations consist of mainly dense forest, grassland and savanna. It is found in the high plateau of the Drakensberg in southern Africa.

II. The Cape regional centre of endemism is found in the south western Cape. It consists of rich flora with a greater number of endemic species. The vegetation mainly consists of fynbos and restiods elements. It also includes forest remnants of Afromontane affinity and is restricted to fire-protected areas with deeper moisture and more fertile soil than adjacent fynbos.

III. The Karoo-Namib regional centres of endemism are found north of the Cape phytochorion. Its characteristic feature is the rich flora with many endemic

species. The vegetation consists of mainly an open dwarf shrub or desert vegetation and woody plants.

IV. The Tongaland-Pondoland regional mosaic centre of endemism is found along the coast of the Indian Ocean. It contains rich flora with endemic species. The vegetation consists of various types but the typical vegetation is forest.

V. The Zambezian regional centre of endemism is found to the north east of the Karoo phytochoria. It is a floristically rich area and is characterized by many species, which are widely distributed, but it contains many endemic species. The typical vegetation consists of woodlands and savannas.

The Eastern Cape Province has been known as an area rich in plant species and communities and one of phytogeographical complexity and diverse flora of mixed origin. The region is an area of transition where climates merge from winter rainfall to summer rainfall and thus it is a juncture for all major biomes of South Africa. It is also a transition zone where four major phytochoria meet namely:

1. The Tongaland–Pondoland forest thicket enters the region along the coast and penetrates up the river valleys.
2. The succulent and dwarf shrubland of the Karoo-Namib region extends down the dry river valleys from the arid interior.
3. The Afromontane elements of the grassland and forest vegetation types extend down the mountains to sea level in the southwestern region of the Eastern Cape where coastal forests are composed of many Afromontane species.
4. The Cape fynbos elements penetrates the Eastern Cape on the sandy, infertile soils derived from the Cape supergroup rocks. The maps of White (1983) shows the phytochorological distribution for the Eastern Cape and Southern Africa is shown in (Fig 1.2 a, b).

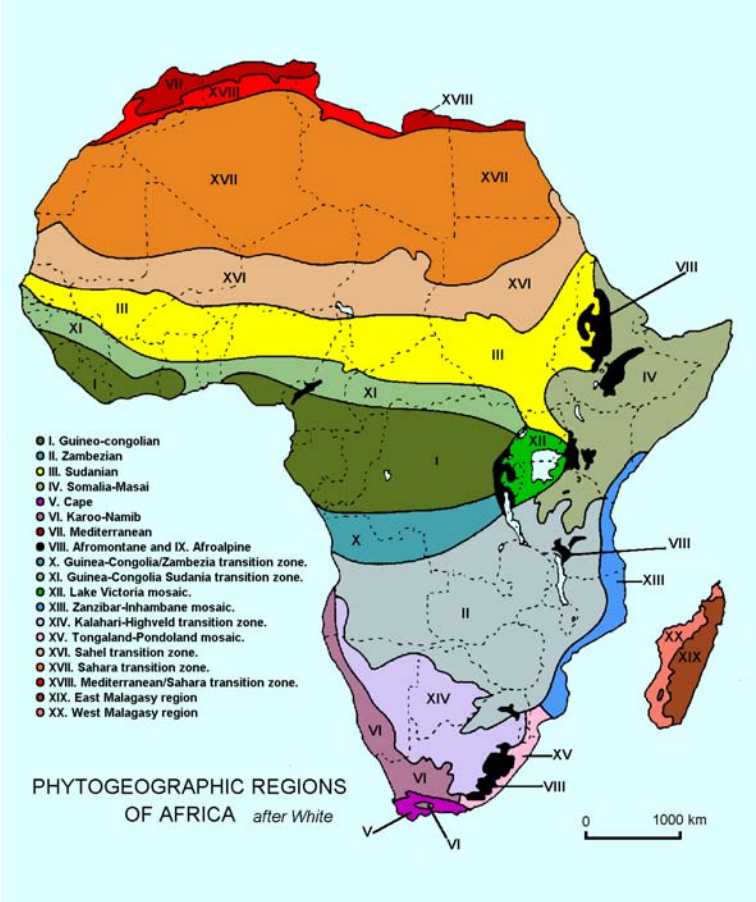

Figure 1.2a Phytochorological regions of southern Africa (White 1983)

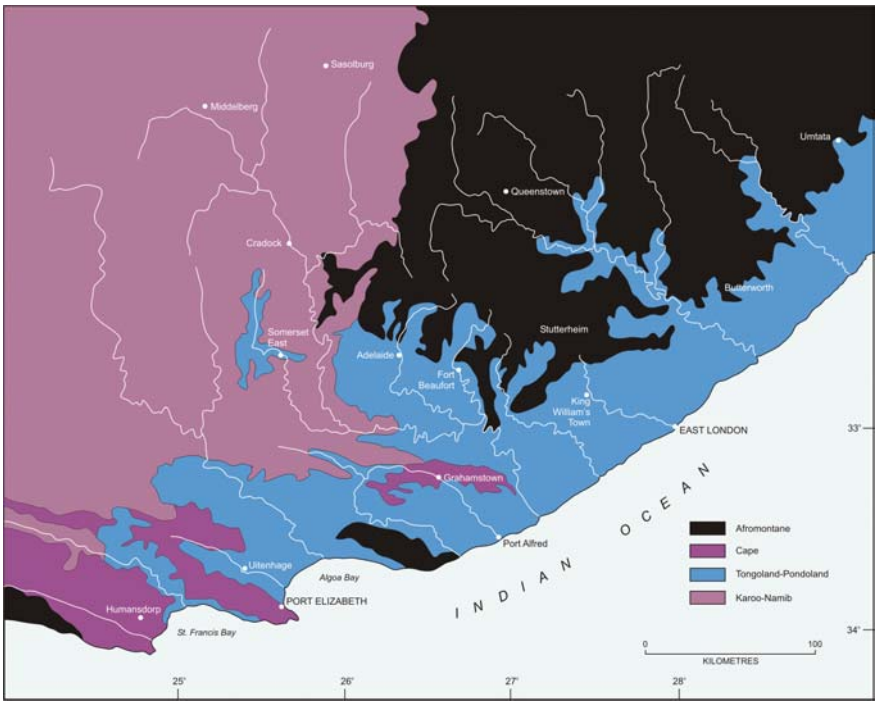

Figure 1.2b Phytochological regions of the Eastern Cape (Lubke 1986)

1.1.2 The relationship between plants and honeybees:

The relationships between plants and insects are the result of a co-evolutionary process (Johnson 1992) Insects are thought to be agents for diversification of plant species within a plant population as a result of their localized movement of pollen, which restricts pollinator-mediated gene flow among the plant population (Kearns *et al*. 1993).

Plant-pollinator interaction can also provide the basis for studies of phenotypic selection and reproductive success of plants (Kearns *et al*. 1993). In many cases, both plants and flower visitors are good candidates for studies of community ecology (the flow of energy in an ecosystem and interdependence of organisms one upon the other). For example, the honeybee plays a role in the transfer of pollen and the fertilization process, which results in seed production and various organisms in the ecosystem utilize the seeds. Which are needed to sustain plant populations.

Honeybees are one of the most important pollinators of angiosperms because of their vegetarian diet, flower visiting habits and hairy bodies that readily pick up pollen grains, and the fact that they exclusively visit many flowers of the same species during a single trip (Delaplane & Daniel 2000). As honeybees visit a succession of flowers, in search of food, their bodies become dusted with pollen grains and in the process the pollen grains make contact with receptive stigmas and effect pollination. This enables the reproduction, productivity and diversification of plants. Honeybees pollinate 16% of flowering plant species in the world and nearly 400 species of agricultural plants (Crane and Walker, 1984). In the absence of honeybee pollination, plant diversity and ecosystem services would be negatively affected.

1.2 The flora and vegetation of Cape Floral Kingdom

The Cape Floral Kingdom comprises an estimated 9000 species of vascular plants (ferns, gymnosperms and flowering plants) native to this area, of which about 69% are endemic (Goldblatt and Manning 2000). The composition of the Cape Floral Kingdom is extremely unusual when compared with floras of other parts of the world including other parts of Africa (Bond & Goldblatt 1984). The major plant families that contribute to the diversity and endemism of the Cape flora are Asteraceae, Fabaceae, Iridaceae, Aizoaceae,

Ericaceae, Scrophulariaceae, Proteaceae, Restionaceae, Rutaceae and Orchidaceae (Goldblatt & Manning, 2000) (see Table 1.1).

The largest genera are *Erica*, *Agathosma*, *Phylica*, *Oxalis*, *Moraea*, *Cliffortia*, *Senecio*, *Muraltia*, and *Gladiolus* (Goldblatt & Manning, 2000).

The main life form in the Cape flora is the sclerophyllous shrub with microphyllous leaves; this has given rise to the word fynbos meaning (fine [leaved] bush) in Afrikaans. Fynbos is characterized by heath-like vegetation. It has similarities with vegetation in other parts of the world that possess a "Mediterranean" climate. Fynbos extends from the Western Cape to the Eastern Cape province just beyond Grahamstown (Moll & Bossi 1984) and it comprises various vegetation types such as Fynbos, Grassy fynbos, Renoster shrubland, Afromontane forest, Thicket, Karriod shrubland and other vegetation (Fig.1.3).

Table 1.1:Ranking of the 20 largest families in the Cape flora by size (Goldblatt & Manning, 2000)

Family	Total number of species	Number of endemic species
Asteraceae	1036	655
Fabaceae	760	627
Iridaceae	661	520
Ericaceae	658	635
Aizoaceae	660	525
Scrophulariaceae	418	297
Proteaceae	330	319
Restionaceae	318	294
Rutaceae	273	258
Orchidaceae	227	138
Poaceae	207	80
Cyperaceae	206	101
Hyacinthaceae	192	87
Campanulaceae	184	140

(Table 1.1 cont.) Family	Total number of species	Number of endemic species
Asphodelaceae	158	81
Geraniaceae	155	91
Polygalaceae	141	122
Rhamnaceae	137	126
Thymelaeaceae	124	94
Crassulaceae	123	35

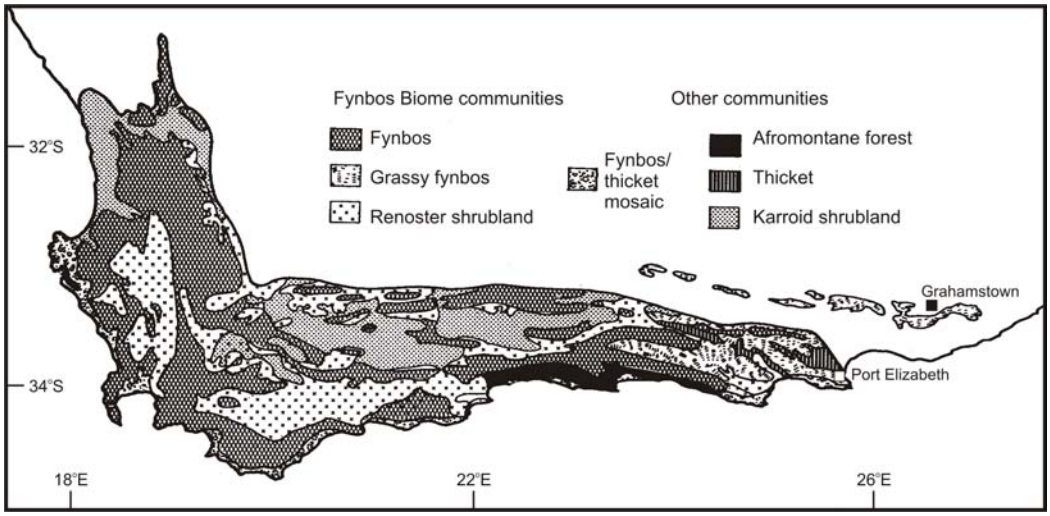

Figure 1.3 Major vegetation communities in the Cape Floristic Region and the distribution limits of fynbos (Bond and Goldblatt 1984).

1.3 Vegetation of the Eastern Cape

Various vegetation and floristic studies were been undertaken in the Eastern Cape by different authors. [Schonland (1919); Pole-Evans (1936), Dyer (1937) and Story (1952)]. But these early studies did not illustrate the complexity and diversity of vegetation in the Eastern Cape. Acocks (1953) attempted to study the complexity of the Eastern Cape vegetation and his "Veld Types of South Africa," has become a standard guide for vegetation study in South Africa. It was based on his thorough knowledge of plant distribution, species composition and abundance in plant communities. Acock's concept of "Veld Type'' has been criticized by Martin & Noel (1960), Cowling (1982a) and

Lubke *et al*. (1986) because he grouped structurally and floristically unrelated vegetation into single veld types. Martin and Noel (1960) published the *Flora of Albany and Bathurst*, which is the only comprehensive list for the area produced to date.

Lubke *et al*. (1986) produced a vegetation map based on a concept by Cowling (1984) and the veld types of Acocks (1975), thus producing a new revised vegetation map of the Eastern Cape (Figure 1.4). This vegetation classification was based on the biome concept and recognized eight vegetation types namely:

- The Cape fynbos shrubland
- Transitional shrublands
- Subtropical thicket
- Karoo vegetation or subdesert
- Grassland
- Afromontane forest
- Littoral strand vegetation

I. **The Cape Fynbos**: consisting of shrubs, which either have large Proteaceous leaves or small fine and hard Ericaceous leaves, and the tufted plants of the Retionaceae. Fynbos shrubland consists of Mountain Fynbos, Grassy Fynbos and Dune Fynbos.

II. **Cape Transitional Shrub Land**: small leaved shrubland occurring in the Transitional region between Coastal and Mountain fynbos of the Succulent Karoo.

III. **Subtropical Thicket**: consisting of closed shrubland to low forest, dominated by evergreen sclerophyllous or succulent trees, shrubs and vines, many of which have stem spines. Subtropical Thicket extends along the coastal margin of southern Africa and is allied to the thicket of the equatorial zones of Africa (Tinely, 1980). It includes Dune Thicket, Valley BushVeld or Succulent thicket, and NoorsVeld and Spekboomveld or Succulent Mountain Thicket.

IV. **Karroid subdesert**: consisting of dwarf sub-desert shrubland. Succulent karriod vegetation extends from the northwest, south eastwards to the Grahamstown area.

V. **Acacia Savanna**: characterized by *Acacia karroo*: extending into the Eastern Cape region from the northeast and adapted to the higher rainfall moist savanna of the Eastern Cape. The Acacia Savannas include coastal Acacia Savannas, and the upland Acacia Savanna of the Eastern Cape.

VI. **Afromontane Forest** (White 1983): occurring from sea level to mountain sites of higher rainfall in the Eastern Cape. These forests are made up of Montane Forest, in part Alexandria Forest and Knysna Forest.

VII. **The Grassland Biome**: occurring chiefly on the central plateau of South Africa, inland areas of Kwazulu-Natal and the Eastern Cape. The Grassland of the Eastern Cape is composed of the three major vegetation types, which include Sour Grassveld, Sweet Grassveld and Mixed Grassveld. Sour Grassveld have higher fibre content and tends to withdraw nutrient from the leaves during winter so that they are unpalatable to livestock. Sweet Grassveld occurs in areas where rainfall is low and generally has lower fibre content, maintains nutrients in the leaves in winter and is therefore palatable to livestock. The Mixed Grassveld, which is transitional between sweet and sour grassveld, is found in low-lying land and in the mountainous northern areas of the Eastern Cape.

VIII. **Littoral Strand Vegetation**: characterized by stoloniferous, rhizomatous and sympodial growth, that is dune-forming plants growing ahead of accumulating sands.

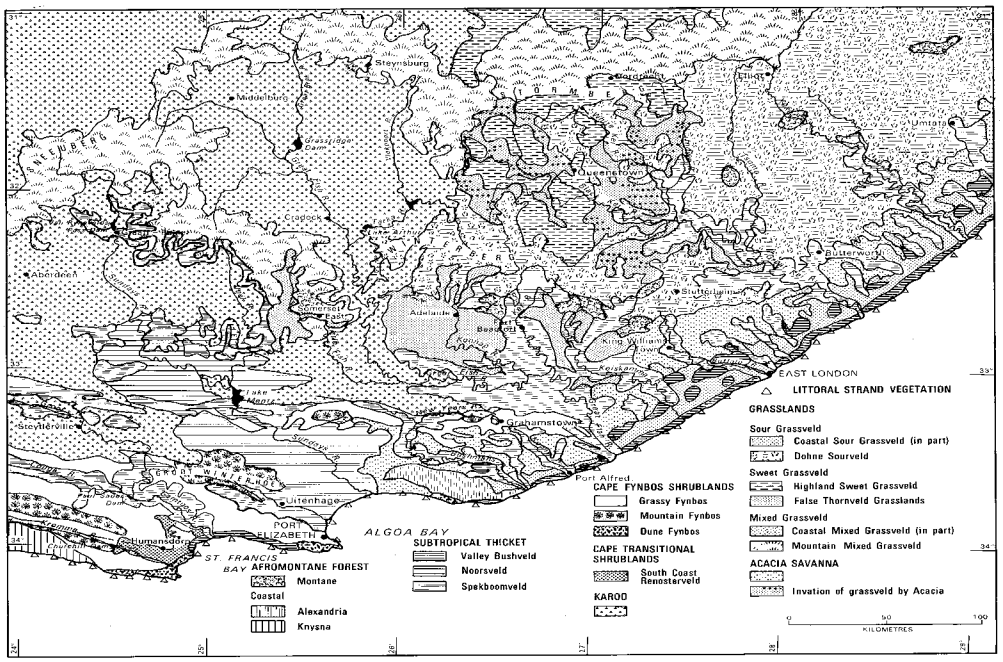

Figure 1.4 The vegetation map of Eastern Cape (Lubke *et al.* 1986).

1.4 Plant diversity Hot spots.

The term hot spot appears to have been first used in botanical literature by Myers in 1988. Hotspots are defined as areas that feature an exceptional concentration of species, with an exceptional level of endemism that are facing exceptional threat of destruction (Myers, 1988). To-date 25 hotspots have been recognized by the team of international scientists (VanWyk & Smith 2001). These hot spots cover less than 2% of earth's land area and account for 44% of vascular plant species and 38% of four vertebrate classes (birds, mammals, reptiles and amphibians) (VanWyk & Smith 2001). Eight hot spots have been recognized in southern Africa. These hot spots are Wolkberg, Maputaland, Pondoland, Eastern Mountain, Albany, Cape, Succulent Karoo and Kaokoveld (Fig.1.5).

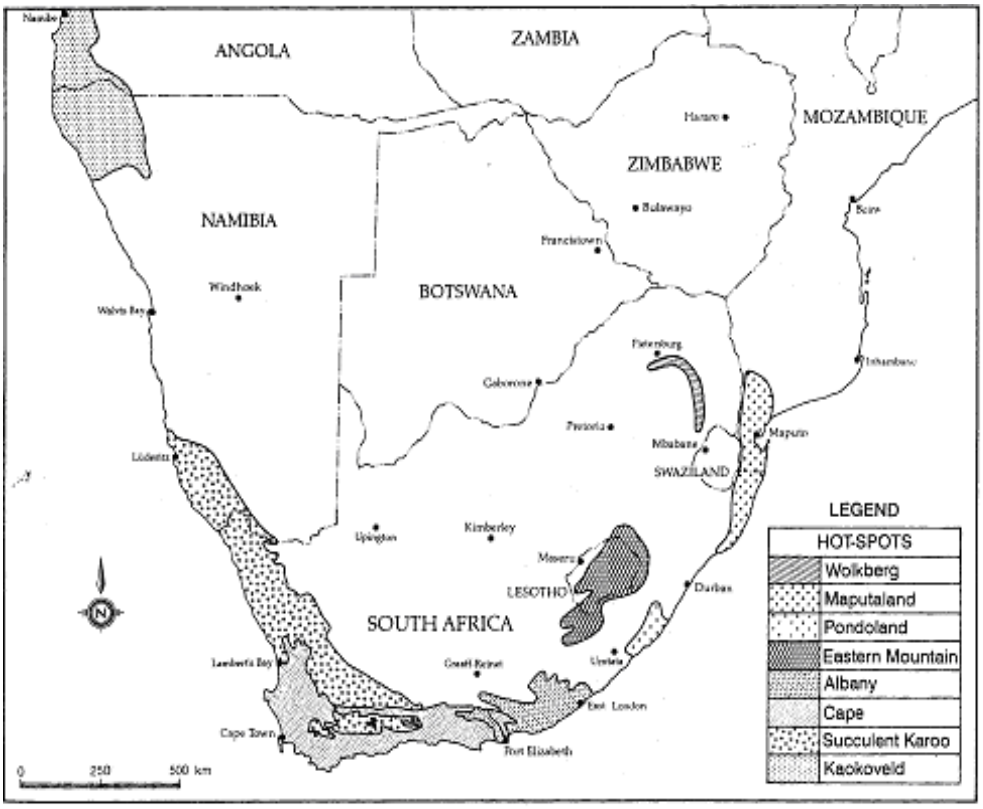

Figure 1.5 Map of southern Africa (Botswana, Lesotho, Namibia, South Africa and Swaziland) with shaded areas indicating location of hot spots (Cowling & Hilton - Taylor 1994).

Dyer (1937) indicated that the southeastern Cape Flora, Karoo-Namib Flora and Subtropical Flora meet in the Albany and Bathurst Districts, now called Makana District, which is centrally located in the Eastern Cape Province. A particularly high diversity of vegetation types is found within a radius of 150 km from Grahamstown in the Eastern Cape (Lubke *et al.,* 1988) and this area corresponds in part with the Albany diversity hotspot (Cowling and Hilton-Taylor 1994, Phillipson 1995).

The Albany Centre named for the district in the Eastern Cape, is thus one of centres of unique plant diversity in South Africa with high floristic diversity. According to Myers' (1988) definition, the Albany can be qualified as one of the hot spots in southern Africa with high plant diversity. It represents a complex transitional mosaic where different floristic regions and their associated vegetation types meet (Phillipson 1995).

At many sites, the mixing is so extensive that species of different phytochoria intermingle in a single stand of vegetation (Gibbs Russell 1981). It should be noted that the highveld grassland and Afromontane phytochoria (White, 1983) also influence the species composition of the Albany area.

The Albany Centre has been demarcated by Phillipson (1995) and consists of a total area of 22500 km^2. It includes the smaller area of Baviaan's Kloof and the Gamtoos River valley reaching the coast west of Port Elizabeth. Moreover, the larger area extends from Port Elizabeth in the southwest to the Kei River in the northeast. It is bounded in the north by the base of the escarpment of the Amatole Mountains and other mountians of the Winterberg range (Fig.1.6).

Various authors have published checklists of plant species for the Albany Centre in the Eastern Cape. Martin and Noel (1960) recorded 2400 vascular plant species for the Albany and Bathurst districts. For the Amatole Mountains, Phillipson (1987) recorded 1215 species of vascular plants. In 1994, Cowling and Hilton-Taylor reported that the Albany Centre, excluding the Afromontane regions, contains about 2000 vascular plant species, of which 200 species of plants are endemic. Rebelo (1994) has provided further evidence of the importance of the Eastern Cape as a centre of plant diversity. Plotting the number of plant species recorded per quarter degree square on a map of South Africa, Rebelo recorded only 28 squares in which over 1000 plant species were present. Two of these squares fall within the Albany Hot-spots. Chan (1992) recored 233 vascular plant species in the Ecca Nature Reserve and Palmer (1981) recoreded 284 plant species in the AndriesVosloo Kudu Reserve, which are located in arid parts of the Albany hot spot.

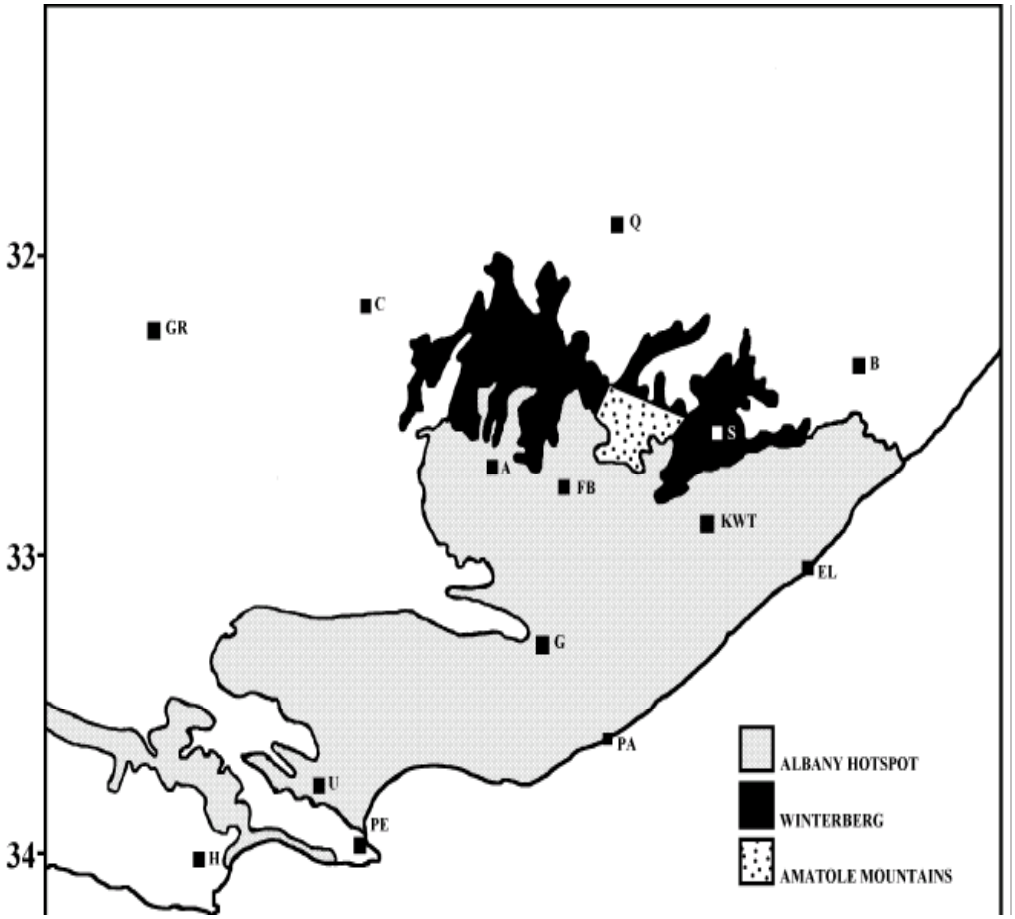

Figure 1.6 M**ap of Albany Hot Spot (Phillipson, 1995) bounded by mountain ranges**

1.5 Taxonomy and distribution of honeybees.

Honeybees belong to the order Hymenoptera, super family Apoidea, series Apiformes, the bees family Apidea, subfamily Apinae, tribe Apini (following Michener 2000) and consisting of 17,000 species of bees. The majority of bees, which produce honey, belong to the subfamily Apinae, including the honeybees (Apini), stingless bees (Melionini) and bumblebees (Bombini).

There are four well-known honeybee species in the world namely: *Apis mellifera*, *Apis dorsta*, *Apis cerana* and *Apis florae*. *Apis mellifera* is native to Europe and Africa, while the rest are native to the Asian continent.

The honeybee *Apis mellifera* is one of the most successful species in the animal kingdom judged by its ability to adapt to a wide climatic range. It is believed to have evolved in the tropics in the mid-Tertiary period, and during the Pleistocene epoch it underwent rapid evolution, which culminated in its spread to Europe (Ruttner 1988). To adapt to a new environment with a different flora, *Apis mellifera* underwent rapid changes in morphology, behaviour, susceptibility to disease and genetic modification processes (Ruttner 1988, Cornuet & Garnery 1991a), which gave rise to many subspecies or races of honeybees. At present about 24 honeybee subspecies of *Apis mellifera* are recognized in the world, corresponding geographically to distinct regions of which 10 are recognized as African honeybee races.

Apis mellifera capensis, one of the subspecies of *Apis mellifera* that occupies the tip of southern Africa has been found in the winter rainfall region of South Africa (Kerr & Laidlaw 1956, Kerr & Portugal–Araujo 1958, Anderson 1963, Guy 1976, Ruttner 1976 a, b, c) but other researchers have described a wider distribution and have concluded that the distribution of *Apis mellifera capensis* more or less coincides with that of the fynbos biome (Tribe 1983, Hepburn & Crewe 1990, 1991a,b). Hepburn & Radloff (1998) refined these results with a morphmetric data set and found that the *Apis mellifera capensis* is distributed from the Western Cape to Port Elizabeth and Grahamstown in the Fynbos biome of South Africa. Therefore they concluded that the distribution of Cape honeybees is strongly correlated with the fynbos biome with its rich flora.

1.6 History of bee plant identification in South Africa

The first recorded attempts to list plant species visited by Cape honeybees and other subspecies of *Apis mellifera* in South Africa were those of Burtt-Davy (1911) and Ferreira (1952). These lists contain a few indigenous plant species and many commonly cultivated plants such as *Eucalyptus* spp and field and fruit crops found around Pretoria and Cape Town. Neither of them provided details of the value of plants to honeybees, their flowering periods or the properties of the honey.

May (1969) devoted in his book to nectar and pollen-bearing flora of South Africa. He listed 25 different species and their values as honeybee plants and the properties of the honey from these species were discussed. The most important article on trees for

beekeeping in South Africa is by Davidson (1970). He lists the more popular *Eucalyptus* spp used for shade, shelter and timber in different areas of the country.

Johannsmeier (1995) identified and classified the important trees, bushes, weeds and cultivated crops that are sources of nectar and pollen for honeybees in the western Cape. The data by Illgner (2003) on honeybee flowering plants of southern Africa is a compilation of the checklists of plant species from Johannsmeier (1995) and Murless (1994). In in this study, types of floral reward (pollen and nectar) and the flowering period of plant species were mentioned, but there is no data on the quantity and the quality of the pollen and major nectar source plants available to honeybees.

1.7 Economic significance and conservation of honeybees

Extensive studies exist on the foraging behaviour and pollination efficiency of the social bees. These mainly concentrate on honeybees (*Apis mellifera*) and the larger bees (*Bombus*) in the northern hemisphere. *Apis mellifera* is the most well-known bee pollinator of crops. One-third of the human diet can be traced directly or indirectly to pollination by bees including honeybees (McGregor, 1976). For example in the USA bees pollinate about 130 agricultural plants and the annual value of honeybee pollination alone to US Agriculture has been estimated at over US $ 9 billion (Delaplane & Daniel, 2000).

Apis mellifera capensis is endemic to the fynbos biome and important pollinators of fynbos. Rebelo *et al.* (1984) reported that the Cape honeybees (*Apis mellifera capensis*) pollinate some genera of *Ericaceae*. Coetzee *et al*. (1985) also reported that *Apis mellifera capensis* pollinates *Protea repens* (Proteaceae).

In South Africa, Anderson (1980) compared the pollination performance of the Cape honeybees and *Apis mellifera scutellata* (African honeybee) using caged plants of lucerne (*Medicago sativum*) in the Fynbos region. He recorded enormous seed yield as a result of Cape honeybee pollination. The Cape honeybees require 20-50 kg of pollen per colony per annum (Anderson *et al.*, 1983). Presumably this high pollen requirement for brood rearing is important for the pollination of fynbos plants through the movement of wild honeybees between flowers of the same species, which facilitate the transfer of pollen between the anthers of the flower to the stigma of the flower.

The fruit industry in the Western Cape is directly reliant on the existence of the Cape honeybees as they provide pollination services to orchards. It is estimated that Cape honeybees contribute up to one billion Rands from the pollination of fruits and vegetables in the western Cape and approximately 50% of the honey production in the fynbos region is attributable to foraging of *Apis mellifera capensis* on fynbos plants. (Turpie, *et al*. 1999). The fynbos can therefore provide potential financial rewards for the beekeeping industry.

Furthermore the Cape honeybees have the ecological capacity to sustain plant reproduction through their efficient pollination thus enhancing the conservation of certain species of plants in fynbos vegetation. Honeybees are crucial to the functioning of the terrestrial ecosystems and. the populations and species richness of honeybee can serve as a bio indicator of the state of the environment (Kevan 1999).

Honeybee pollination sustains native plants and indirectly contributes to the control of soil erosion, the maintenance of plant biodiversity, which also beautify the human environment. Moreover honeybees pollinate native plants, which provide food for wildlife, and as inherent members of the local ecosystems. They play an important role in sustaining natural plants and animal communities that depend on them. Honeybees products (honey, beeswax, propolis and royal jelly) serve as food for many animals, including humans. Honeybees are perceived as important for sustainable utilization of the vegetation. Beekeeping can enhance pollination and thereby improve the regeneration of plants.

There is a rapid decline of honeybee populations in the world (Buchmann 1998 and Watanabe 1994). The environmental problems most likely to adversely affect the honeybees are deforestation, pollution, pesticides and disease. It was found that destruction of the natural habitats of honeybees may reduce plant species richness and the abundance of the honeybee pollinator populations, resulting in the disruption of plant-pollinator interaction, reduced seed-set and changes of gene flows among the plant population (Steffan and Tscharntke, 1999). This would negatively affect human life as well as that of other organisms in the natural ecosystem.

A knowledge of the role of honeybees in maintaining the ecosystem through pollination is essential for the management of natural resources. Thus our effort should be directed at maintaining its populations through good conservation management such as protection of their natural habitat, avoiding the application of dangerous pesticides, control of possible diseases of honeybees and creating awareness of the importance of honeybees for ecosystem stability.

1.8 Phenology of flowering and Cape honeybee colony cycle

The western Cape flora as whole shows a peak in September– October (spring) while the flora of south-eastern Cape (non seasonal rainfall region) shows a peak October–November (Johnson 1993). This difference in flowering seasonality between the winter rainfall and non-seasonal rainfall region of the Cape influences reproductive phenology of Cape honeybees. Hepburn & Jacot-Guillarmod (1991) analysed the relationships between the major activities of honeybees on an annual basis (reproductive swarming, absconding migration and cycle of brood rearing) in relation to the flowering seasons of the main bee plants in the fynbos biome. They established high and low flowering intensity periods based on monthly flowering frequency on an east-west transect of 1000 km in the Fynbos biome in South Africa. They showed that flowering phenology consistently varies along the transect. Due to these variations, the flowering phenology and biological cycle of honeybees vary from one locality to another, which results in variation of brood rearing and honey flow seasons.

The study by Hepburn and Jacot-Guillarmod (1991) on the phenology of plants in relation to phenology of Cape honeybees in the fynbos biome may not be applicable to the actual conditions in southeastern Cape. Since the southeastern Cape region has a complex climate and diverse flora of mixed origin.

1.9 Research questions

From an apicultural point of view the fynbos is under-utilised and awaits further investigation (Johannsmeier, 1995). Our knowledge of the fynbos with reference to Cape honeybee utilization is incomplete, and questions need to be addressed such as:

- Which plants are important sources of nectar and pollen, quantity and quality of pollen available for honeybees?

- What is the seasonal availability and preference of honeybees for the different plant taxa?
- What is the relationship between flowering phenology and the brood rearing activities of Cape honeybees?
- What is the influence of weather on pollen and nectar collection, flowering period and the foraging activities of honeybees?
- How do different plant communities contribute in presenting floral rewards to the pollinators in order to maintain different pollinator populations in the community and conservation of biodiversity?
- What is the reason for the apparent correlation of the distribution Cape honeybees and the Cape Floristic Region?

1.10 Aims and Objectives

The principal aim of this study was to test the hypothesis that Cape honeybees utilize as the primary source of nectar and pollen plant species limited to the Cape region or fynbos vegetation in a study area near Grahamstown where fynbos vegetation mingles with forest and grassland communities.

The subsidiary aims and objectives of the study were:

a. To compile a checklist of vascular plants of the area

b. To investigate the phytochorological affinity and Albany endemic plant species in the area.

c. To distinguish the vegetation communities in the area.

d. To identify beeplants among existing flora and to determine which plants are likely pollen and nectar source plants in the area of the study?

e. To determine the predominant pollen source plants in the area.

f. To determine the relationship between brood population and seasonal collection of pollen and phenology of plants in the study area.

g. To determine the volume of nectar produced and peak times of nectar secretion of commonly visited honeybee plant species.

h. To examine the effect of meteorological factors on pollen collection and flowering phenology of beeplants.

i. To determine flowering periods of beeplants in the study area.

1.11 The study area

The area selected in which to conduct this study was Rivendell farm. The farm is located in the Albany district of the Eastern Cape Province, about 18 km southwest of Grahamstown on the Port Elizabeth road (Fig.1.7). It lies between 33^{o} 21' 50" S and 26^{o} 30' 20" E. The lowest altitude on the farm is 500m above sea level, while the highest rises to 650m above sea level. The total area of the farm is 37 hectares and Featherstone Kloof borders it to the north.

The area is dominated by a variety of plants, ranging from herbaceous through to bushes and trees, which are important for bee forage. The available water resource near the site makes the area suitable for bee research and practical beekeeping. The site was already established with captive honeybees for a number of studies by the Zoology and Entomology Departments of Rhodes University. The farm is owned by Nick and Helen James who maintains a fish farm, and do not use farmland for grazing. Mr and Mrs James have a keen interest in the natural ecosystems of the Farm and have attempted to maintain the vegetation in a natural state by the control of alien-invasive plants and grazing.

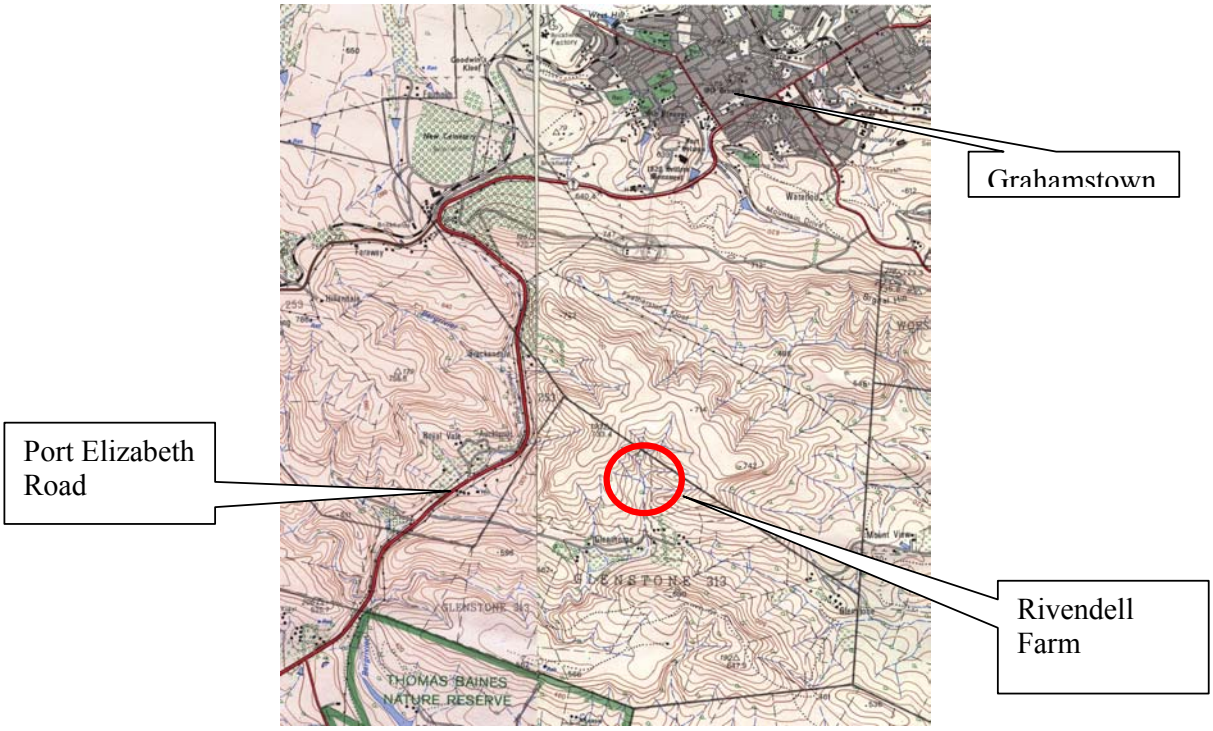

Figure 1.7 Map of the study site (Rivendell farm)

CHAPTER 2 BIOPHYSICAL DESCRIPTION OF RIVENDELL FARM.

2.1 Introduction

The aim of this part of this study was to provide background data on the geology, soils and climate of the study site. In addition, detailed studies have been conducted on the flora and vegetation, with the following specific aims:

1. To compile a checklist of vascular plants, Albany endemic plant species and to investigate the phytochorological affinity of the plant species in the area.

2. To classify the vegetation communities in the area in order to draw up a basic reference for future taxonomic, floristic and ecological research at Rivendell farm and areas with similar vegetation. All aspects of this part of the study may be relevant to issues of ecosystem conservation and sustainable resource uses see discussion (Chapter 1).

2.1.1 Vegetation of study area

The study site, Rivendell farm, is located at the Albany centre of plant diversity and the major floristic types in the area fall into the Cape phytochorion, one of the four phytochoria occurring in the Eastern Cape (Lubke *et al*. 1988). The vegetation consists of Grassy fynbos, Grassland, Bush clumps, a patch of Forest and Oldenburgia grandis occurs on Witteberg rock outcrops. Exotic plants such as *Eucalyptus* spp., *Acacia longifolia*, as well as dense thickets of *Hakea sericea* are found in some sites close to the study area. No previous vegetation survey had been carried out for this area and consequently there is no checklist of plants available for the area.

2.1.2 Geology of the study area

According to Lock (1974) the geology of the Grahamstown and surrounding areas, including the study site, form part of the Cape Supergroup. It consists of three major units at the base is the Table Mountain Group, in the middle the Bokkeveld Group and at the top, the Witteberg Group. These three units combine to produce the distinctive mountain and valley topography of the southern section of the Eastern Cape.

The rocks of the Grahamstown districts (Fig.2.1) can be separated into three broad divisions: those belonging to the **Cape Supergroup,** the **Karroo Supergroup,** and those younger deposits which overlie them and which are found only in coastal areas.
Rocks of the Cape Supergroups are all sedimentary rocks laid down in a variety of depositional environments within the last 400 million years, representing less than 10% of geological time from the formation of the earth (Rust 1986).

Only the upper two divisions of the **Cape Supergroup** are present in the Grahamstown area. The older of these**, the Bokkeveld Group** consists of alternating brownish sandstone and shale. The group is not well exposed and can be seen clearly only in a few road cuttings along N2 national road to Port Elizabeth. The **Witteberg Group** is the youngest unit of the Cape Supergroup; it overlies the Bokkeveld Group without any break in the sequence. It consists mainly of pure quartz sandstone which form most of the high ground around Grahamstown and is well exposed in quarries to the south of the city and along the N2 national road.
Three divisions of the Karoo Supergroup project out in Grahamstown area, mostly to the north of the city. Many rocks of the Cape and **Karoo Supergroup** observed in the Grahamstown district are folded in a series of undulations. The mountainous area of Grahamstown including Rivendell and central Albany is formed mainly of Winterberg Quartzite and lies on an extension of the Zuurberg Range situated further to the west (Martin 1965). These unique rock formations and the overlapping of different rock systems make the area unique in plant distribution and mixed types of vegetation.

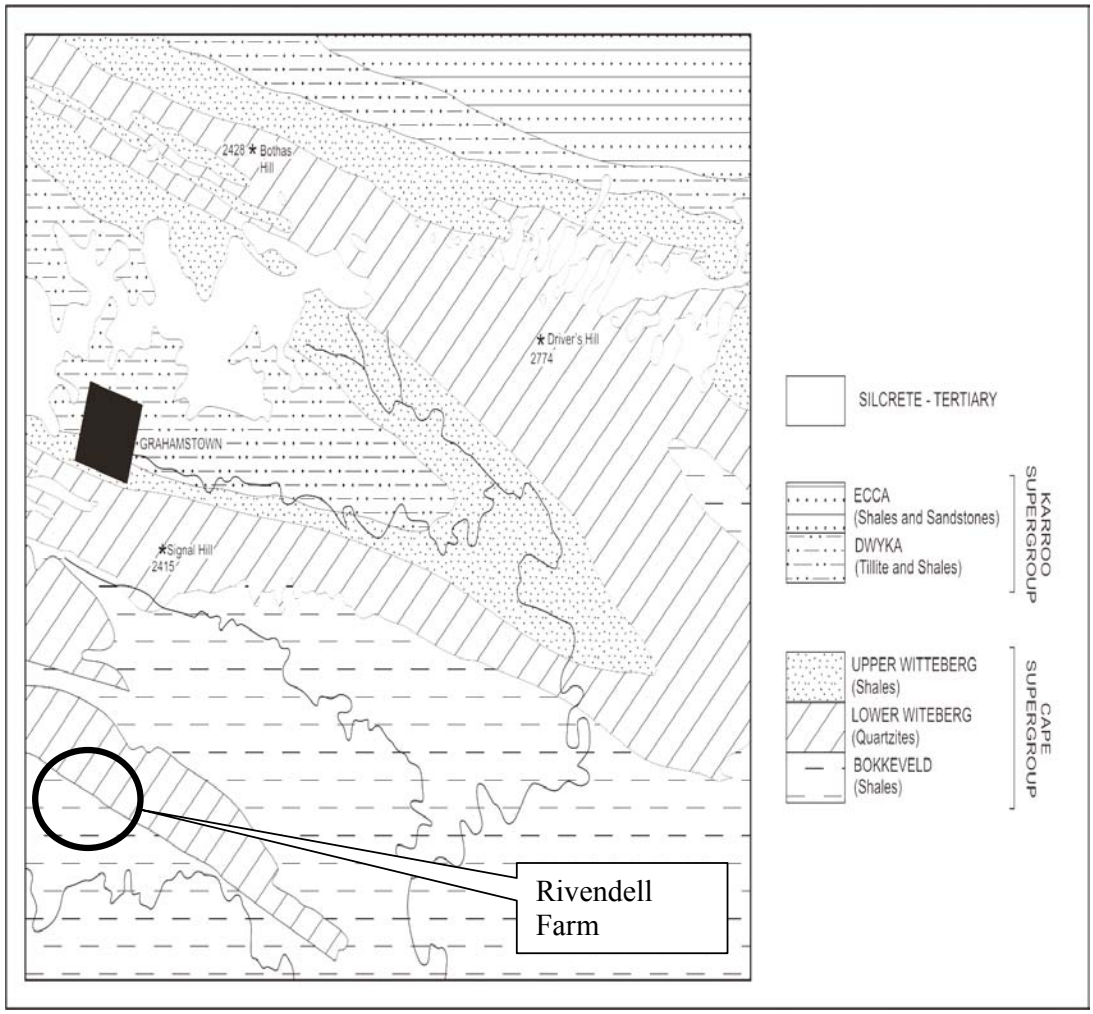

Figure 2.1 Geology of Grahamstown and surrounding area (Lock 1974).

2.1.3 Soils

The soils of the study area are dominated by lithosols and weakly developed acidic nutrient poor soil and the terrain is generally rocky. Soils are generally shallow and consist of a dark grey topsoil horizon overlying rocks or partially weathered rocks. The parent rocks are Katberg or Witteberg sandstone or conglomerates (Hartman 1986). The soil series commonly found in the study area are Mispah, Kanon Klop, Platt, Williamson and Trevanian (Siphugu 1994).

2.1.4 Climate

The climate of Grahamstown in general and of the study site in particular is unpredictable and very variable and temperatures show extensive daily and seasonal

fluctuations. Various quantitative systems, based on different parameters and indices, have been used to classify climates. One such system, which is discussed by Schulze (1947) is based on the Koppen system, classifies climate on the basis of rainfall and temperature averages.

On the basis of the Koppen system Grahamstown and surrounding area can be classified as subtropical with all months having temperatures usually in the range of 10 to 20° C and at least 60mm of rainfall (Kopke 1986). The actual average annual rainfall of Grahamstown area is 615mm calculated over 20 years. Some months have as low as 30 mm and this contradicts Koppen's classification. There are two periods of elevated rainfall during the spring and autumn (October–November and February-April respectively) with the lowest rainfall in winter (May – July). The average annual rainfall of the farm is 930 mm. This was calculated over ten years. Rainfall at the study site was 30% higher than in Grahamstown, the nearest town. The average monthly temperature of the Grahamstown area ranges from 10 to 21.5°C calculated for over 12 years. The hottest months are December, January, February and March and the coldest months are May, June and July. The minimum monthly temperature of the study area ranges from 8°C to 14°C and the maximum temperature ranges from 16°C to 25°C.
The detail summary of climatic data for Grahamstown is shown in Fig.2.2

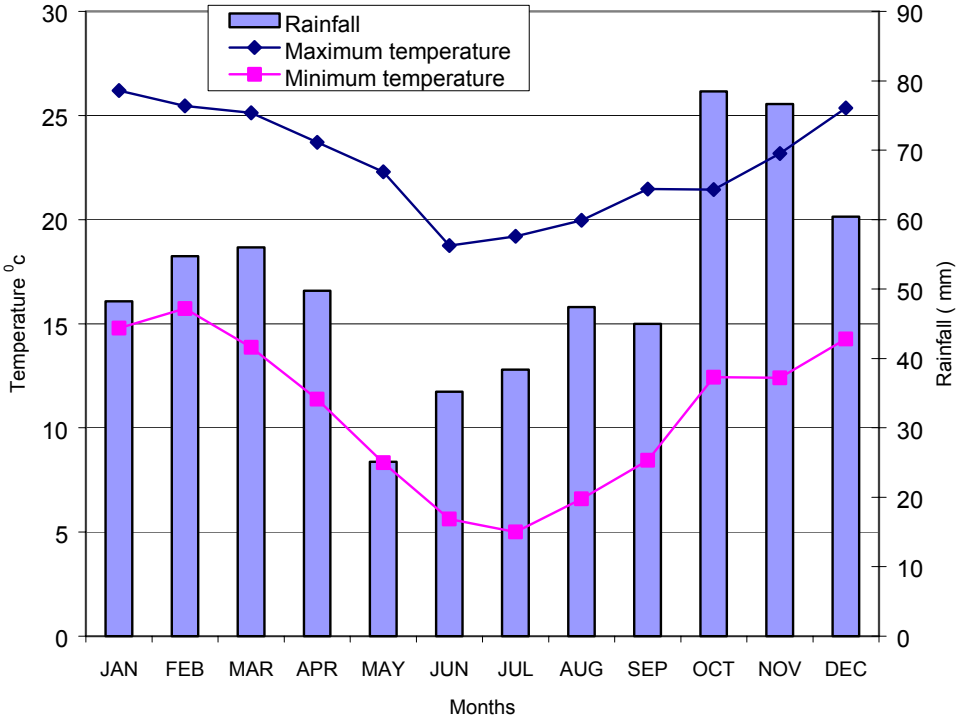

Figure 2.2 The distribution of monthly rainfall, maximum and minimum temperature for the Grahamstown district.

(Data from the Institute for Water Research, Grahamstown).

2.2 Materials and Methods

2.2.1 Determination of endemism and phytochorological affinities of the study area

The number of Albany endemics present in the study area was determined using the Everard (1986) and Vanwyk and Smith (2001). A checklist of Albany endemic plant species are presented in Appendix I. Phytochorological affinities of the Rivendell farm were obtained from published and non published checklists of Chan (1992) and Cowling (1983 b).

2.2.2 Vegetation sampling

A survey of the vegetation was conducted and an aerial photograph (1: 8000) of the study site was mapped. Only vegetation found within a one-kilometre radius of the hives of the foraging Cape honeybees in the study site was sampled, because honeybees effectively utilize the plant resource within one kilometre radius (Steffan-Dewenter *et al.* 1999). The nested quadrats were used for different homogenous vegetation units to ensure that the sample plots were representative of the vegetation in the area. Species area curves were used to determine optimum plot size by sampling plots of various sizes from each vegetation unit. The principle of determination of the plot size using minimal area curve is derived from methodology of the Braun-Blanquet school of vegetation classification and phytosociology (Kent and Coker 1992). On the basis of minimal area curve plot size was determined and fixed for each vegetation unit. The vegetation was randomly sampled within these stratified vegetation units. Before undertaking the vegetation sampling, different vegetation types could be identified and the area was stratified into 12 homogenous vegetation units subjectively, which could be identified on basis of species composition, structure and growth forms. The ecotones or edges were avoided in sampling. Plant species were collected, identified and a total floristic list compiled.

A total of 160 relevés were sampled. Percentage cover was recorded for each species in the relevé. Co-ordinate (Longitude-Latitude) positions and altitude were obtained for each relevé using the global positioning system (GPS) and an altimeter. Aspect and slope of each relevé were determined using the Abney level and compass. Sampling of

vegetation was carried out from 15 to 28 March in 2002 from the different sites of the study area.

A sample collection point was produced by examining the aerial photograph taken. An aerial photo was taken in 1998 with a scale of 1:8000 (Fig 2.3). The Aerial photograph was scanned and imported into Arcview Gis version 3.1. Co-ordinates superimposed on the aerial photo together with recorded characteristics of the plots. Other landscape features were included such as roads, Dams and Residential houses. (Fig 2.4) It was not possible to produce a vegetation map of the study area due to time constraints and the ecotones were not clearly identified. Identifying the ecotones was beyond the scope of this study.

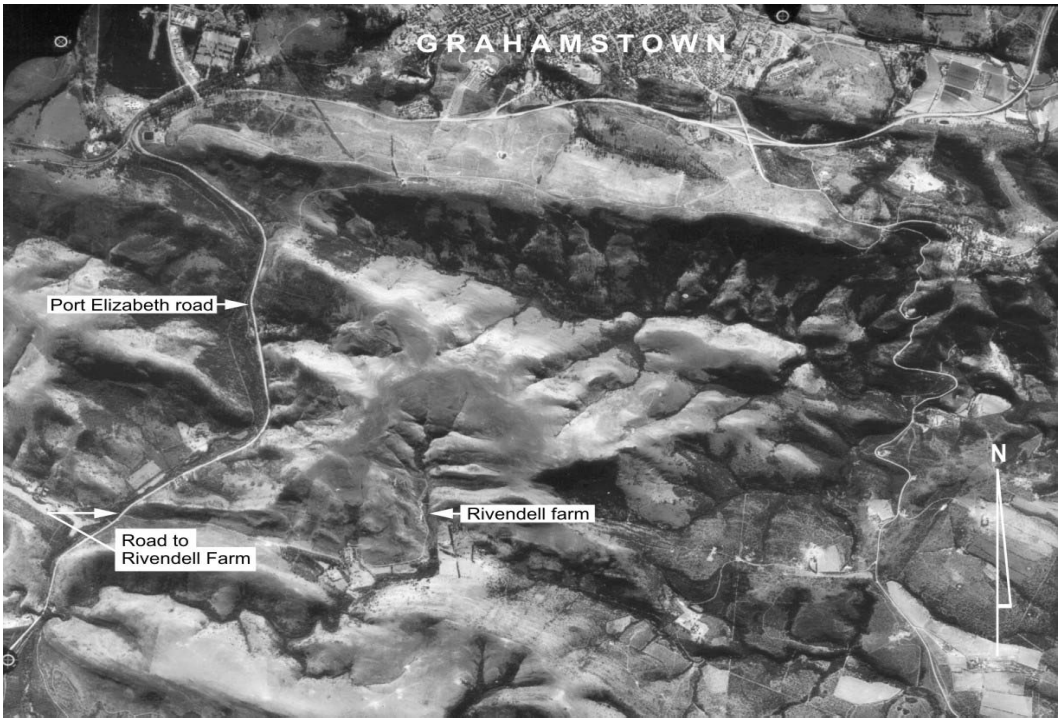

Figure 2.3: Aerial photograph of the study site.

2.2.3 Classification of vegetation

Analysis of the relevé data was carried out using multivariate techniques of classification and ordination. The classification of floristic data was carried out using the two-way indicator species analysis (TWINSPAN) (Hill 1979b), which is a polythetic divisive technique that produces a hierarchical classification (Hill 1979b, Gauch & Whitaker

1981). TWINSPAN produces a classification of samples by the progressive splitting of ordinations by reciprocal averaging, at the centre of gravity, and the diagnostic species are chosen to define the group of data at each split (Hill, 1973). The output of TWINSPAN is a dendrogram showing the samples of hierarchy using sequence of division.

Gauch & Whittaker (1981) compared five hierarchical clustering techniques and two-way indicator species analysis was found to be the most powerful clustering technique when compared with other hierarchical clustering techniques. These techniques have been used successfully in a number of similar plant ecological studies in the Eastern Cape (Lubke & Strong 1988 and Avis 1992) in which they were considered the most suitable for analysing the community data.

To examine the abundance and distribution of plant species in the community, synoptic tables for each vegetation community were extracted. The table summarizes the constancy of the species within each group or association. Constancy is rated on a scale 1-5 scale: 1 = 1-20%, 2 = 21-40%, 3 = 41-60%, 4 = 61-80% and 5 = >81% and the occurrence of a species with very low constancy in the community was not shown in a synoptic table.

The same data was then ordinated using Detrended Correspondence Analysis Ordination (DECORANA) which serves to summarize community data (such as species abundance) by producing a low-dimensional ordination space in which similar species and samples are plotted close together and dissimilar species and samples are placed far apart (Hill *et al*. 1980). The first and the second axes, which showed percentage similarity, were plotted for the same samples. The sampled vegetation quadrat was analysed on the basis of percentage cover abundance of the species.

2.2.4 Plant specimen collection and identification

The herbarium specimens were collected on monthly visits during 2001 and 2002 from different sites in the study area (Fig.2.4).

Plant specimens were collected from the study area with leaves; stems, inflorescence and underground parts were also collected when necessary. Plants were pressed (using a

plant press) dried in an electrical oven using the conventional method. Then specimens were identified using recently or revised herbarium literature and other publications. Specimens difficult to identify using keys were compared with existing herbarium specimens to assist or verify identification. Plant specimens were collected over the 18 months period. Botanical nomenclature follows Arnold & De Wet (1993) and voucher specimens collected were mounted and placed in the Selmar Schonland Herbarium (GRA) and duplicates will be distributed to other major herbarium.

2.3 RESULTS

2.3.1 Analysis of the flora

Ninety-seven plant families, 271 genera and 448 plant species were identified from Rivendell farm and a checklist of all species occurring in the area is presented in Appendix II. The 10 most abundant plant families in terms of number of species are given in Table 2.1.Among these Asteraceae is the largest with 65 species. The second largest family is Fabaceae, with 35 species, followed by Poaceae, Orchidaceae and Rubiaceae with 33, 32 and 18 species respectively. The largest genera in the flora are *Senecio, Crassula*, and *Helichrysum* with 13, 13 and 10 species respectively (Table 2.2).

Table 2.1 The number of plant species contained by the 10 largest families at Rivendell farm.

Plant families	No. of species	Proportion (%)	Growth form
Asteraceae	65	29.5	Shrubs,Herbs, climbers
Fabaceae	35	15.5	Trees, Shrub, Herbs, Climbers
Orchidaceae	33	15	Herbs
Poaceae	32	14.5	Herb
Rubiaceae	18	8.8	Shrubs, herbs
Iridaceae	9	4.09	Geophytes
Celastraceae	9	4.09	Shrubs, Trees
Euphorbiaceae	8	3.63	Herb, shrubs
Scrophulariaceae	6	2.7	Herbs, shrubs
Apiaceae	5	2.2	Herbs, shrubs

Table 2.2 The number of species contained in 10 largest genera at Rivendell farm.

Genera	No. of species	Proportion (%)	Growth form
Senecio	13	17.3	Shrub, Herbs, Trees
Crassula	13	17.3	Herbs
Helichrysum	10	13.3	Herbs
Rhus	8	10.6	Trees, shrubs
Aspalathus	6	8	Woody herbs
Erica	6	8	Shrub
Eragrostis	6	8	Herb
Eulophia	5	6.6	Herb
Pelargonium	4	5.3	Herb
Satyrium	4	5.3	Herb

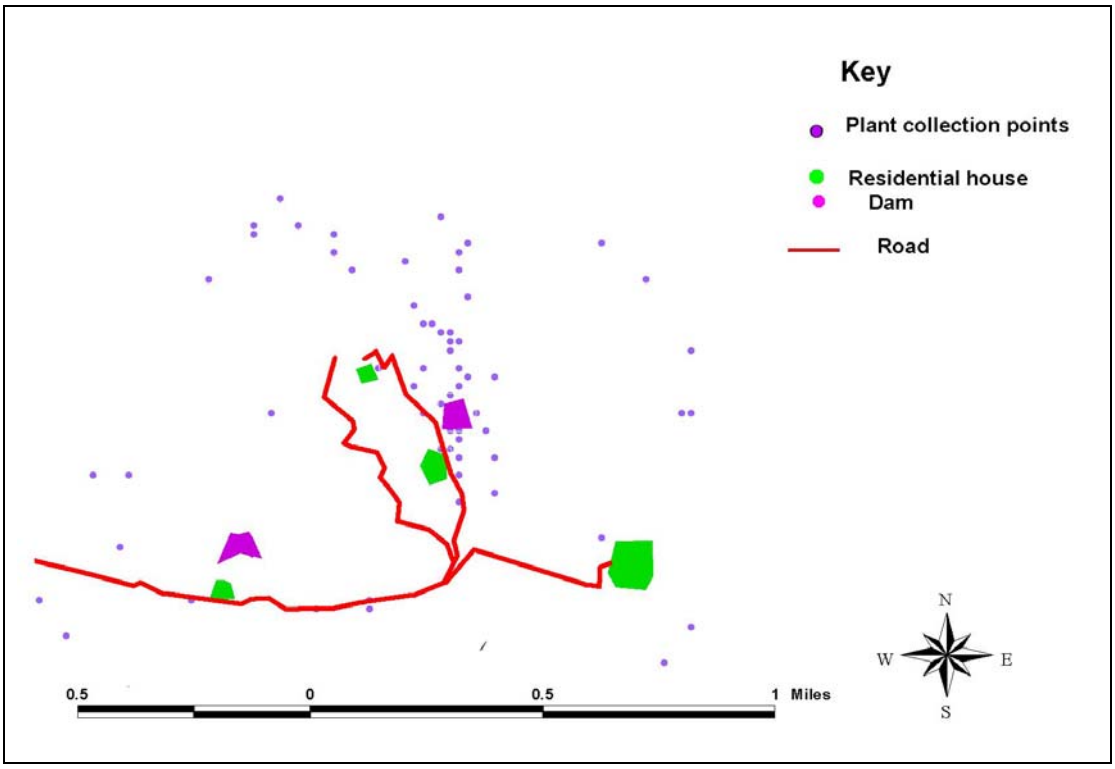

Figure 2.4 Map of the plant collection points from the study site.

2.3.1.1 Endemic plant species.

The numbers of endemic plant species reported by Everard (1987) in the Eastern Cape and VanWyk & Smith (2001) in the Albany Hot-spot were determined for the study site. The total number of endemic plant specie to Albany or near endemic to the Eastern Cape found at the site was 21, which is 4.6% of the total flora of the site. The number of Albany endmic or near Eastern Cape endemic is given in Table 2.3. The succulent family Crassulaceae has the largest number of Albany endemic species with six species. Asteraceae has the second largest family with four species. Families represented by 2 species are Ericaceae, Mesembryanthemaceae and by 1 are Fabaceae, Iridaceae, Santalaceae and Euphorbiaceae (Appendix I).

Table 2.3 The number of endemic plant species in different families

Family	Genera	No. of Albany endemic species
Asphodelaceae	1	1
Asteraceae	4	4
Crassulaceae	2	6
Ericaceae	1	2
Fabaceae	1	1
Euphorbiaceae	1	1
Asphodelaceae	1	1
Iridaceae	1	1
Mesembryanthemaceae	2	2
Orchidaceae	1	1
Santalaceae	1	1
Thymelaeaceae	1	1

2.3.1.2 Phytochorological relation of the flora.

The analysis has revealed that the flora at the study area contains typical elements of different phytochorologiacal groups recognized by White (1983). Species endemic to particular phytochoria are presented below.

a. Genera that are endemic or near endemic to the Cape region, which are highly diversified in the Cape region, include: *Restio*. *Erica, Phylica Aspalathus Protea, Leucadendron, Agathosma, Gladiolus, Muraltia* and *Berzelia*

b. The Afromontane elements include Forest trees such as *Podocarpus falcatus*, *Rapanea melanophloeos*, *Nuxia floribunda*, *Olea capensis* and *Ilex mitis*.

c. The Karoo-Namib linking species that were found in the study area were *Chrysocoma ciliata*, *Mesembryanthemum aitonis*, *Delosperma ecklonis*, and *Crassula* spp.

d. The Pondoland and Tongaland linking elements that were described by Moll and White (1978) found in the area include *Cussonia spicata*, *Canthium inerme*, *Apodytes*

dimidiata, *Cassine peragua*, *Maytenus acuminata*, *Sideroxylon inerme* and *Rhoicissus tridentata*.

2.3.1.3 Vegetation classification

The 12 homogenous vegetation units were identified:

1. *Bobartia orientalis-Restio filiformis* fynbos
2. *Cliffortia linearifolia – Erica* chamissonis grassy fynbos
3. *Agathosma ovata- Festuca costata* grassy fynbos
4. *Alloteropsis semialata-Restio filiformis* Gasssy fynbos
5. *Tristachya leucothrix- Aspalathus frankenioides* Fynbos
6. *Leucadendron salignum-Berzelia intermedia* dominated fynbos,
7. *Oldenbergia grandis–Metalasia muricata* shrubland
8. *Passerina rigida* shrubland,
9. Grassland
10. Savanna
11. Bush clumps
12. Forest

Using the minimal area curve or species area curve concept, fixed plot sizes were obtained for the different vegetation units. The plot sizes were fixed at $4m^2$ (2mx2m) for Fynbos, $1m^2$ (1mx1m) for Grassland, $16m^2$ **(**4mx4m) for Shrubland, and 100^2 (10m x 10m) for the Forest (Appendix IV) and each relevé was sampled for different vegetation from the different sites of the study area.

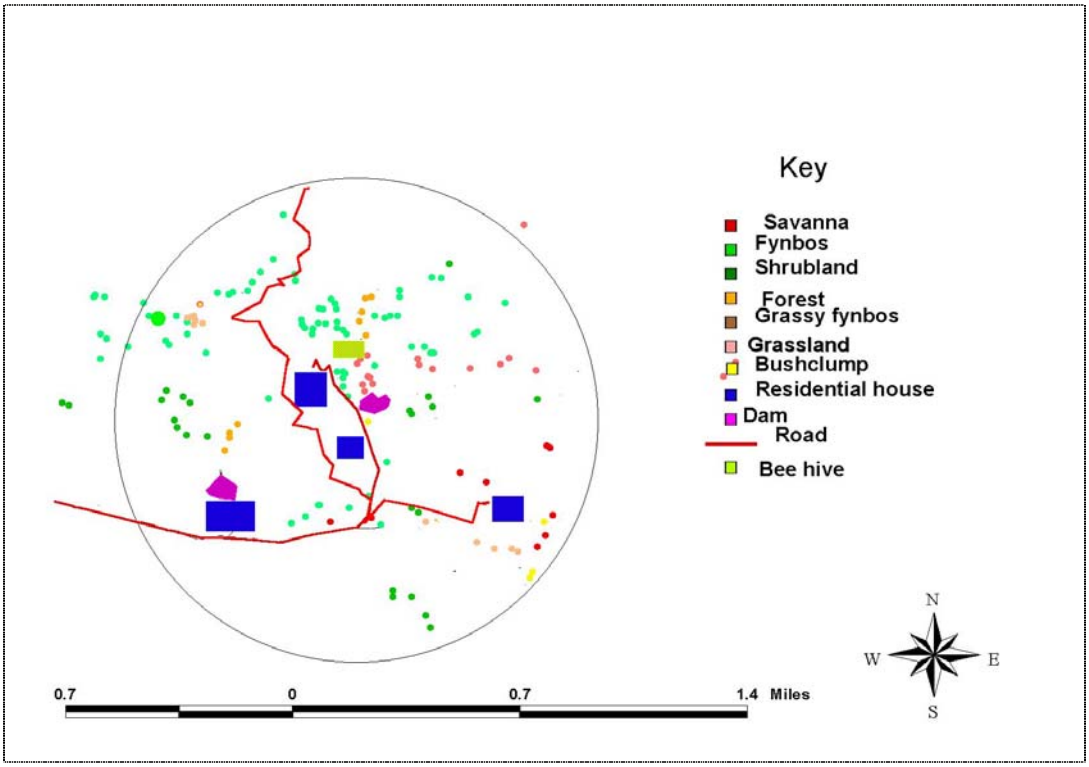

Figure 2.5 Relevé sampling points from different vegetation units in the study site

The TWINSPAN classification technique divided the data set into distinct groups on the basis of the differences between the various sample quadrats. Plots with similar species compositions are grouped together. The plots sampled at each vegetation units generally had similar species composition, and they have remained grouped within vegetation units. TheTWINSPAN classification identified seven, major groups of vegetation types. However each division of the dendrogram represents plant communites within a major vegetation unit identified by TWINSPAN and a total of 31 plant communites were identified. At the first hierarchical level, TWINSPAN separated predominately Forest and Bushclumps and Acacia savanna plant communities from the remaining plant communities (Grassland, Grassy Fynbos, Fynbos and Shrubland). A summary of the classification of the different plant communities is presented in a dendrogram (Fig.2.4). The abundance of the common species in each vegetation community were expressed as constancy values, summarized in a synoptic table (Appendix III). Life form compositions, species richness, number of species per relevé were also presented (Table 2.4).

Table 2.4 Species diversity and life form composition of seven vegetation communities identified by TWINSPAN

Communities	No. of relevés	No species per relevés	Total species richness	Life form composition of communities (%)							
				Geophytes	Grasses	Sedges	Succulents	Herbs	Climbers	Shrubs	Trees
Forest	11	4.8	53	1.1	0	9.4	1.8	17.86	9.4	37.7	22.6
Bush clumps	3	11.3	34	0	5.8	0	2.94	32.35	2.94	44.11	11.76
Acacia savanna	12	3	36	0	8.33	0	2.77	30.55	5.55	44.44	8.33
Grassland	16	1.25	20	0	25	0	0	70	0	5	0
Grassy fynbos	17	3.35	57	1.1	17.5	0	3.58	56.89	3.50	17.5	0
Fynbos	79	1.13	90	4	12.2	2.2	4.4	59.3	1.1	16.6	0
Shrubland	17	3	51	2	19.60	0	7.8	45.0	1.9	23.5	0

2.3.2 Community description

2.3.2.1 Forest vegetation

Forest occurs on the southwest-facing slope and as small patches in the valley along the stream. It consists of three vegetation strata, namely a herb layer, a shrub layer and a tree layer. Trees cover more than 70% of the relevé area. Herbs form the under storey with a maximum height of 20-30 cm, while shrubs were 3-4 m tall. A total of 11 relevés sampled and only four plant communities were separated by the TWINSPAN as shown in (Fig.2.4). A total of 53 plant species were recorded in this community (Table 2.4) dominated by *Nuxia floribunda*, *Psychotria capensis*, and *Rapanea melanophloeos*, *Apodytes dimidiata, Maytenus heterophylla* and *Podocarpus falcatus*. The herbs and grasses found in this community include *Plectranthus ecklonis, Hypoestes forskaolii*, *Galopina circaeoides*, and O*plismenus hirtellus.* The 10 species with the highest % cover are given in Table 2.5.

Table 2.5. The dominant plant species, total % cover and life forms in forest vegetation**.**

Plant Species	**No. relevés found**	**Average % cover**	**Life form**
Nuxia floribunda	9	30	Tree
Apodytes dimidiata	10	21	Tree
Maytenus heterophylla	10	24	Shrub/Tree
Rapanea melanophloeos	10	11	Shrub
Psychotria capensis	10	25.5	Shrub
Podocarpus falcatus	8	19	Trees
Plectranthus ecklonis	10	75	Herb
Hypoestes forskalii	6	53	Herb
Galopina circaeoides	9	6.3	Herb
Oplismenus hirtellus	10	49	Sedge

Plate 2.1: *Nuxia floribunda* and A*podytes dimidiata* dominated plant community.

2.3.2.2 Bushclump vegetation type

This vegetation type occurs in the southeastern part of the farm. The vegetation types consist of randomly located bush clumps, separated by open areas of grassland. The bush clump is composed of small trees, shrubs and herbs. The tree and shrub strata are up to 3-5m tall. A total 34 plant species were recorded. The TWINSPAN divided the vegetation types into three plant communities (Fig 2.3). The dominant trees and shrub species include *Scutia myrtina*, *Acacia karoo*, *Apodytes dimidiata*, *Rhus Pallida*, *Canthium inerme* and *Maytenus heterophylla*. The herbs and grasses are also common in this community. The herbs are represented by *Senecio purpureus, Centella coriacea,* and *Galopina circaeoides*. The important grass species common to this community are *Eragrostis curvula*, *Eragrostis capensis*, *Themeda triandra*, and *Panicum maximum* (Table 2.6).

Table 2.6.The dominant plant species and % cover in bush clump plant community.

Plant species	No relevé's found	Average%cover	Life forms
Scutia myrtina	5	66	Climber
Acacia karroo	4	26.5	Tree
Rhus Pallida			Shrub
Canthium inerme	4	5	Shrub
Maytenus heterophylla	4	4	Shrub
Senecio pterophorus	3	9	Herb
Centella coriacea	4	50	Herb
Galopina circaeoides	5	15	Herb
Eragrostis curvula	4	41.25	Grass

Plate 2.2: ***Scutia myrtina- Acacia karoo*** **dominated bushclump.**

2.3.2.3 Acacia savanna vegetation type

TWINSPAN identified *Acacia karoo–Scutia myrtina* dominated Savanna at the second hierarchical level. A total of 12 relevés were sampled and the TWINSPAN divided this vegetation type into five communities (Fig. 2.4). This vegetation type is found on the southeast facing gentle slope. The total number of species richness in this community is 36. It is dominated by the small tree of *Acacia karroo* and accompanied by the grasses

Eragrostis curvula and *Cynodon dactylon*. It consists of a herb layer, a shrub layer and a grass layer (Table 2.7). Herbs found in this community are *Spermacoce rulliaie,* and *Centella coriacea*. The grasses include *Eragrostis curvula* and *Cynodon dactylon.*

Table 2.7. The dominant plant species in Acacia savanna grassland

Plant species	**No. relevé's found**	**Average % Cover**	**Life form compositions**
Acacia karoo	6	58	Tree
Eragrostis curvula	6	56	Grass
Cynodon dactylon	5	64	Grass
Centella coriacea	6	32	Herb
Senecio pterophorus	6	58	Herb
Scutia myrtina	5	16.5	Shrub
Spermacoce ruelliaie	5	68	Herb

Plate 2.3 The *Acacia karroo* and *Eragrostis curvula* dominated savanna.

2.3.2.4 Grassland vegetation type

Eragrostis curvula dominated grassland was identified at the third hierarchical level. It is located on the southeast-facing slope adjacent to Acacia savanna and bush clumps but restricted to the gentle slopes. This vegetation type subdivided into three communities by TWINSPAN (Fig.2.3). This community is relatively species poor; containing only 20 species. The vegetation is dominated by *Eragrostis curvula*, *Tephrosia polystachya*, *Helichrysum odoratissimum*, *Centella coriacea* and *Tristachya leucothrix* (Table 2.8)

Table 2.8 The dominate plant species and % cover of plant species in Grassland

Plant species	No. of relevé found	Total % cover	Life forms
Eragrostis curvula	16	80.6	Grass
Tephrosia polystachya	3	8.75	Herb
Helichrysum odoratissimum	3	17.5	Herb
Tristachya leucothrix	4	11.6	Herb
Centella coriacea	5	17	Herb

Plate 2.4 Eragrostis curvula Grassland occurring in east facing slope.

2.3.2.5 Grassy fynbos

This vegetation type is confined to the centre of the valley along a small dam on the north-facing slope. It was identified by TWINSPAN at the fifth hierarchical level. The TWINSPAN also divided the vegetation type into four communities (Fig. 2.3). The association is distinguished by the presence of small leaved shrubs dominated by *Cliffortia linearifolia* and other herbaceous components such as *Anthospermum herbaceum*, *Helichrysum subglomeratum, Helichrysum odoratissimum* and *Berkheya heterophylla*. The total number of species in this vegetation type is 57 Commonly occurring grass species in this community were *Themeda triandra* and *Digitaria eriantha, Cymbopogon marginatus* and *Festuca*

Table 2.9 The dominant plant species and % cover in grassy fynbos community

Plant species	No. Relevé'	Total % cover	Life form
Anthospermumherbaceum	4	7.5	Climber
Berkheya heterophylla	4	5	Herb
Cliifortia linearifolia	8	78	Shrub
Cymbopogon marginatus	3	46.6	Grass
Digitaria eriantha	5	9	Grass
Festuca costata	8	79	Grass
Helichrysum subglomeratum	10	25.5	Herb
Themedia trindra	8	35	Grass

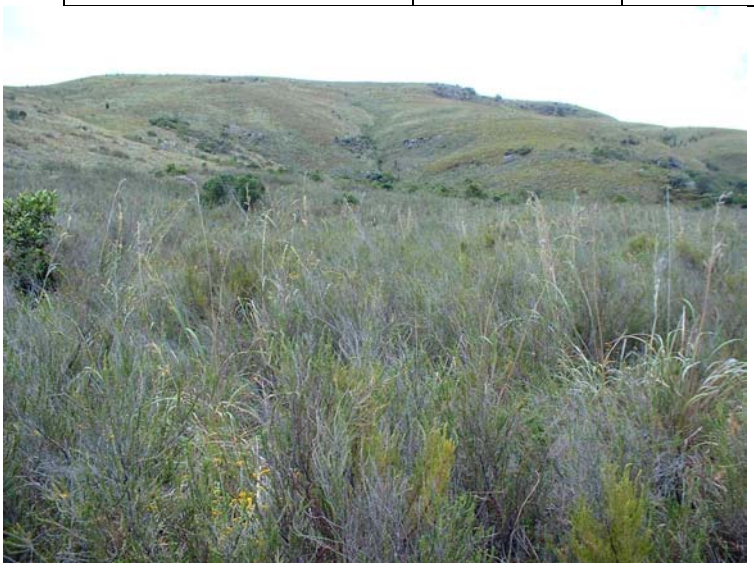

Plate 2.5 Grassy fynbos dominated with Cliffortia linearifolia and Themeda triandra.

2.3.2.6 Fynbos vegetation type

The Fynbos vegetation type is found on the northwest-facing slope. The community separated at the fifth hierarchical level. The TWINSPAN divided this vegetation type into five communities (Fig 2.4). Ninety species of plants were recorded for this vegetation community (Table 2.4) The community had a remarkably high species diversity compared with the other six plant communities because of the Cape floristic diversity.

Table 2.10 The dominant plant species and % cover in Fynbos plant community.

Plant species	No. relevés found	Total % cover	Life forms
Agathosma ovata	6	12.08	Woody herb
Alloteropsis semialata	22	26	Woody herb
Bobartia orientalis	14	35	Grass?
Erica cerinthoides	8	5.25	Herb
Erica glumiflora	13	3.4	Woody herb
Helichrysum subglomeratum	40	15	Herb
Helichrysum anomalum	10	35.5	Herb
Hypoxis villosa	15	9	Herb
Leucadendron salignum	9	20	Herb
Metalasia muricata	16	14	Shrub
Miscanthus capensis	14	37	Grass
Restio filiformis	19	37.36	Grass
Rhodocoma capensis	24	30.2	Grass
Senecio speciosus	8	5.6	Herb
Selago corymbosa	6	9.64	Herb

Plate 2.6 Fynbos dominated by Aspalathus frankenioides and Helichrysum subglomeratum.

2.3.2.7 Shrubland vegetation type

The shrubland community was separated at the fourth hierarchical level. The vegetation types divided into six communities by the TWINSPAN (Fig.2.5). The dominant species are *Metalasia muricata* & *Oldenburgia capensis*. It is located on south facing slopes. It is restricted to Wittberg rocky outcrops and consists of low trees, shrubs, herbs, creeper, climbers and grasses. A total of 51 plant species were recorded from this vegetation community (Table 2.5). The distinguishing plant species in this community were *Oldenburgia grandis, Metalasia muricata*, *Cineraria saxifraga* and *Passerina rigida* (Table 2.11). The grass layer includes *Tristachya leucothrix*, *Alloteropsis semialata*, and *Restio filiformis*.

Table 2.11 The dominant plant species and % cover in shrubland community.

Plant species	No.relevé's found	Total % cover	Life form
Cineraria saxifraga	9	22.5	Herb
Burchellia bubalina	5	7	Shrub
Metalasia muricata	11	54.5	Shrub
Miscanthus capensis	6	9.58	Grass
Oldenburgia grandis	8	45.6	Shrub
Passerina rigida	6	50	Shrub
Restio filiformis	6	10.14	Grass
Tristachya leucothrix	6	23.3	Grass

Plate 2.7 Metalasia muricata-Oldenburgia capensis shrubland.

2.3.3 Ordination

The scatter diagram in Fig.2.6 indicates the distribution of sample relevés along the first and second axes. Seven relatively distinct groups (as identified by TWINSPAN) representing major vegetation types i.e. Forest, Bushclumps, and Acacia savnna, Grassland, Grassy fynbos, Fynbos and Shrubland will be discussed.

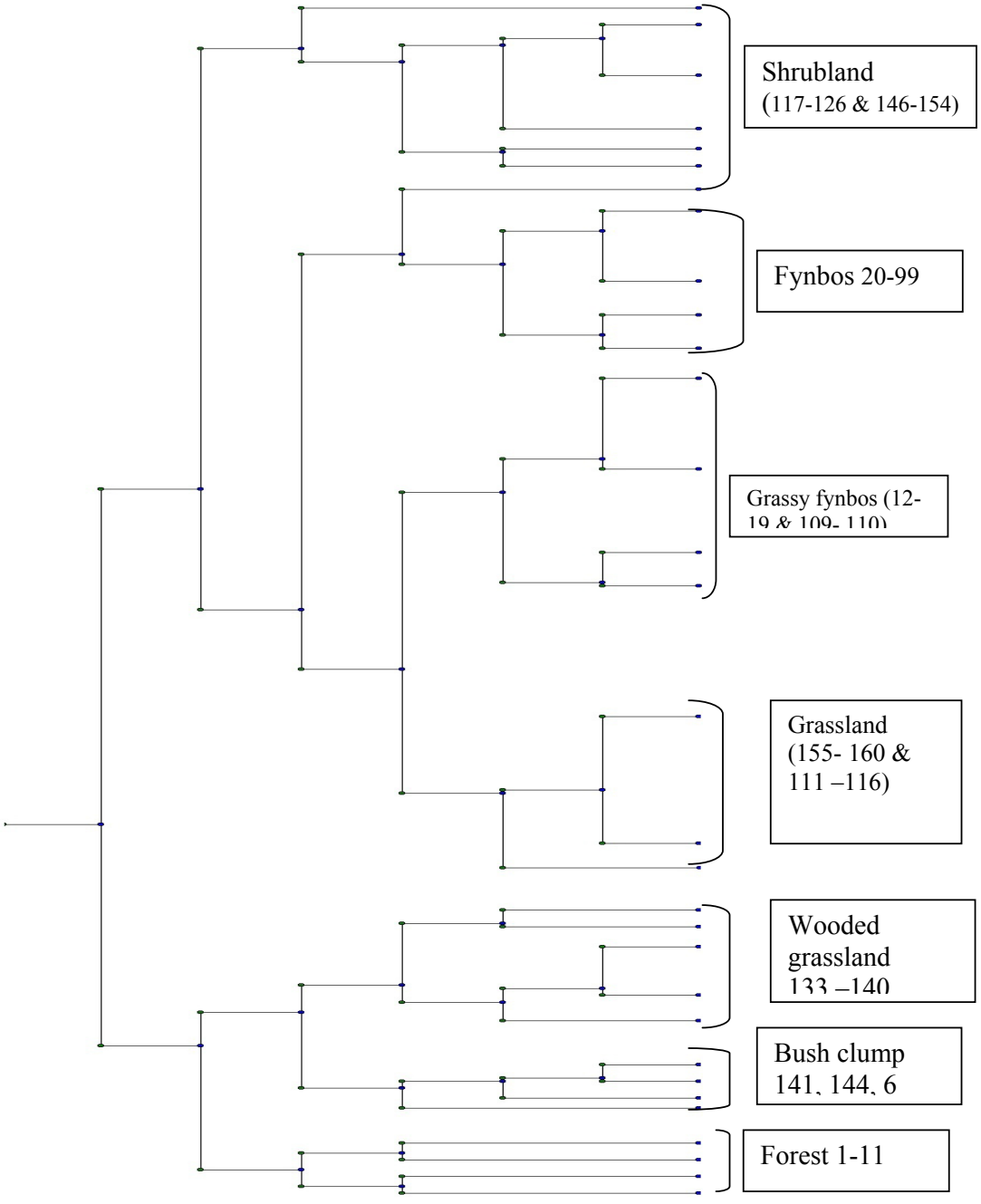

Figure 2.6 Dendrogram of the hierarchical classification of the plant communities produced by TWINSPAN.

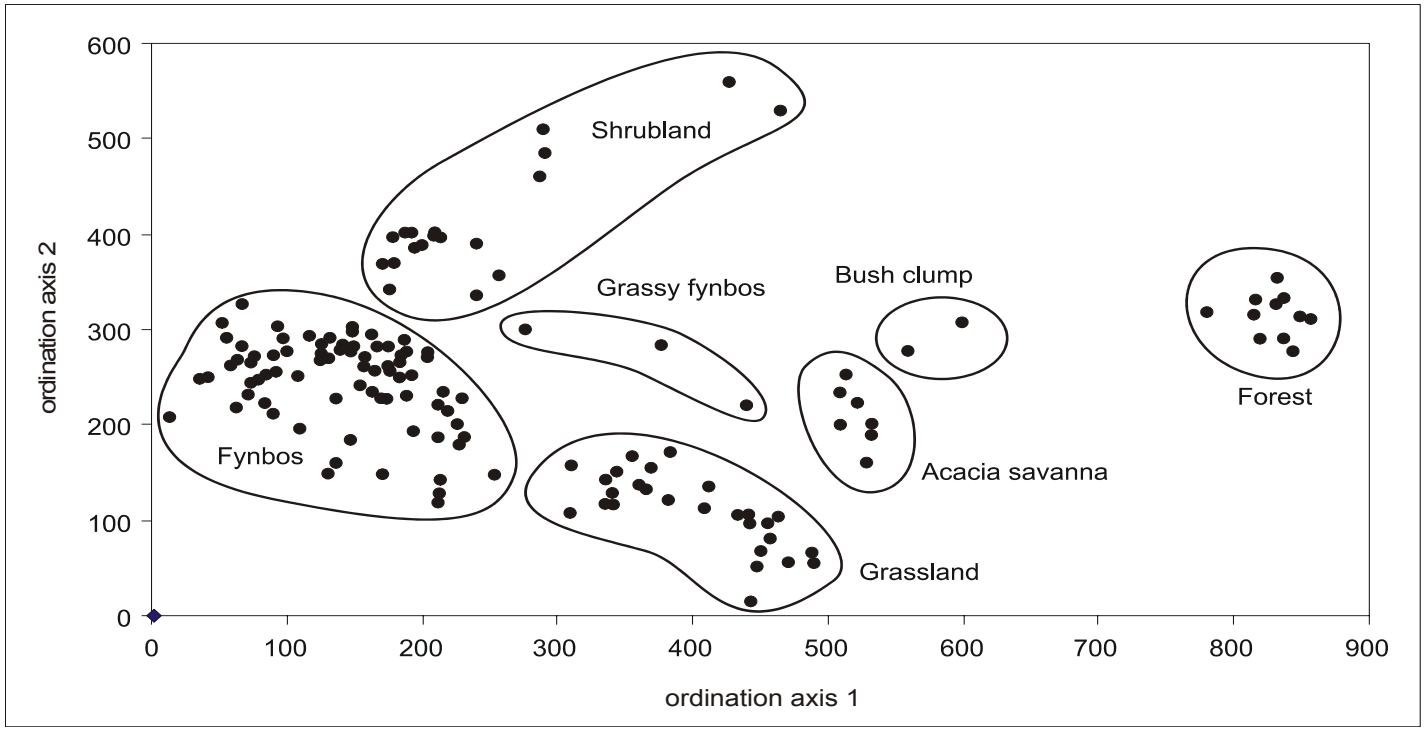

Figure 2.7 distribution of relevés on the first and second axis of Detrended correspondence analysis

2.4. Discussion

2.4.1 Floristic analysis of the area

The diverse number of families, genera and species in the area is an indication of the floristic richness of the Eastern Cape, which is confirmed by a similar study by Martin and Noel (1960) who identified 145 families, 908 genera and 2289 species in the Albany and Bathurst districts. Asteraceae, Fabaceae, Poaceae and Orchidaceae are the largest families in the area in terms of the number of species, followed by Rubiaceae, Iridaceae and Celastraceae etc. The general order of families, ranked by the number of species agrees with those recorded earlier for the Albany and Bathurst Districts (Lubke *et al*. 1988) and (Phillipson 1987) in the Amatole Mountains, but it differs from the Cape Floristic Kingdom, which has a large number of Iridaceae, Aizoaceae, Ericaceae, Proteaceae and Restionaceae (Goldblatt and Manning 2001).

Considering the small area of the farm (37ha), the number of families, genera and species was high when compared to other areas near Grahamstown such as the Ecca Nature Reserve and Andries Vosloo Kudu Reserve. The numbers of plants collected in the Ecca Nature Reserve are 60 families, 145 genera and 233 species (Chan 1992). In the Andries Vosloo Kudu Reserve there are: 59 families, 180 genera and 284 species (Palmer 1981). But the Amatole Mountains are exceptionally rich in species an area covering 900km^2 with1215 taxa (Phillipson 1987) and VanWyk *et al*. (1988) recored 1100 species of plants from the Zuurberg national park.

2.4.1.1 Endemic plant species

The Eastern Cape possesses a range of climate, soils, topography and geology and the region is arid. Because of this heterogeneity of its environment it would be expected to have rich flora but it does not show the expected level of endemism (Gibbs Russell and Robinson 1981). The estimated % endemism for the Eastern Cape is only between 6 % and 7% Lubke (1988).

Cowling ’s results (1982) agreed with the assertion of Gibbs Russell and Robinson (1981) that the percentage endemism in the Eastern Cape was low when compared to other well-known endemic areas in southern Africa.

The numbers of Albany endemic plant species recorded were low compared to the total flora of the area. The majority of endemic plant species was from Crassulaceae, but there are only four species of endemic plant from Asteraceae. The following families Ericaceae, Euphorbiaceae Mesembryanthemaceae, Fabaceae, Asphodelaceae and Thymelaeaceae only have a few species and most of them are represented by one endemic species. The high number of Albany endemic taxa from succulent taxa indicates that Eastern Cape is an important centre for diversity of succulent flora, especially in arid parts of the region.

2.4.1.2 Phytochrological affinity of the area

The grass species that were identified in the area had subtropical affinities (Pondoland and Tongaland) they were *Themeda triandra*; *Eragrostis curvula* and *Tristachya leucothrix* and the trees include *Apodytes dimidiata* and *Cussonia spicata*. This corresponds with Gibbs Russell and Robinson,(1981) who investigated the Eastern Cape grasses and trees and noted their sub Tropical origin.

The plant species also display Afromontane affinity due to the presence of affromontane species in forest communities. This phytochorological analysis corresponds with studies by Phillipson (1987) in the Amatole Mountains.

The numbers of Karroid affinities are small because the study site is found at the edge of the fynbos limit and dominated by the grassy fynbos. However some members of the Mesembryanthemaceae, Euphorbiaceae and Crassulaceae were recorded which are characteristic of the Karroid affinities.

There are many linking species in the area from different phytochoria including Cape, Afromontane, Pondoland, and Tongaland and Karoid phytochoria; for example, *Apodytes dimidiata Cussonia spicata*, *Canthium inerme*, *Olea capensis* & *Clodendrum capense*.
Different authors have given possible reasons for the presence of linking elements from different phytochoria as follows:

I. The variability of the environment and the fact that the Eastern Cape is a convergence zone of several phytochoria resulted in the selection of a generalist genotypes rather than specialist one.

II. Instability of climate has produced species that are able to fill by migration any niches that become empty (Gibbs Russell and Robinson 1981).

2.4.2 The plant communities

The quantitative overview of the vegetation of the study site has provided detailed descriptions of the plant communities and their species composition.

The communities determined by multivariate analysis of the data coincide with vegetation biomes discussed by Lubke *et al*. (1986), and Cowling (1983a) for the Eastern Cape Province, which include Fynbos, Grassland, Acacia *S*avanna and Afromontane and subtropical Thicket and Grassy Fynbos communities.

The forest community identified in the study area falls under the Afromontane forest category that was described by Acocks (1953) Martin and Noel (1960) and White (1978) which form pockets or islands extending from the Drakensberg Mountains over a number of the mountain regions of the Eastern Cape Province. The forest community is restricted to the valleys, which is a characteristic of Afromontane forest, presumably confined to sites where soil moisture is not a limiting factor, and along boulder-strewn stream beds where it is protected from fire. This forest community has several aspects of species composition in common with the studies of Seagrief (1950) in Fern Kloof and Jessop *et al*. (1969) in Thomas Baines Nature Reserve near Grahamstown. Common species for all 3 areas are *Apodytes dimidiata*, *Cussonia spicata* and *Pavetta lanceolata, Cassine peragua Rhoicissus tridentata Nuxia floribunda*, *Rhus chirindensis Maytenus hetrophylla*. The community is characterized by a strong component of Afromontane-Tongaland-Pondoland linking species (*Apodytes dimidiata*, *Calodendrum capense*, *Cussonia spicata* and *Canthium inerme*).

The bushclump community identified in this area belongs to the subtropical thicket, identified by Everard (1987). The community is distinguished by a very dense thicket of woody shrubs climbers and trees, which are similar to thicket in the river valleys of the eastern parts of the Western Cape, extending through the Eastern Cape to Kwazulu Natal. There is a great diversity of the species in this community. This community has an invasive nature and has spread to large parts of the grassland in the study area. This is in

agreement (with Lubke *et al*. 1986); who had established that subtropical thicket is an expanding ecosystem invading and replacing grasslands and savannas.

The Acacia savanna community identified in the study area corresponds with the savanna described by Lubke *et al*. (1986). It is one of the most common communities found in the Eastern Cape Province Lubke *et al*. (1986). It is characterized by an abundance of *Acacia karoo* extending into the Eastern Cape region from the northeast and is adapted to the higher rainfall and moist savanna of the Eastern Cape. This community is dominated by a variety of grass genera with some fynbos elements (*Senecio pterophorus*, *Bobartia* orientalis, *Disparago tortilis*).

The grassland communities identified in the study site fall into the sweet grassveld catagory, which was identified by Lubke *et al*. (1986). Sweet grassveld is found in areas of low erratic rainfall (less than 500mm per annum). It has common C4 subtropical grasses found in the region described by Lubke *et al*. (1986) such as *Themedia trindra* and *Eragrostis curvula*. It is characterized by lower fibre content and maintains nutrients in the leaves during winter making it palatable to livestock. It is thus highly favoured by livestock farmers in the area.

The Grassy fynbos community identified in the area corresponds with the *Themeda triandra-Cliffortia linearifolia* plant community, which was recognized in Humans dorp by Cowling (1984). The grassy fynbos community in this area also coincides with the concept of false macchia or derived fynbos, as described by Acocks (1953).

A number of researchers have studied grassy fynbos vegetation in the Eastern Cape in more detail than Acocks. Cowling (1983a, 1984) has described the vegetation in Humansdorp, Euston Brown (1995 cited by Hoare 1997) studied the Baviaans Kloof Mountain North of Port Elizabeth and Martin (1966) worked in Grahamstown. These authors described the grassy fynbos as a floristically variable and rich in plant diversity.

The presence of widespread Afromontane linking species namely, *Helichrysum odoratissimum*, *Helichrysum subglomeratum* and *Helichrysum anomalum* and some grass elements indicated that grassy fynbos is biogeographically characterized by a high

proportion of Cape-Afro montane linking species and wide distribution of subtropical grasses (*Themeda triandra* and *Eragrostis curvula*).

The Fynbos community is the most abundant plant community in the study area. It was recognized by various authors namely Lubke *et al*. (1986), Cowling (1984), Martin (1960) and Jessop *et al*. (1969). It is characterized by members of the families Restionaceae, Ericaceae and Proteaceae. These adapted to nutrient poor soil with a winter rainfall. The typical fynbos genera defined by Taylor (1978), such as *Protea*, *Erica, Leucadendron* and *Phylica*, are the main characteristics of this community in the study area.

The Shrubland community identified in the area are small leaved transitional Shrubland, which corresponds to Cowling's findings (1984). This plant community dominated by *Metalasia muricata* and *Oldenburgia capensis. Metalasia muricata* is derived from fynbos and has weedy characteristics and is able to grow under a wide range of conditions.

2.5 Conclusion

The checklist produced provides an important baseline for future research and management at the Rivendell farm or areas with similar vegetation in the Eastern Cape. The large numbers of plant species identified from the small area of the study site is due to the convergence of different phytochoria and the fact that the area is located in the Albany Centre of plant diversity, which results in the floristic richness of the area.

The numbers of Albany endemic species found in the area are low compared to total flora of the study area, which is in agreement with other studies in the Eastern Cape. The highest number of endemic plant species are of succulent family Crassulaceae, indicating that the Eastern Cape is an important centre for diversity of succulent flora, typically the arid parts of the province

TWINSPAN and DECORANA classification identified seven distinct plant communities namely: Forest, Bushclumps, Acacia savanna, Grassland, Grassy fynbos, Fynbos and Shrublands. The identified plant communities belong to the four major phytochoria (White 1983): Cape, Afromontane, Pondoland and Tongaland and Karoo-Namib,

indicating that the Eastern Cape is a point of convergence for the different phytochoria. This was supported by the presence of transgressor species (linking species) from different phyochoria, indicating that the Eastern Cape is in floral transition, and flora of mixed origin.

CHAPTER 3 OBSERVATION OF FLORAL RESOURCE UTILIZATION AND POLLEN COLLECTION BY *APIS MELLIFERA CAPENSIS* AT RIVENDELL FARM

3.1 INTRODUCTION

Honeybees are dependent on flowering plants because plants provide bees with food in the form of nectar and pollen. Nectar and pollen are a primary reward to insect pollinators in general and to honeybees in particular. As honeybees require large quantities of nectar and pollen at particular times they utilize particular species of plant for a limited period of time. During the flowering period or anthesis there is a considerable movement by honeybees between plants of the same species. This in turn favours the successful cross-pollination of plants. (Percival 1965; Faeger & Van der Pijl 1979 & Free 1970).

Numerous workers have studied honeybee visitations on flowering plants, for example Ribbands (1953) and Singh (1950). They investigated plant species that provide nectar and pollen to honeybees during different seasons. Honeybees communicate the source of good forage to other honeybee workers from the hive and entire colony tends to collect nectar and pollen from only a few plant species at any one time (Free, 1970)

Most of the methods for obtaining information about plants utilized in an area are based on direct field observation of foraging honeybees on flowers. The analysis of bee plant pollen loads and palynological analysis of honey samples (Hepburn *et al*.1998), can provide the true picture of the honeybee flora of the area.

Pollen is widely used as a source of food by various insects and by honeybees for brood rearing. Numerous studies have been undertaken on the chemical composition and nutritive value of pollen and its effect on brood rearing growth and the longevity of honeybee colonies. Pollen provides bees with their only natural source of protein, which is needed for larval development and also fulfils other dietary requirements for lipids, sterols, vitamins and minerals (Herbert 1992). The protein content of the pollen is a direct measure of pollen quality in the diet of the honeybee (Pernal and Currie 2001). Moreover, it was found that fresh pollen contains high protein content and is 100% effective in the development of the hypophrangeal glands of worker honeybees (Haydak

1970) that secrete the royal jelly for the feeding of young larvae of honeybees. The pollen-gathering activities of honeybees from different plant species have been widely studied for example by Synge (1947), Eckert (1942), Percival (1965) and Free (1970) who found that the availability, quantity and nutritive value of pollen varies among the plant species.

The pollen load is a good indicator of the surrounding flowering plant species that are providing pollen for the honeybees. The pollen loads also reflect the availability of the dominant pollen food resource for the different pollinators in the ecosystem.

Honeybee collected pollen loads have become economically important due to their high content of protein and amino acids. It has different applications including a nutritional complement for humans and of medicinal value for the preparation of antibiotics and feed for animals (Diaz-Losada *et al*. 1998).

This part of the research aimed to address questions such as: which plant species are nectar and pollen source to Cape honeybees, which are the predominant pollen source plants, and what is the relationship between pollen and brood production? It also aims to test the hypothesis that the Cape honeybees utilize as the primary source of nectar and pollen plant species limited to the Cape region or fynbos vegetation in a study area near Grahamstown where fynbos vegetation mingles with forest and grassland communities.

3.2 MATERIALS AND METHODS

3.2.1 Bee observation

Captive Cape honeybees were established in the study area augmenting the naturally occurring population of wild honeybees. Plants visited by honeybees were observed from September 2001- September 2002 in various vegetation types of the study site. During observations, the types of food source offered by plants and behaviour of honeybees while collecting nectar and pollen were studied. The habitats of the beeplants were recorded during the plant specimen collection and vegetation sampling in the study area (seeChapter Two).

3.2.2 Nectar and pollen collection by bees

Honeybee plant species providing nectar were distinguished by carefully watching honeybee activities on flowers. Activities observed included insertion of proboscis in the corolla of flowers and the"pumping"movement of the abdomen when they were sucking the nectar.

The pollen source plants were detected and distinguished by observing Cape honeybees collecting pollen loads on their hind legs and alighting on anthers of the flower or coming in contact with the anther of the flower. In addition to these observations, a literature review was done of Johannsmeier (1995), Anderson (1985) and Illgner (2003) who had determined nectar and pollen sources for the plants in the Cape region. The time spent by individual bees in collecting nectar and pollen from flowers was measured with a stopwatch from landing on a flower to leaving that flower.

The foraging abundance of Cape honeybees was determined within a 1km flight range because honeybees efficiently forage in close proximity to hives so as to conserve energy. Fourteen honeybee visited plant species were selected based on abundance and relative distance from the hives. The number of honeybees visiting flowers was counted for about ten minutes per $1m^2$ quadrat areas of flowers.

Distances between hives and plant visited were recorded using a global positioning system unit (GPS). The hives were closed for a day and observations were made to establish the abundance of wild honeybees within a one-kilometre radius.

Observations were made on flowering periods at different periods and records were made on dates of blooming and shedding of flowers of the plant species that were visited by the Cape honeybees**.**

3.2.3 Preparation of reference slides

To identify the pollen pellets collected by the honeybees, a sample of ripe pollen grains was collected from mature flower buds directly from the field. From these samples reference slides were prepared. Flower samples were kept in individual envelopes to avoid contamination with other species of the pollen grains. Reference slide sets were prepared by acetolysis (Erdtman 1969). The ripe pollen grains were shaken directly onto microscopic slides. The fat content was washed out using ether to enhance the transparency of pollen grains. The slides were then covered with a cover slip and examined under 400x magnification. A total of 112 sets of reference slides were prepared and housed at the Botany Deprtment of Rhodes University.

A scanning electron microscope (SEM) was used to identify morphologically similar pollen of different plant species, which could not be clearly identified by light microscopy. Dried pollen grains were directly dusted onto brass stubs provided with double sided tape and coated with gold for 2 minutes using the Balzer's sputtering device. Important morphological features of the pollen grains such as form, shape, size and aperture type were examined.

3.2.4 Pollen trapping

Pollen loads were collected over a 12 months period from (September 2001 September 2002) (Plate 3.1), using the pollen traps fitted at the entrance of four hives having 22% trapping efficiency. Pollen trap efficiency was measured during the spring flowering by counting 100 bees entering the hives with pollen loads on their legs. The trap was then emptied of pollen and percentage efficiency of the trap was calculated by dividing number of loads remaining on the collecting tray by the number of bees entering with pollen loads. Pollen traps are devices that are fitted into the entrance of the hives and have wire grids or holes that allow bees to pass through. During this process pollen loads are scrapped off from the legs of honeybees to the collecting tray (Synge 1947).

Four Cape honeybee colonies of about equal population size were purchased from local beekeepers around the study area. After establishment of the bee colonies the pollen was sampled for 4 days at two-week intervals over the year-long period.

3.2.5 Analysis of pollen

The trapped pollen pellets were collected every day, weighed using a Bel Engineering, Mark 205A electronic balance and allowed to dry overnight at room temperature. The pollen was then sorted by colour and size. Representative pellets of each colour were washed with ether and mounted on glycerine jelly for microscopic examination. The plant sources of the pollen pellets were identified using the light microscope by comparing them with prepared reference slides. In addition to this, identification was made by watching the colour of the pollen loads on the legs of the bees while working on flowers. After sorting pollen loads by colour, identification was made to species or genus level. The dry pollen weight of each plant species was determined as above for fresh pollen.

3.2.6 Protein determination

Protein concentration was determined using the Bradford's method (1976) using bovine serum albumin (BSA) as a standard. The reaction was carried out as follows: 5µl (0.1g/ml) of samples of pollen were added to a microtiter plate. This was followed by the addition of 250µl Bradford reagent (Sigma Co. South Africa). The absorbance was determined at 595nm using power wavelength X. The complete reaction mixture containing distilled water instead of the reaction sample served as a blank (The Calibration curve is shown in Appendix V.)

3.2.7 Brood population

The total area of honeybee brood (eggs, larvae and pupae) was estimated every 21 days using a wooden frame 7.5 cm x 15 cm in size. This frame was further subdivided. The frame was placed over each side of the brood combs after the honeybees had been shaken from the combs. The area occupied in cm^2 was recorded and the brood populations were calculated from the total area occupied by the brood.

A one-way analysis of variance (ANOVA) was used to analyse the pollen weight variation between seasons and Turkey's test was used to separate the means of pollen between the seasons.

Plate 3.1 Pollen loads from honeybee collected pollen

3.3. Results

3.3.1 Nectar and pollen source plant species.

Fifty-four plant species belonging to 26 different plant families were observed being visited by bees that were collecting either pollen or nectar (or both). Of these, 90.7% were pollen yielders, and 35.2% yielded nectar. The dominant plant families were Asteraceae, Fabaceae, Myrtaceae, Ericaceae, Crassulaceae, and Celastraceae. Species of these families comprised 23.6%, 9%, 7.2%, 3.6% and 3.6% respectively of the total bee flora of the area. The data is presented in Table 3.1.

The greater proportions of identified bee plants were pollen providers as honeybees were observed collecting pollen loads from the flowers of these plant species. In terms of habitat distributions of bee plants 50 % and 14.6 % of the bee plant species were growing in fynbos and forest while 14.8 % and 9.2 % were growing in scrubland and cultivated land and 7.4 % and 3.7% were growing on waste and wetland (Table 3.1.)

Table 3.1 The 54 nectar and pollen source plant species identified at study area.

Plant species	Family	Habitat	Food source		Flowering period (months)
			Pollen	Nectar	
Metalasia muricata	Asteraceae	Shrubland	X	-	Dec - Apr
Helichrysum odoratissimum	Asteraceae	Fynbos	X	-	Oct - Dec
Helichrysum anomalum	Asteraceae	Fynbos	X	-	Mar - May
Helichrysum cymosum	Asteraceae	Fynbos	X	-	Nov - Mar
Eucalyptus cinerea	Myrtaceae	Cultivated	X	X	Jan -May
Eucalyptus camaldulensis	Myrtaceae	Cultivated	X	X	Jul - Nov
Erica chamissonis	Ericaceae	Fynbos	X	-	Aug - Nov
Crassula cultrata.	Crassulaceae	Fynbos	X	-	Dec- Mar
Apodytes dimidiata	Icacinaceae	Forest	X	-	Nov - Feb
Cyperus sp.	Cyperaceae	Forest	X	-	Dec - Jan
Maytenus heterophylla	Celastraceae	Forest	X	-	Oct - Dec
Erica demissa	Ericaceae	Fynbos	X	X	Sept - Nov
Delosperma klinghardtianum	Mesembryanthemaceae	Fynbos	X	-	Mar - Apr
Psoralea pinnata	Fabaceae	Fynbos	X	X	Jan - Dec
Chrysanthemoides monilifera	Asteraceae	Shrubland	X	-	Jun - Nov
Cassine cf. peragua	Celastraceae	Forest	X	-	Dec - Feb
Agathosma ovata	Rutaceae	Fynbos	X	X	Jun - Nov
Psychotria capensis	Rubiaceae	Forest	X	X	Jun - Dec
Pelargonium zonale	Geraniaceae	Fynbos	X	X	Jun - Nov
Bobartia gracilis	Iridaceae	Fynbos	X	-	Apr - Jun
Berzelia intermedia	Bruniaceae	Fynbos	X	-	Dec -Mar
Hypochoeris radicata	Asteraceae	Grassland	X	-	Sept - Jan
Acacia longifolia	Fabaceae	Acaica woodland	X	-	Mar - Oct
Restio filiformis	Restionaceae	Fynbos	X	-	Nov - Jan
Berkheya carduoides	Asteraceae	Fynbos	X	-	Dec - Apr
Conyza ulmifolia	Asteraceae	Shrubland	X	-	Nov - Dec
Crassula pellucida	Crassulaceae	Fynbos	X	X	Mar - Apr
Erica nemorosa	Ericaceae	Fynbos	X	-	Apr - Jul
Erythrina lysistemon	Fabaceae	Cultivated	-	X	Jul - Oct
Leonotis leonurus	Lamiaceae	Shrubland	-	X	Mar - Oct
Clutia pulchella	Euphorbiaceae	Shrubland	X	X	Apr - July
Callistemon rigidus	Myrtaceae	Cultivated	X	-	Jun - Jan
Nymphaea spp	Nymphaeaceae	Wet land	X	X	Dec - May
Nymphoides indica	Menyanthaceae	Wet land	X	X	Oct - Mar
Hypoestes forskaolii	Acanthaceae	Forest	X	-	Sept - Mar
Nuxia floribunda	Loganiaceae	Forest	X	X	Aug - Nov
Agathosma pegleriae	Rutaceae	Fynbos	X	-	Jun - Aug
Chrysocoma ciliata	Asteraceae	Fynbos	X	-	Aug - Dec
Aspalathus recurva	Fabaceae	Fynbos	X	-	Aug - Nov
Mesembryanthemum aitonis	Mesembryanthemaceae	Fynbos	X	-	Nov - Dec
Cotula heterocarpa	Asteraceae	Grassland	X	-	Nov - Dec
Pelargonium capitatum	Geraniaceae	Fynbos	X	-	Sept - Dec
Erica caffra	Ericaceae	Shrubland	X	X	
Senecio purpureus	Asteraceae	Fynbos	-	X	Jun - Sept
Scabiosa albanensis	Dipsacaceae	Fynbos	X	-	Oct - Jan
Athanasia dentata	Asteraceae	Fynbos	X	-	Oct - Jan
Wahlenbergia oppositifolia	Campanulaceae	Grass land	X	-	Aug - Jan
Selago polystachya	Selaginaceae	Fynbos	X	-	Oct - Jan
Protea neriifolia	Proteaceae	Fynbos	X	-	Sept - Dec
Acacia karroo	Fabaceae	Shrubland	X	X	Dec- Feb
Syzygium cordatum	Myrtaceae	Cultivated	X	-	Dec -Mar
Burchellia bubalina	Rubiaceae	Forest	-	X	Nov - Jan
Scutia myrtina	Rhamnaceae	Shrubland	-	X	Aug - Jan
Berkheya heterophylla	Asteraceae	Shrubland	X	-	Oct - Jan
		Total no.	**49 (90.7%)**	**19 (35%)**	

Flowering time of the bee plant species observed in the area varied with the different seasons of the year. Most of the bee plant species in the area flowered from the end of August following the winter rains and continued to flower in September, reaching the highest peak in October and November when summer rainfall stimulates flowering. Approximately 50 % of the bee plant species flowered during spring (Sept – Nov), 29.9% during summer (Dec- Feb), 14.8 % during autumn (Mar–May) and 8.92 % during the winter (Jun-Aug) (Fig 3.1). There was considerable variation among the plant species with respect to time of flowering. Some of the individual species produced a few flowers for a few days but some plant species bloomed for longer periods, lasting from several weeks to several months. Some plant species that flowered for short period included. *Crassula pellucida*, *Delosperma Klighardtianum Helichrysum cymosum* and *Erica chamissonis* while *Psorlea pinnata*, *Eucalyptus grandis*, *Metalasia muricata Helichrysum anomalum* have longer flowering time (Fig.3.2).

Apis mellifera capensis was observed on flowers of selected plant species. More time was spent on a flower when foraging for pollen than nectar. The average time spent in collecting pollen loads from different plant species appeared very similar with an average of 11.6 seconds per flower for pollen and 3.6 seconds per flower for nectar (Table 3.2.).The most rapid foraging rate of honeybees were recorded for *Burchellia bubalina*, *Callistemon vimnalis*, *Agathosma ovata*, *Metalasia muricata, Erica chamissonis* and *Agathosma* pegleriae. The percentage of the relative abundance of honeybees visit to these plants were 22%, 13.04 %, 13.04% 10 % 8.6%, and 8.6% respectively (Table 3.2). The foraging density was smaller for the remaining plant species.

The foraging rate of *Apis mellifera capensis* declined significantly with increasing distance from the hives. Most honeybees preferred to work close to their hives. The regression analysis (Fig 3.3) showed a negative correlation between the distance from the hives and foraging abundance of *Apis mellifera capensis* ($r = -0.29$) and the correlation between the distance from the hives and foraging abundance of *Apis mellifera capensis* was significant $F(1,12)$ $P < 0.0305$.

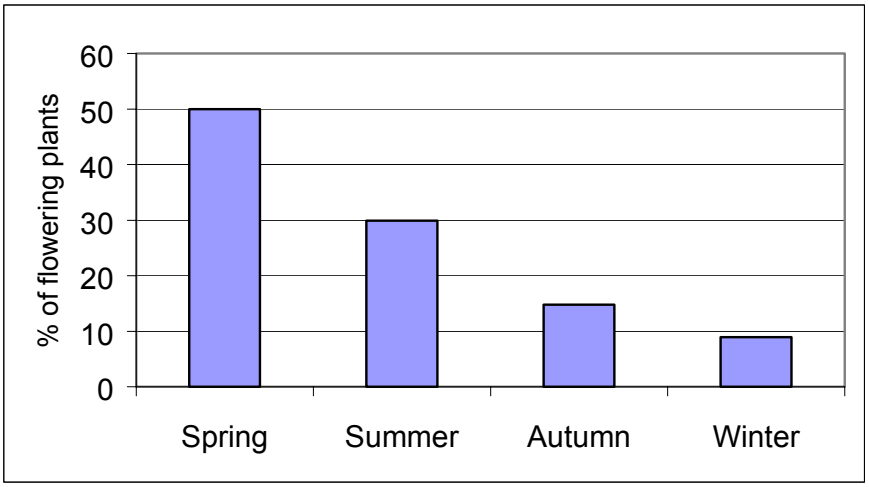

Figure 3.1 The Percentage of flowering plant species at different season.

Table 3.2 Foraging rate and abundance of *Apis mellifera capensis* on major melliferous plant species

Plant species	Floral reward	Time(secs) spent Per visit per flower (Mean±SD)	Distance from the hives (m)	No. of honeybee visit per plot per 10 minutes	% of honeybees per flower
Burchellia bubalina	Nectar	5 ± 1.8	33	50	22
Erica chamissonis	Pollen	6 ± 1.7	49	20	8.6
Chrysanthemoides monilifera	Pollen	7 ± 2	168	10	4.3
Agathosma ovata	Nectar	2 ± 0.6	153	30	13.04
Psychotria capensis	Nectar	3 ± 0.7	306	10	4.34
Callistemon vimimalis	Nectar	5.3 ± 1	225	30	13.04
Agathosma pegleriae	Pollen	18 ± 8.4	500	7	3.04
Helichrysum odoratissimum	Pollen	32 ± 12	301	20	8.6
Metalasia muricata	Pollen	8 ± 3.5	300	24	10.4
Acacia karroo	Pollen	7 ± 2.8	1012	5	2.17
Wahlenbergia oppositifolia	Pollen	3 ± 0.6	913	3	1.30
Berzelia intermedia	Pollen	19.2 ± 4.	935	6	2.6
Scutia myrtina	Nectar	2.1± 0.7	893	10	4.34
Hypochoeris radicata	Pollen	7.7± 5.19	682	5	2.17

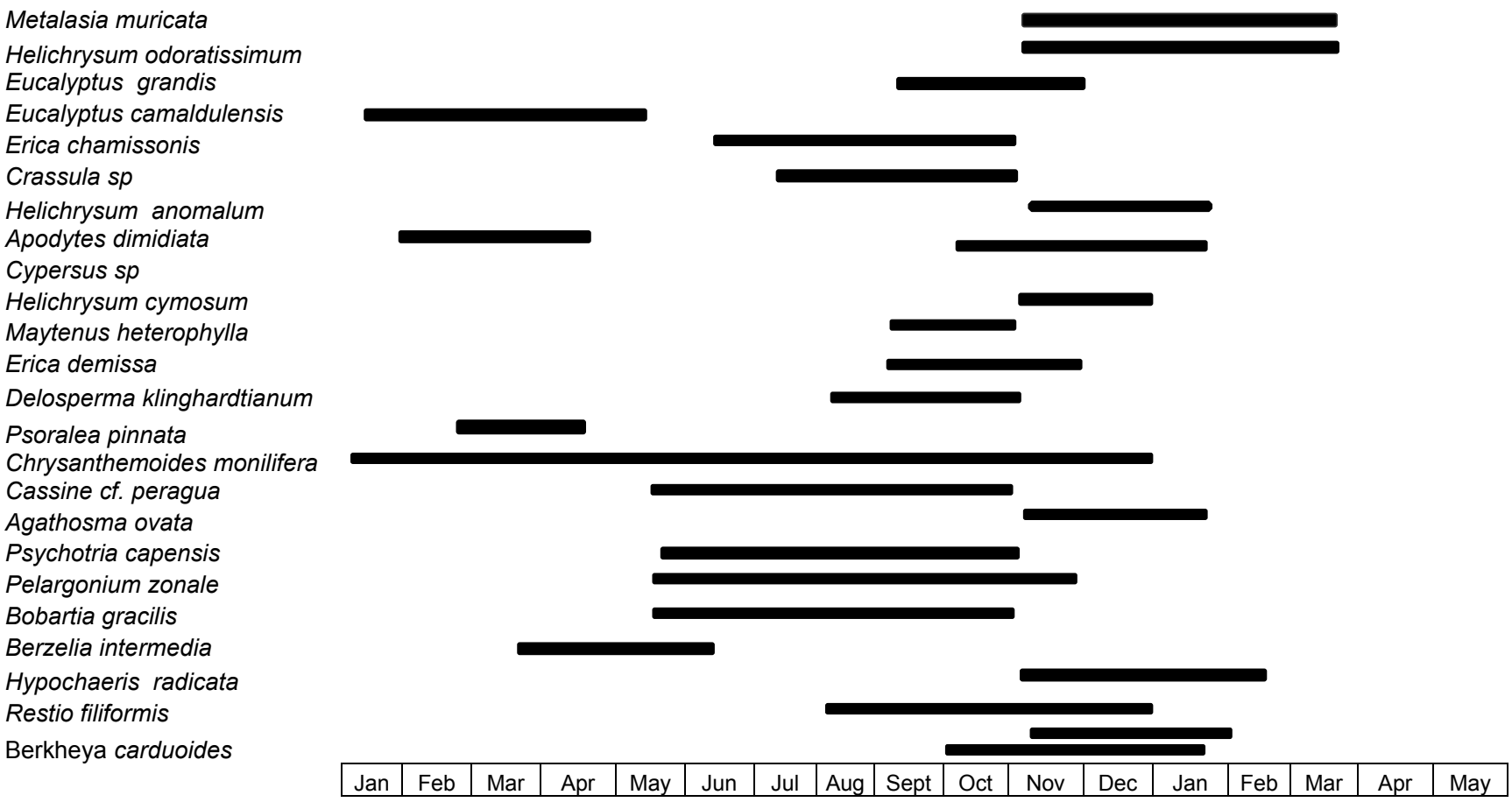

Figure 3.2 The Flowering phenology of bee plants in the study area

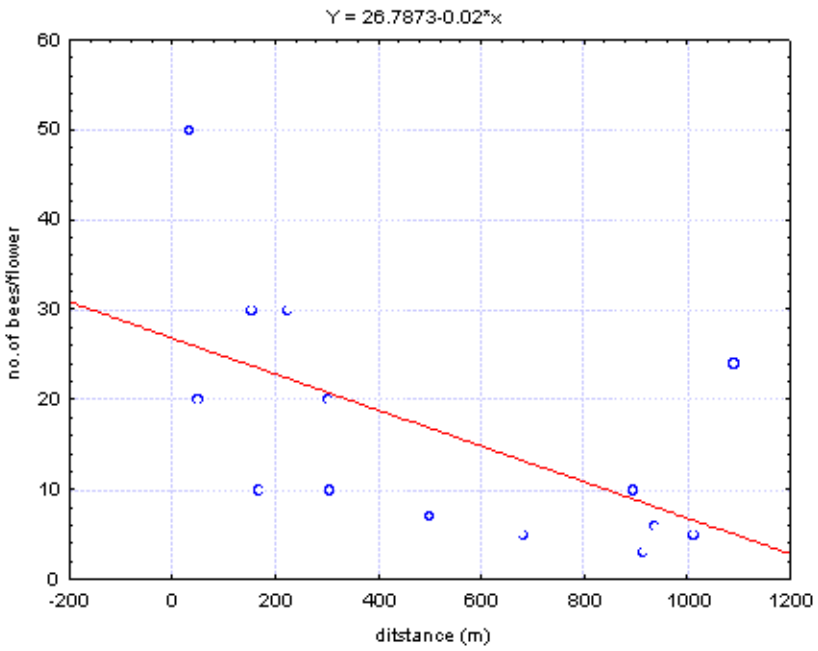

Figure 3.3 The relationship between number of foraging honeybees and distance from the hives.

3.3.2 Determination of the weight of the pollen by source plant

Due to adverse weather and the absconding of some honeybee colonies, it was not always possible to sample pollen from all colonies. A total of 280 pollen samples were examined during the sampling period. Table 3.3 gives the results of the total annual incoming pollen weight during the flowering period from bee visited plant species only. A total of 37 pollen source plant species were identified in mixed vegetation of grassy fynbos, forest, shrubland, and grassland and *Acacia* savanna. Photographs of the important pollen grains are shown in Plate 3.2 a and b.The bulk of the pollen came from comparatively few plant species. Ten plant species yielded almost 82.14% of the total pollen weight. The ten pollen source plant species favoured by Cape honeybees in the study sites were *Metalasia muricata, Helichrysum odoratissimum, Eucalyptus grandis*, *Eucalyptus camaldulensis*, *Erica chamissonis*, *Crassula cultrata*, *Acacia longifolia*, *Hakea sericea*, *Helichrysum anomalum* and *Helichrysum* spp. The pollen yields of plants were calculated in terms of vegetation units. The greatest proportions of pollen income were from fynbos, (60 %) with only 5.4 % from forest, 8 % from shrubland and 6 % cultivated plants (Fig 3.4). The fynbos and shrubland vegetations

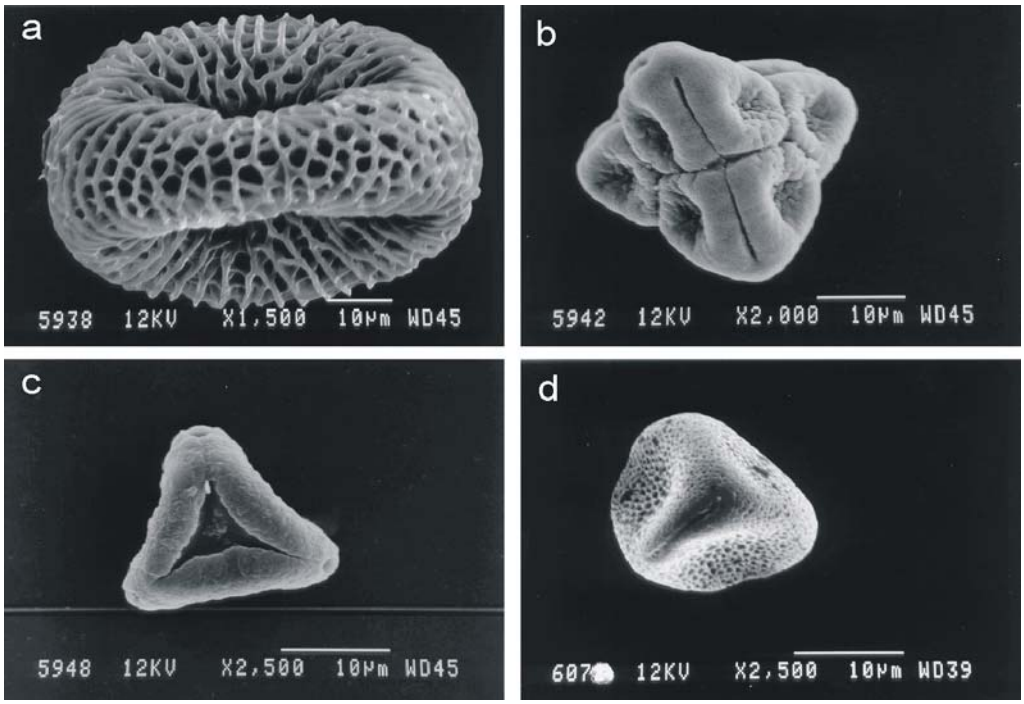

Plate 3.2a Pollen grain photos from honeybee collected pollen loads: *Burchellia bubalina* (a); *Erica chamissonis* (b); *Eucalyptus camaludensis* (c); *Apodytes dimidiata* (d).

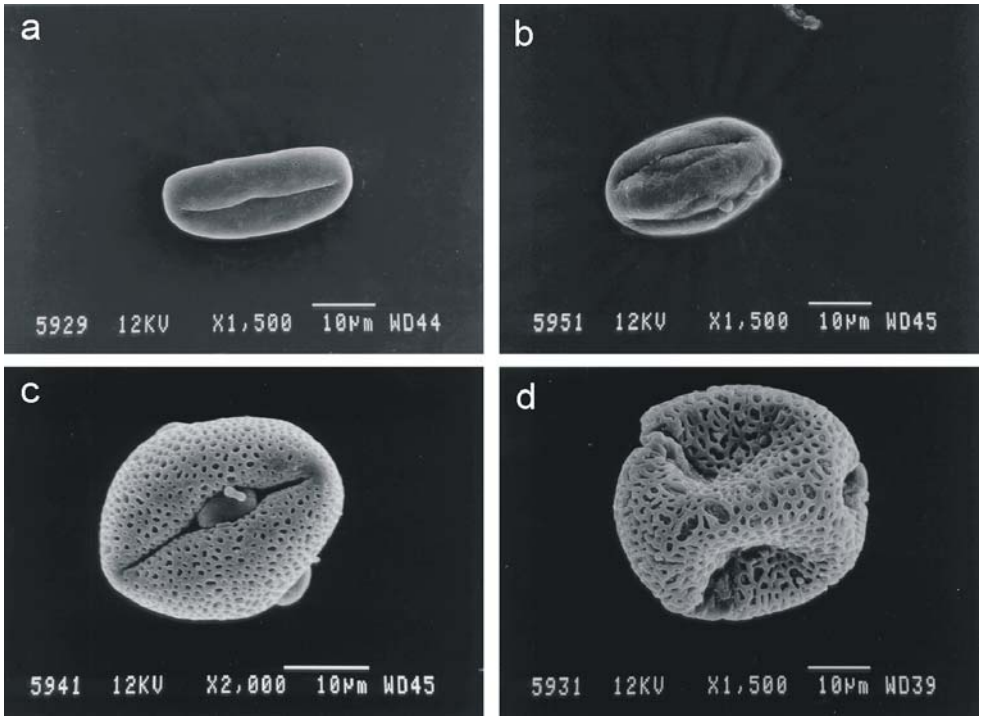

Plate 3.2b Pollen grain photos fromhoneybee collected pollen loads (continued)*: Agathosma ovata* (a); *Clutia pulchella* (b); *Maytenus heterophylla* (c); *Psychotria capensis* (d).

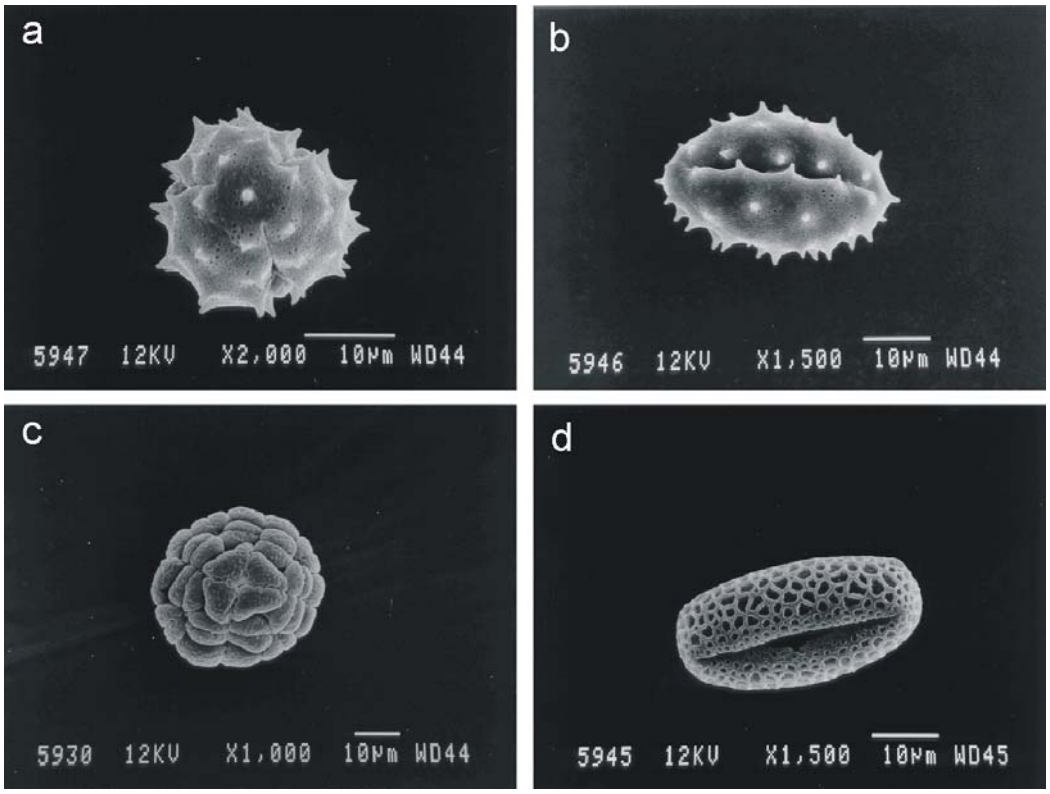

Plate 3.2c Pollen grain photos from honeybee collected pollen loads (continued) ***Conyza ulmifolia*** **(a);** ***Helichrysum odoratissimum*** **(b);** ***Acacia karroo*** **(c);** ***Pelargonium zonale*** **(d).**

are the most abundant in the area and comprising the most dominant beeplant that provide pollen for Cape honeybees. These are *Helichrysum odoratismum, Erica chamisonis*, *Metalasia muricta* and *Agathosma pegleriae* No grasses are foraged by the bees in the area but herbs growing in association with grasses such as *Helichrysum anomalum and Berkheya heterophylla* were observed being visited by bees.

Table 3.3 The total proportion of annual income of pollen by dry weight.

Plant species	Pollen weight/gm	Proportion (%)
Acacia longifolia	32.7	4.52
Agathosma ovata	1.9	0.26
Agathosma pegleriae	7.1	0.98
Aloe ferox	11.0	1.5
Apodytes dimidiata	19.6	2.71
Berkheya carduoides	0.6	0.08
Berzelia intermedia	1.4	0.19
Bobartia orientalis	1.5	0.20
Cassine peragua	2.9	0.40

Chrysanthemoides monilifera	3.0	0.41
Conyza ulmifolia	0.2	0.03
Crassula cultrata	33.8	4.68
Crassula pellucida	0.1	0.01
Cyperaceae	11.1	1.53
Delosperma klinghardtianum	4.4	0.6
Erica chamissonis	45.1	6.23
Erica demissa	4.4	0.6
Erica nemorosa	0.04	0.04
Eucalyptus camaldulensis	46.2	6.39
Eucalyptus grandis	56.9	7.88
Gazania krebsiana	3.9	0.54
Hakea sericea	25.5	3.53
Helichrysum anomalum	25.0	3.46
Helichrysum cymosum	1.5	10.9
Helichrysum odoratissimum	72.6	10.05
Helichrysum sp.	32.8	4.54
Hypochoeris radicata	1.2	0.16
Maytenus heterophylla	1.02	7.4
Metalasia muricata	223	30.88
Nuxia floribunda	3.9	0.54
Pelargonium zonale	1.6	0.22
Psoralea pinnata	4.0	0.55
Psychotria capensis	1.8	0.24
Restio filiformis	0.6	0.08
unidentified Fabaceae	0.2	0.03
Unknown pollen 2	0.24	0.03
Unknown pollen1	24.0	3.32

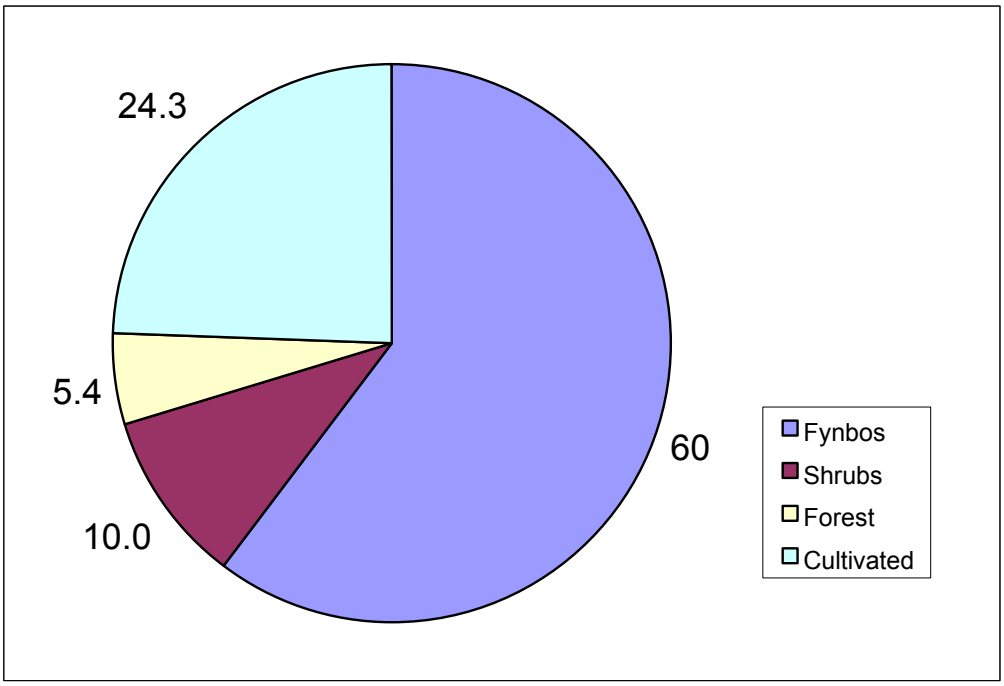

Figure 3.4 The total percentage annual incoming pollen weight from different vegetation units.

3.3.3 Daily incoming pollen weight

The daily incoming pollen weight per hive from different plant species ranged from 0.002g –32.9g/ day with mean pollen income of 2.8 g /day during 96 days of sampling. The total daily incoming pollen weights for the dominant pollen source plant species are shown in Fig 3.5 with different colour bands.

The number of pollen loads brought in each day varied greatly due to changing weather conditions and the availability of food in the area. The daily incoming pollen weight is affected by bad weather conditions, which result in a reduction in the incoming pollen or nil as indicated by empty spaces on Fig.3.5. The daily incoming pollen loads from the different plant species vary in terms of species composition. An examination of (Fig 3.5) shows that the greatest amount of pollen is collected at the time when the major pollen source plants are in flower

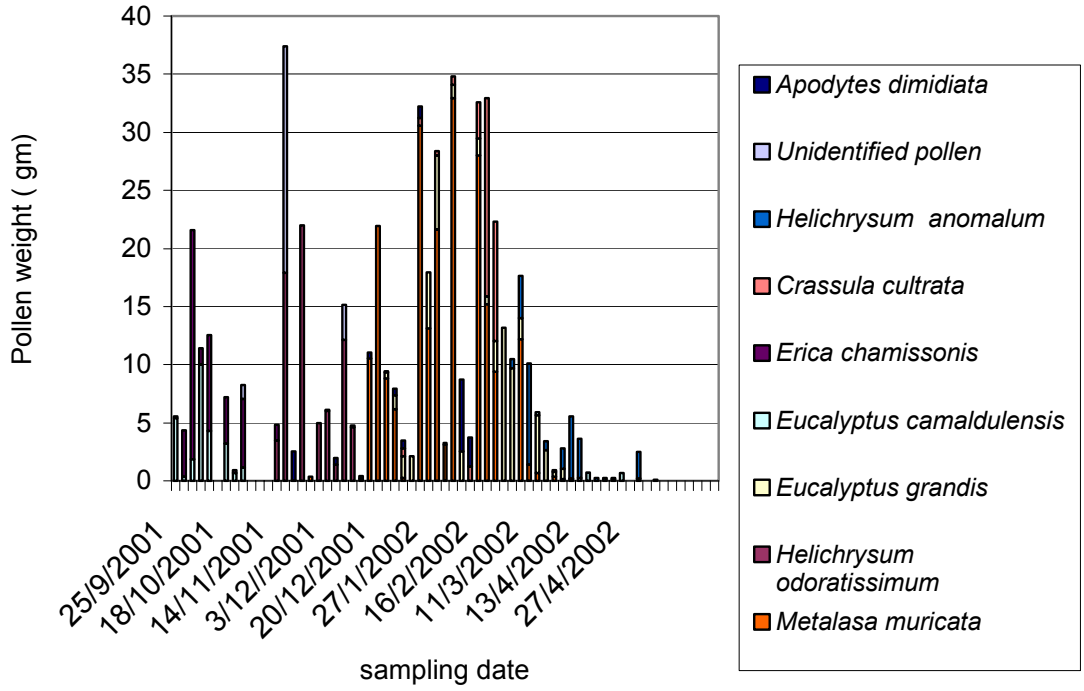

Figure 3.5 The total daily percentage of plant species incoming to the hives during the sampling period.

3.3.4 Seasonal availability of pollen

The monthly pollen weight ranges from 4.27gm to 128 gm. The highest pollen yield weight was obtained for the months of October, November, December, January and February, while the lowest pollen yield was recorded for May, June and July as indicated in Fig. 3.6. The mean differences in pollen yield between the seasons was found to be highly significantly different F (3,8) = 6.73, P = 0.014 (Table 3.4).

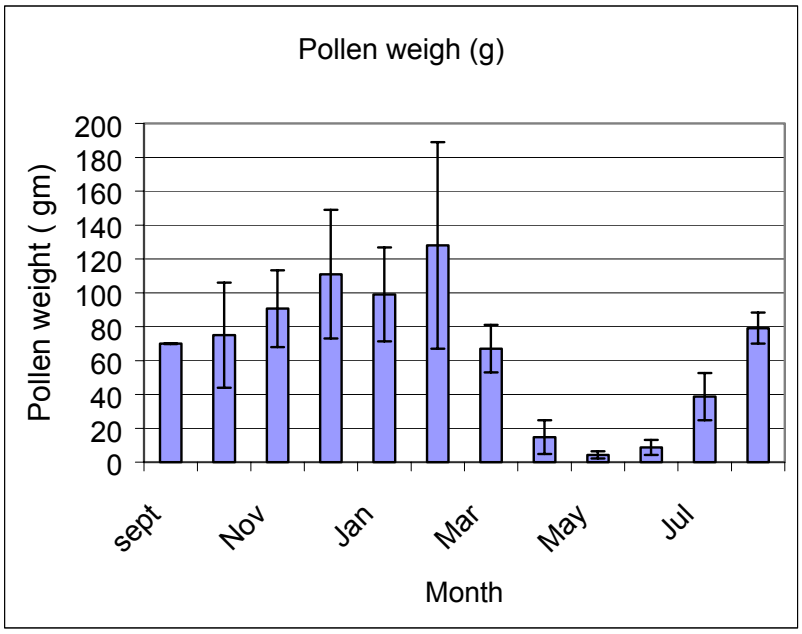

Figure 3.6. Monthly pollen weight collected by Cape honeybees in the mosaic vegetation of the study area.

Table 3.4 P-values for the mean pollen yield for the four seasons. Figures in brackets indicate mean pollen yield in gm. * Statistically significant, P<0.05

SEASONS	Spring: (80.53)	Summer: (128.6)	Autumn: (28.69)	Winter 4: (42.17)
Spring		0.322356	0.269505	0.496605
Summer	0.322356		0.021140*	0.043016*
Autumn	0.269505	0.021140*		0.952917
Winter	0.496605	0.043016	0.952917	

3.3.5 Distribution of pollen source plants in relation to Cape honeybees

The identified major pollen source plants in the pollen sample have different phytogeographical origins and wide range of distribution. Some of these plant species are indigenous to the Cape Floral Kingdom of South Africa. These include the *Erica chamissonis Agathosma ovata, Erica demissa, Berzelia intermedia* and *Restio filiformis* which coincide with the natural distribution of Cape honeybees Two other plant species, *Metalasia muricata, Helichrysum odoratissmum,* identified from pollen loads, are not limited only to the Cape fynbos, being also found in subtropical regions of South Africa.

Other species, *Apodytes dimidata*, *Maytenus heterophylla* and *Nuxia floribunda*, are widespread taxa found throughout Africa. The remaining two species, *Eucalyptus grandis* and *Eucalyptus camaldulensis* are exotics, introduced from Australia. The daily incoming pollen weight for the seven dominant pollen source plants indicated in Fig. 3.7 a,b,c,d,e,f. The 12 plant species contributed 69.94% of the total pollen weight and *Metalasia muricata* provides 30.8 % of the total pollen weight.

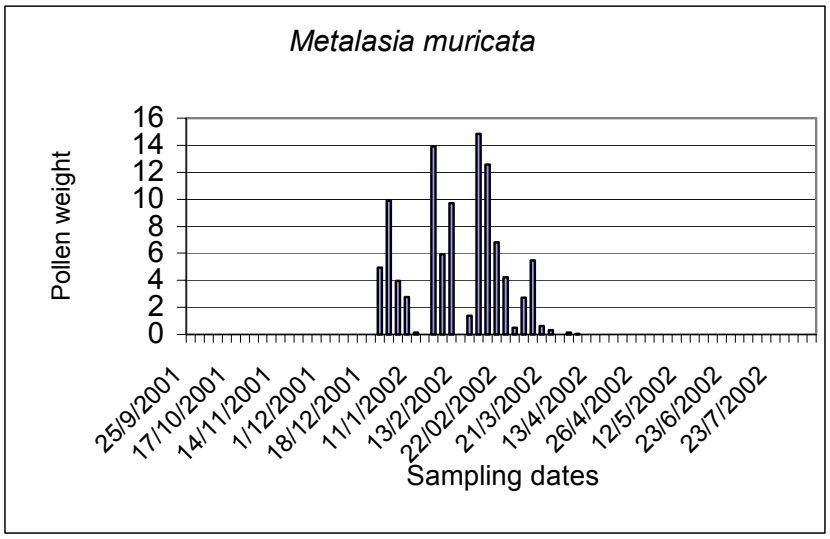

Figure 3.7a The total daily pollen weight of *Metalasia muricata*.

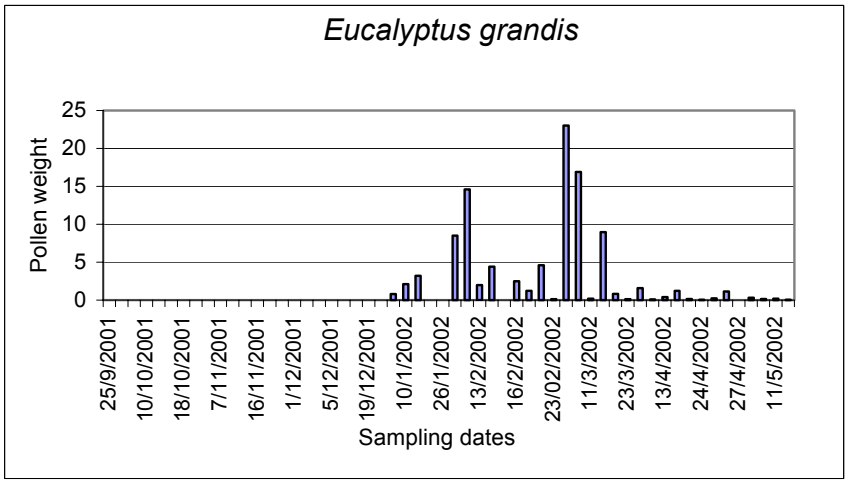

Figure 3.7b The total daily pollen weight of *Eucalyptus grandis*.

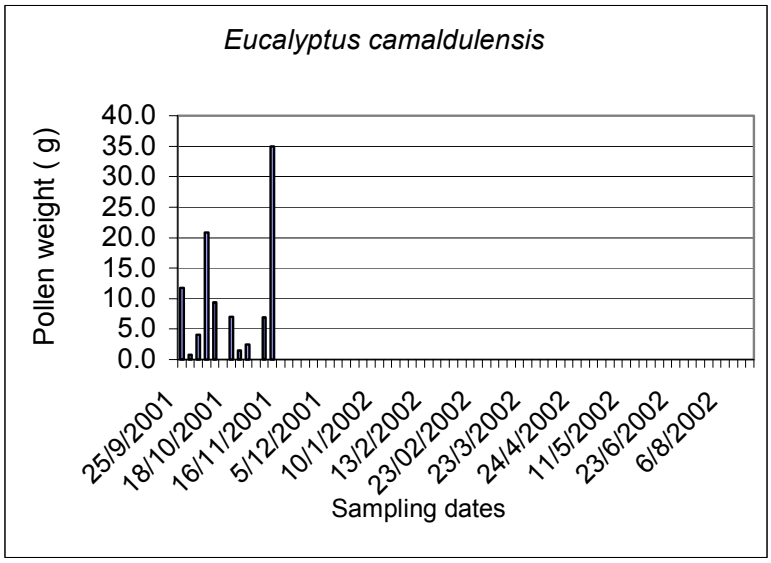

Figure 3.7c The total daily pollen weight of *Eucalyptus* camaldulensis.

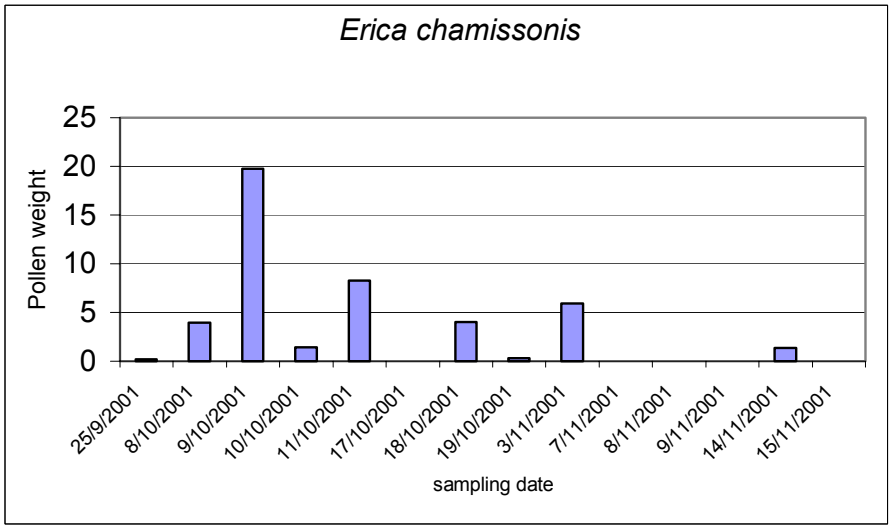

Figure 3.7d The total daily pollen weight of *Erica chamissonis*.

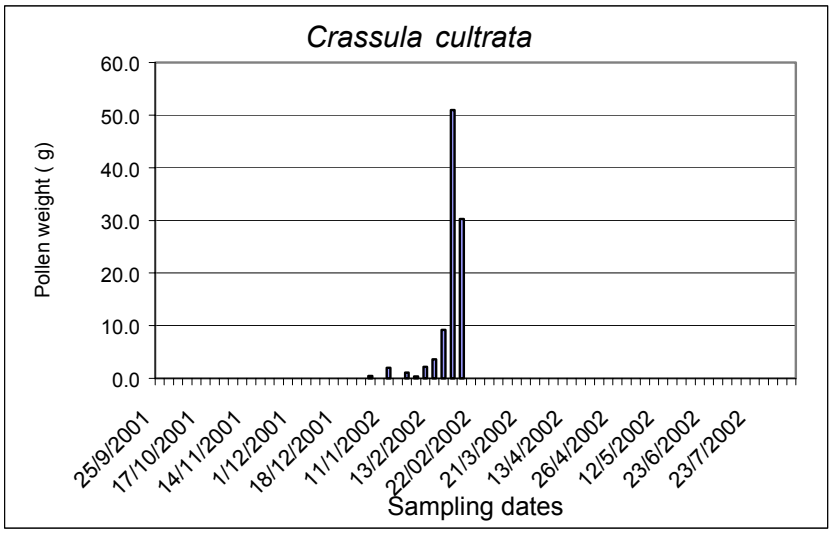

Figure 3.7e The total daily pollen weight of *Crassula cultrata*.

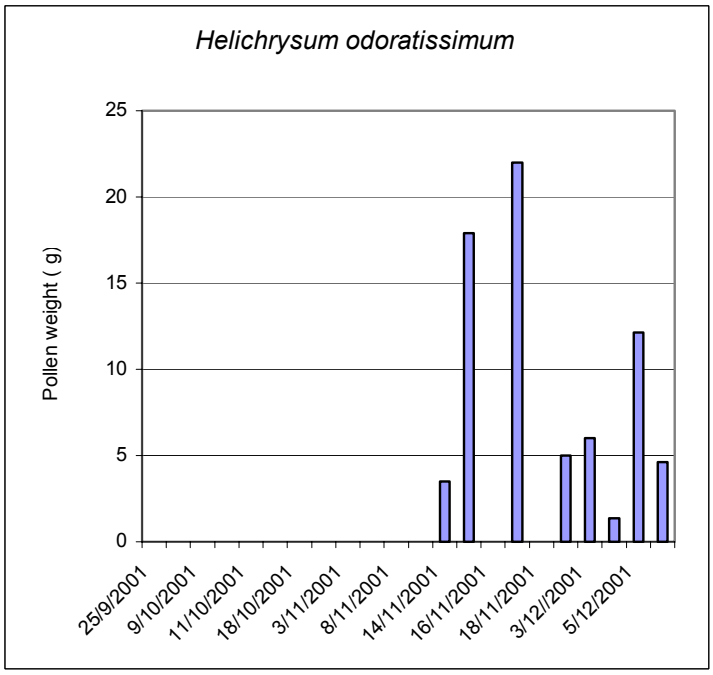

Figure 3.7f The total daily pollen weight of *Helichrysum odoratissimum*.

3.3.6 Protein determination

The protein determination of pollen source from plant species showed wide ranges of variation. The protein content ranged from 1.5 % to 12.7 %. Pollen from *Aloe ferox, Hypochoeris radicata*, *Eucalyptus grandis*, *Agathosma ovata*, *Gazania krebsiana*, *Chrysanthemoides monilifera*, *Cyperaceae* and *Apodytes dimidiata* was found to be high

in protein content yielding 12.7%, 7.9%, 7.3%, 6.3%, 5.5%, 5.05%, 4.9 %, and 4.86% of protein respectively (Fig. 3.8).

The protein content of identified plant species did not positively correlate with quantity of pollen collected. The plant species identified with dominant pollen weights had lower protein content (E.g. *Helichrysum odoratissimum* and *Eucalyptus camalduensis*), while plant species with lower pollen weights were found to be higher in protein content (*Aloe ferox, Hypochoeris radicata*, *Gazania krebsiana* and *Agathosma ovata*). Even though *Aloe ferox* provide high protein for honeybees but it is available only for certain periods. In terms of pollen weight, the high amount of pollen obtained from *Metalasia muricata* and its low protein content is compensated by high pollen yields, which can sustain the honeybee colony for a longer period of time (Fig 3.10)

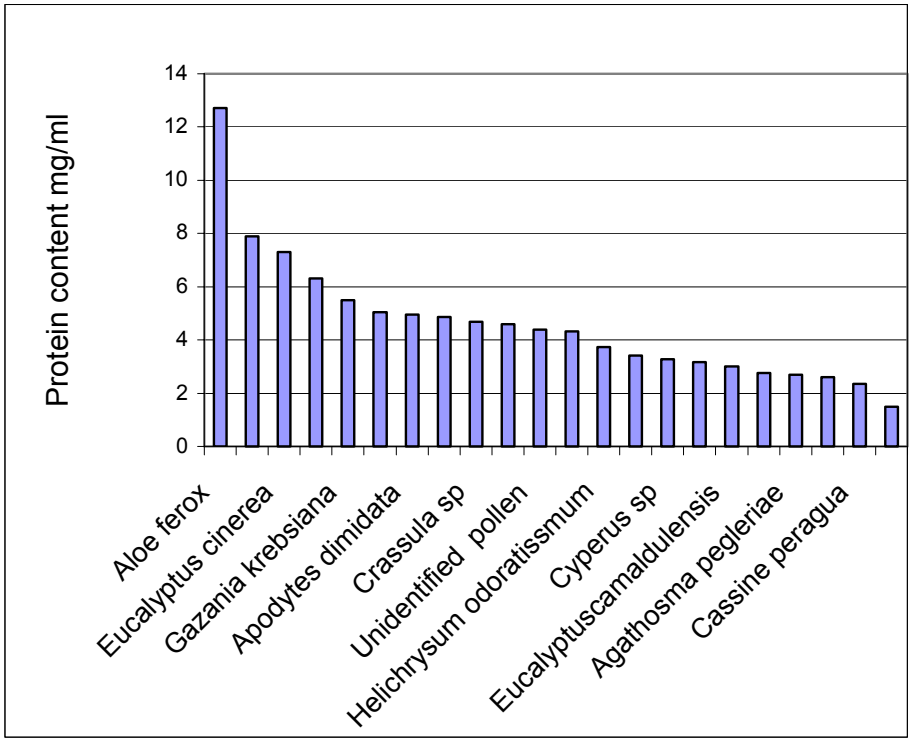

Figure 3.8 The protein content of identified pollen source plant species in descending order.

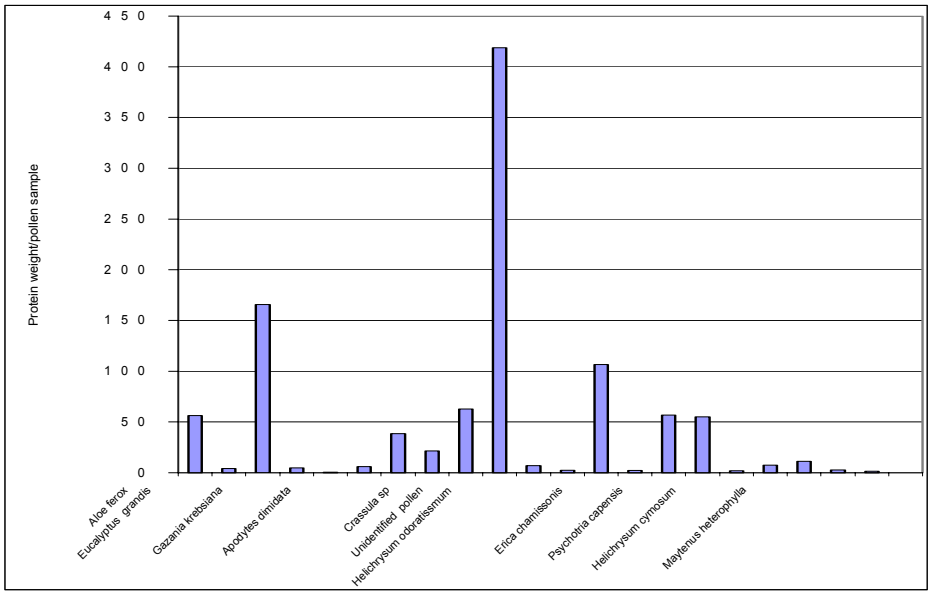

Figure 3.9 The Acquisition of protein from different pollen source plants.

3.3.7 Brood population

The brood rearing pattern of Cape honeybees is strongly and positively correlated with collected monthly pollen weight from different pollen source plants (Fig. 3.10). The correlation was highly significant (r = 0.73) and $P< 0.008$). Brood rearing activity is positively correlated with the peak flowering season of major plant species in the area, while the pollen flow depends on the availability of flowering plants.

The brood population of honeybees is highest during the spring and summer and lowest in autumn and winter. Both brood population and pollen weight declined gradually with the onset of autumn (March through May) and continued to decline through June, rising again in July to August (Fig 3.10).

It was also observed that there were fluctuations of both brood rearing patterns and pollen flow periods depending on weather conditions. Brood population and pollen flow reached a peak in November then dropped slightly in January due to excessive rainfall (Fig.3.9) Again both brood rearing and pollen collection rose until February due to the availability of *Eucalyptus grandis* and *Metalasia muricata* pollen, which were at peak flowering and provided large quantities of pollen.
The uninterrupted brood rearing could be attributed to the sequential flowering of plants out the year, contributing to the availability of pollen throughout the year.

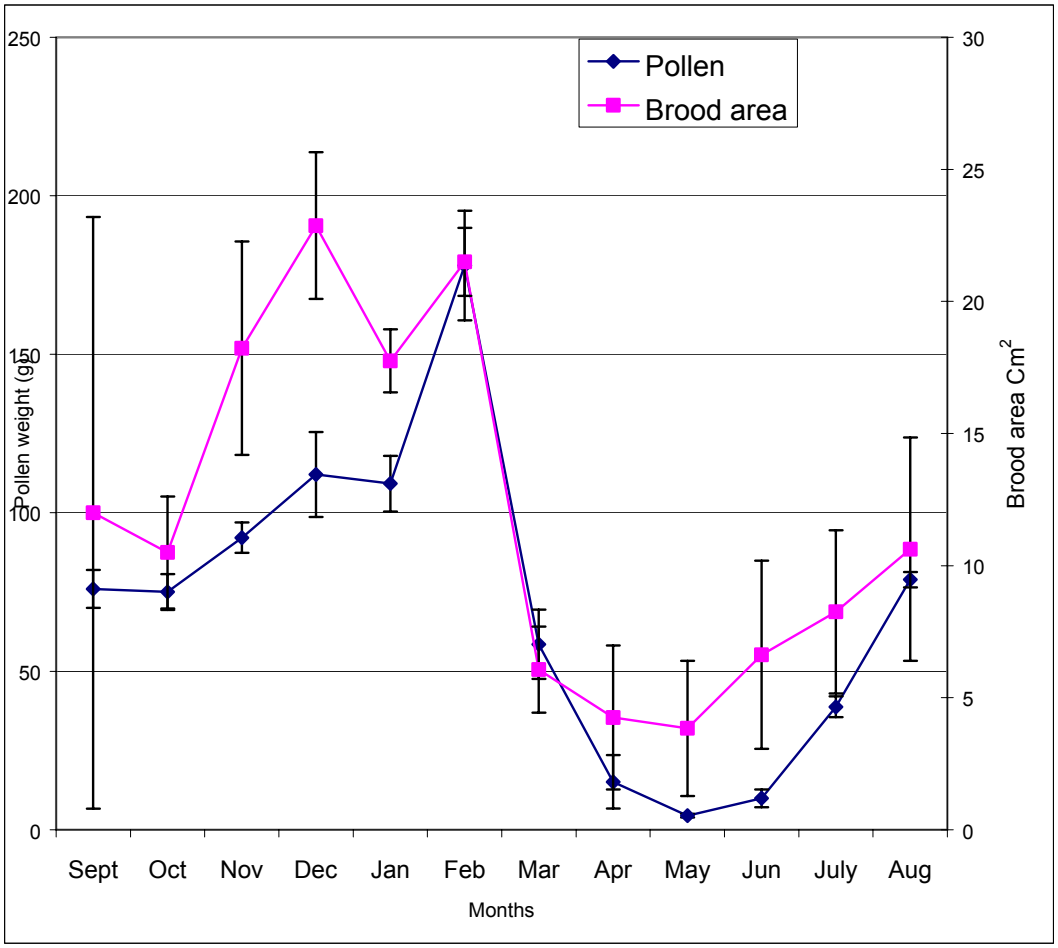

Figure 3.10 The relationship between monthly pollen weight and Cape honeybee brood area during the flowering seasons.

3.4 Discussion

3.4.1 Bee observation

The field observation of nectar and pollen source plant species identified 54 melliferous plant species (see Table 3.1), 21 plant species belong to the families Asteraceae, Fabaceae and Ericaceae. These plant families are the largest plant families in terms of species composition in the Cape Floral Kingdom (Goldblatt & Manning, 2000). The Asteraceae, Fabaceae and Ericaceae are represented by 23.6%, 9% and 7% respectively at the study site.

The number of pollen yielders in fynbos vegetation is greater than the other vegetation types. The reason may be dry and rocky nature of the soil in fynbos plants might tend to adapt to produce more pollen as a floral reward for different pollinators. The nectar and pollen analysis data suggest that pollen presenters may have better chances of being pollinated by pollen foragers than nectar yielding plants. Since pollen foragers move from one flower to another and the chance of pollen coming in contact with a stigma is very high this might increase the pollination efficiency of the plants. Similar observations were made by Free (1960) who showed that pollen foragers provide better pollination than nectar foragers. Flowers have a greater chance of receiving pollen on their stigma and being pollinated by pollen foragers than nectar foragers.

In the present study Cape honeybees were found spending more time on pollen collection per flower than nectar collection This is presumably because pollen collecting and packing is a more time consuming activity than nectar collection and hence more time is taken to fill the pollen loads in the pollen baskets of honeybees or they may be need more pollen. The amount of available food in the flower of a plant also may determine the time spent by honeybees for collecting nectar and pollen. It has been shown that bees forced to forage in resource poor habitats tend to spend more time on a flower than rich nectar and pollen source plant species. Therefore the time they spent on a flower in collecting nectar and pollen depends on the availability of the food resource. It is also known from pollination perspectives that honeybees moving rapidly between flowers with short time interval accomplish a high rate of pollination of the plants rather than staying relatively longer periods on a few flowers.

The high foraging density of honeybees in *Burchellia bubalina*, *Callistemon vimimalis*, *Agathosma ovata*, *Metalasia muricata* and *Erica chamissonis* might be because they produce large quantities of nectar and pollen and have conspicuous flowers. This is in agreement with the finding of Southwick *et al*. (1981) who demonstrated that bee visitation rates increased in flower patches with increasing number of nectar bearing flowers, nectar volume and sugar concentration.

The study showed that the foraging rate of honeybees decreased when the distance from the hives increased. Cape honeybees forage preferentially near their hives provided that resource richness, availability of pollen and nectar source plants permits. This was

supported by findings of Delaplane *et al*. (2000); Nunez (1982); Free (1970) and Norman (1992) who have shown that honeybees frequently visit and make use of resources available close to their hives. This implies that honeybees used for honey production or crop pollination should be placed near plant resources or near target crops that provide nectar and pollen.

The highest proportion of flowering plants was in spring (Sept–Nov) due to winter rainfall, which appeared at the end of August followed by warm temperature, both of which stimulate active growth of plants and flowering. The number of plant species flowering decreased in summer through autumn and winter. This could be due to high temperatures and low soil moisture in summer and cold temperatures in winter. What emerges from these observations is that flowering might be influenced by a number of physical factors, which cause conspicuous differences in blooming timing, duration and intensity. The sequential flowering pattern of plants in the study site explains the availability of the food resource for the pollinators throughout the year. Plants in the study area showed some variations in the duration of flowering, which in part has been correlated with soil fertility and soil moisture

3.4.2 Pollen collection

The identification of bee-collected pollen loads from pollen traps indicated not only the plants from which the honeybees had collected the pollen but it also showed the relative importance of each plant species as a pollen source for honeybees.

Of the 37 plant species identified, the bulk of pollen came from only a few plant species, that are abundant and provided greater quantities of pollen for foraging *Apis mellifera capensis*. These plant species are from different vegetation origins such as Fynbos, Shrubland Forest exotic and grassland. Fynbos shrubland are the most abundant pollen source plants in the area. The highest pollen yield came from a few species of plants such as *metalasia muricata, Erica chamissonis, Helichrysum odoratissmum*, and *Helichrysum anomalum*. This shows that the pollen yielding potential of the plants not only depend on number of plant species but also abundance of the plants in the area.

Honeybee foraging on plants favours those plant pollens, which are the most efficiently collected and richest in nutrients and energy. The daily variation of incoming pollen

weight among the plant species shows that availability and production of pollen is governed by different factors such as weather conditions see (Chapter Four).

The presence of the pollen loads from plant species of different vegetation types indicates that Cape honeybees are not restricted to foraging on fynbos. The pollen load identification of bee-visited plants shows that most of the plant species are widespread and originate from different phytogeographic regions. The identification of pollen loads of widespread taxa (*Apodytes dimidiata* and *Metalasia muricata*) and exotic plant species (*Eucalyptus grandis Eucalyptu camaludenis* and *Hakea sericea*) supports the alternative hypothesis that Cape honeybees are not restricted to Cape endemic plant species as pollen source plants and make use of the pollen available regardless of the plants of different phytogeogaphical origins. These findings support those of Hepburn & Radloff (1998) who found that *Apis mellifera* in general, and the Cape honeybee in particular exploit floral resources independent of vegetative form and community structure. The data in this paper also generally support the findings of Free (1963) and Heinrick (1975) that *Apis mellifera* is an essentially polytropic species whose community collectively visits a wide range of plant species that may offer rewards in terms of nectar and pollen throughout the seasons. Therefore honeybees collect pollen from different plant species in order to meet their nutritional requirements regardless of the vegetation types.

Pollen quality has a considerable potential influence on colony performance such as brood rearing, growth, and longevity, because protein content among floral species varies widely. The quality of pollen is measured on the basis of protein content. The protein content among the floral species varies widely (Shuel 1992). The protein determination of the pollen samples in our study clearly showed that the honeybee preference for protein does not relate to plants with high pollen yields. The pollen from plants with a high pollen yield was found to contain low protein levels and pollen from plants with smaller pollen yields was found to contain high protein levels. This finding is supported by Moezel, *et al*. (1987) who indicated that protein is the most important component of honeybee diets but honeybees do not appear to show special preference for plants with higher protein content with respect to their needs for pollen inside the hives. However, when pollen is in short supply, especially in winter and autumn the available pollen had high protein content. For example *Aloe ferox, Gazania Krebsiana* and *Hypochoeris radicata* flower during winter and autumn when there are no other plant species in flower. Thus the bees visiting these give an appearance of the preferential selection for

higher protein pollen but the available plants may force them to choose high protein pollen. During the spring flowering seasons, honeybees collect pollen from many plant species and the overall incoming protein level is enough to satisfy the colony requirements.

The positive correlation of monthly pollen weight and brood population revealed that honeybees require an influx of fresh pollen to raise their brood. This finding is in agreement with Haydak (1937), and Elton *et al*. (1992) who showed strong positive correlations between brood and pollen collection, as a colony cannot rear its brood without pollen. Moreover pollen affects the performance of the colony because pollen storage level reflects the potential for immediate growth in a colony through brood production.

The sequential flowering pattern of plant species in the fynbos indicates the availability of food resources throughout the year, facilitating continuous brood rearing in the colony cycle without interruption.

3.5. Conclusion

Direct field observations established that 54 nectar and pollen source plant species have been identified. The data collected indicated that these plant species provide a food source in the form of pollen and nectar.

The study also demonstrated the total number honeybee plants, the percentage of nectar producing plant species (26%) was smaller than the percentage of pollen producing plants (66%) and that only about 8% were both pollen and nectar producers. The reason for the low number of nectar producers as compared to pollen presenters, I believe, may be the limited soil moisture and infertile soils of the fynbos which can inhibit the nectar secretions of the plants therefore plants are adapted to produce more pollen as floral rewards for insect to enhance cross pollination.

The number of plant species flowering during the spring is greater than during the other seasons. This is the result of winter rainfall, which stimulates many plant species to bloom. However, plant species were found to flower in a sequential pattern, throughout the year, which is advantageous for the presentation of the food source throughout the

year. Honeybees tend to forage nearby their hives, as was supported by the finding that the density of bee population significantly declined the further one moved.

The analysis of pollen loads provides a picture of the plants of the area that are visited by honeybees. Those plants with a higher percentage of pollen weight in the pollen traps are plants that are more abundant in the area. While plants with a lower percentage of pollen weight in the traps were less commonly occurring plants. This was confirmed by the higher percentage of pollen collected from *Metalasia muricata, Helichrysum odoratissimum, Eucalyptus grandis*, *Eucalyptus camaldulensis*, *Erica chamissonis*, *Crassula cultrata*, *Acacia longifolia*, *Hakea sericea*, *Helichrysum anomalum* and *Helichrysum* spp*,* which are more abundant in the area.

The pollen loads collected by *Apis mellifera capensis* come from a wide range of plants not only from Cape endemic taxa, but also from other plants that are more widely distributed across South Africa and plants found in other parts of Africa and elsewhere in the world. This indicates that even though Cape honeybees are endemic to the Cape regions of South Africa, they are not restricted in their foraging behaviour (nectar and pollen collection) to Cape endemic species, but also collect pollen from various species from different phytogeographical origins. This disproves the hypothesis that Cape honeybees prefer Cape endemic plants.

The original expectation was that the plants from which honeybees collect vast or large amounts of pollen would always be those with higher or high protein levels. The data appears to reveal that the protein content of different plant species does not positively correlate with the quantity of pollen collected. The results show that the collected protein levels changes with the flowering seasons. During the spring flowering season, the incoming pollen loads from different plant species are greater and therefore overall there is an abundance of protein in the colony but during the winter when the incoming pollen loads from different plant species are small the overall protein level is smaller. The data appears to reveal that honeybees show a preference for plants with high protein content in winter, but this apparent preference for high protein may be simply function of availability. In pollen sample data the high protein content plants were *Aloe ferox*, *Gazania krebsiana* and *Hypochoeris radicata*, which flower in winter when there are not many plants in flower.

CHAPTER 4 THE EFFECT OF METEOROLOGICAL FACTORS ON POLLEN COLLECTION ACTIVITY OF *APIS MELLIFERA CAPENSIS*

4.1. Introduction

The main aim of this study is to investigate the effect of meteorological factors on pollen collection and flight activities of honeybees and the correlation of rainfall and flowering phenology of plants. The subsidiary aim of this study was to examine the effect of meteorological factors (Temperature, humidity and wind speed) on pollen collection and flowering phenology of bee plants.

The interactions of pollinators and plants are strongly influenced by meteorological conditions acting on both components. Important physical factors known to influence honeybee pollen collection are light, cloud cover, temperature, humidity and wind speed (Goodman 1994). The availability and timing of flowering is also influences the interaction.

Free (1970) in England found that pollen collection by honeybees is reduced in bad weather, compared to warm and sunny conditions, which are more suitable for honeybee foraging. Extreme temperatures and humidity have also been found to affect the pollen collection activity of honeybees.

Pollen collection and flight patterns change with changes of temperature in all races of honeybees. For some plant species, temperature and relative humidity are positively or negatively correlated with pollen collection. According to Atallah *et al*. (1988), the mean weekly temperature and relative humidity correlated positively with pollen collected from maize flowers but correlated negatively with grass pollen. Strong winds tend to slow the flight speed of bees and hence reduce the number of flights per day. Therefore, strong wind has the potential to influence the pollen collection activities of honeybees

4.2. Materials and methods

4.2.1 Weather records

Temperature, relative humidity and wind speed were recorded every day using the weather Monitor II data loggers (Davis Instruments Hayward California, USA). Climatic data were downloaded using the weather monitor programme Weather PCA link (Davis Instrument Company). Rainfall data were obtained from the weather station on farm that has been recorded for the last 10 years.

The influence of weather on flight activities was determined by counting the number of bees flying out of the hives for five minutes every 3 hours between from 06:00 and 8:00. This was done twice monthly.

4.2.2 Flowering phenology and weather conditions

Monthly flowering frequency was recorded and data were related to rainfall, temperature, and brood and pollen weight. Rainfall and temperature frequency distributions were plotted monthly, giving 12 classes. Means and standard deviations were calculated. The mean was subtracted from each monthly value and the remainder divided by the standard deviation. The end product was expressed as a positive or negative percentage value for each month. A multiple correlation analysis was conducted to determine the relationship between honeybee-collected pollen and environmental variables (temperature, relative humidity and wind speed).

4.3. Results

4.3.1 Rainfall and Temperature of the study site

The average annual rainfall of the farm is 930 mm. This was calculated over ten years. Rainfall at the study site was 30 % higher than in Grahamstown, the nearest town (personal communication). There are two periods of maximum rainfall, spring (October - December) and autumn (March-April). The minimum monthly temperature of the area ranges from 8°C to 14°C and the maximum temperature ranges 16°C to 25°C. The hottest months in the area being January, February and March and the coldest months May, June and July (Fig 4.1).

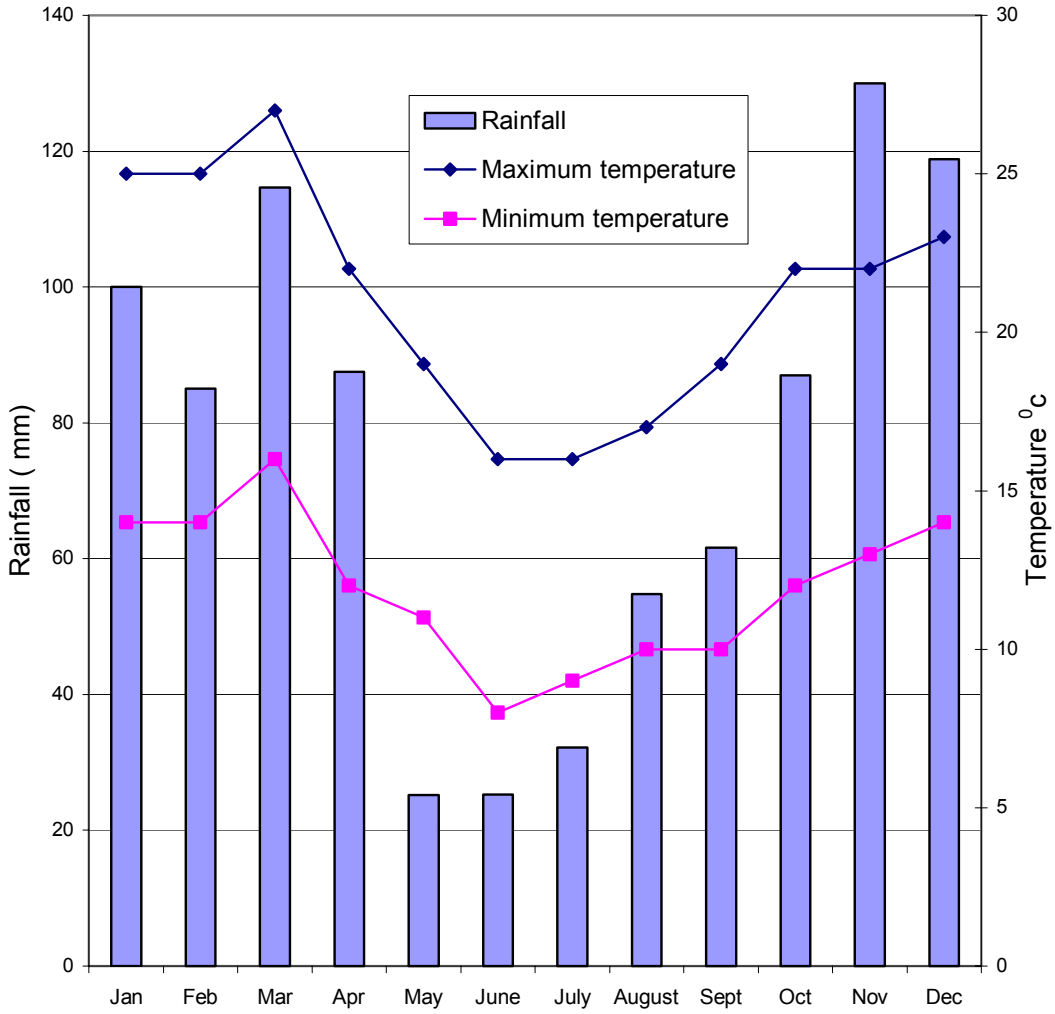

Figure 4.1 Climate data for Rivendell farm

4.3.2. Effect of weather on pollen collection activity

The correlation analysis shows that pollen weight collected by *Apis mellifera capensis* is significantly and positively correlated with maximum temperature (r = 0.52, P = 0.0048) and with minimum temperature (r = 0.46, P=0.018) and negatively correlated with hourly wind speed (r = -.40, P = 0.006). No significant correlation was found between daily pollen collection and relative humidity (r = -.096, *P* = 0.862), (Fig 4.2, 4.3 & 4.4). The significant negative correlation was found between wind speed and daily pollen collection (r = - 0.43 , p = 0.0032).

Maximum temperature ranges from 17 to 26° C and minimum temperature range from 14°C to19°C were found to be optimum temperatures for pollen collection (Fig. 4.2 & 4.3). Temperatures below 10° C and above 26° C reduced pollen collection

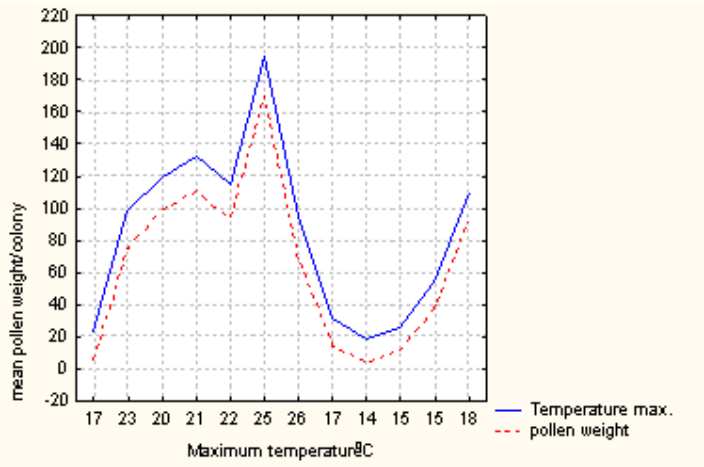

Figure 4.2 The correlation between pollen collection and maximum temperature.

Figure 4.3 The correlation between minimum temperature and pollen weight

Wind speeds up to 4 m/s did not affect pollen collection, but speeds above 5m/s were found to significantly reduce bee flight and subsequent collection of pollen (Fig. 4.4)

The combined effect of strong winds and low temperatures reduced the flight activity as honeybees were observed clustering in their hives during windy periods and low temperatures.

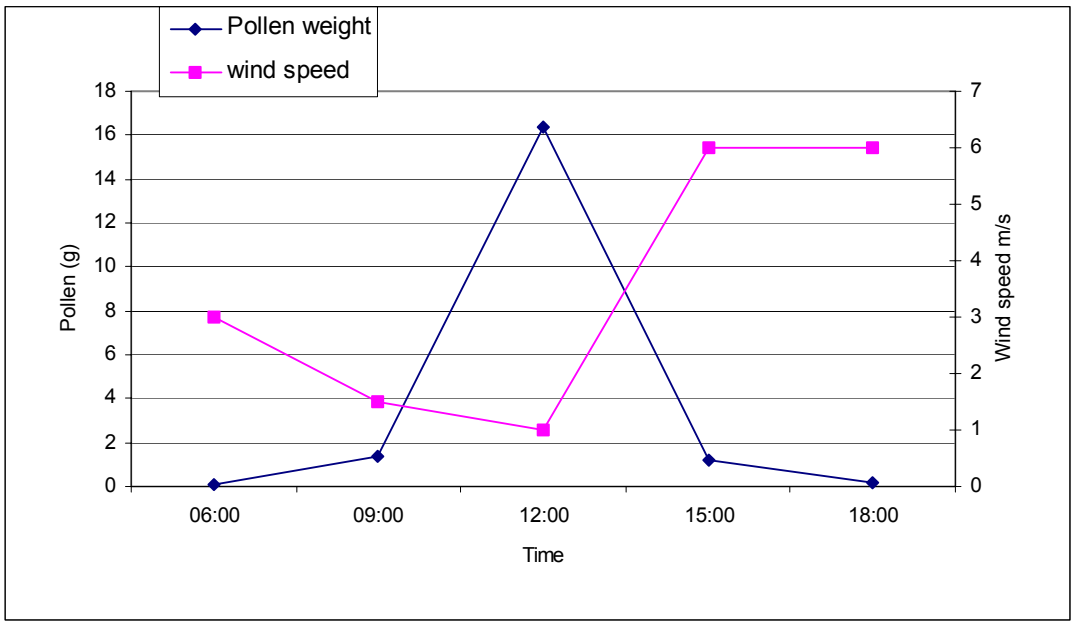

Figure 4.4 The correlation between hourly wind speed and pollen collection activity of Cape honeybees.

There was no significant correlation found between daily or monthly relative humidity and collected pollen. However, the influence of relative humidity became more pronounced on rainy days and when there was heavy cloud cover.

The effect of weather on daily pollen collection of bees on major pollen source plant species is shown in (Fig 4.5 a, b, c). It was observed that the combined effect of temperature, humidity and wind speed had more profound effects on pollen collection than single effect of each weather factor. For instance on March 24 and April 13–15, when there were cold temperatures and high relative humidity, there was reduced *Eucalyptus grandis* pollen weight collected. On 11 January, 13 February and 21- 23 March there was reduced pollen collection from *Metalasia muricata* (Fig. 4.6). Similar results were found for *Erica chamissonis*, *Eucalyptus camaldunesis*, *Helichrysum odoratissimum* and *Apodytes dimidiata* that combined effect of extreme temperature, relative humidity and wind speed has reduced the pollen collection.

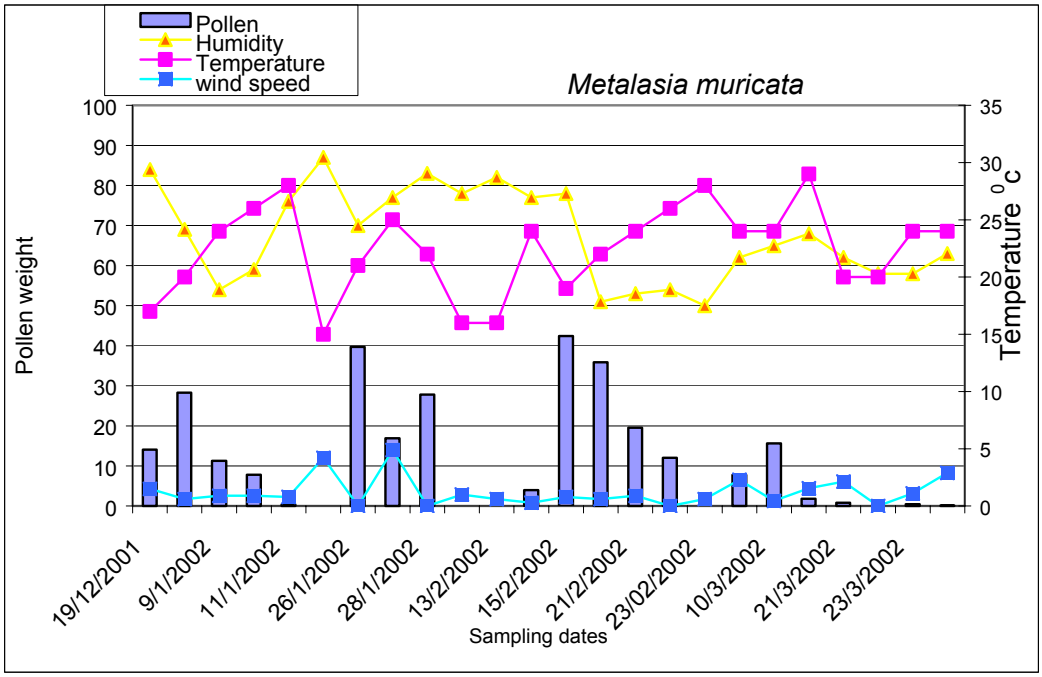

Figure 4.5a The effect of temperature, relative humidity and wind speed on daily pollen collection of, *Metalasia muricata*

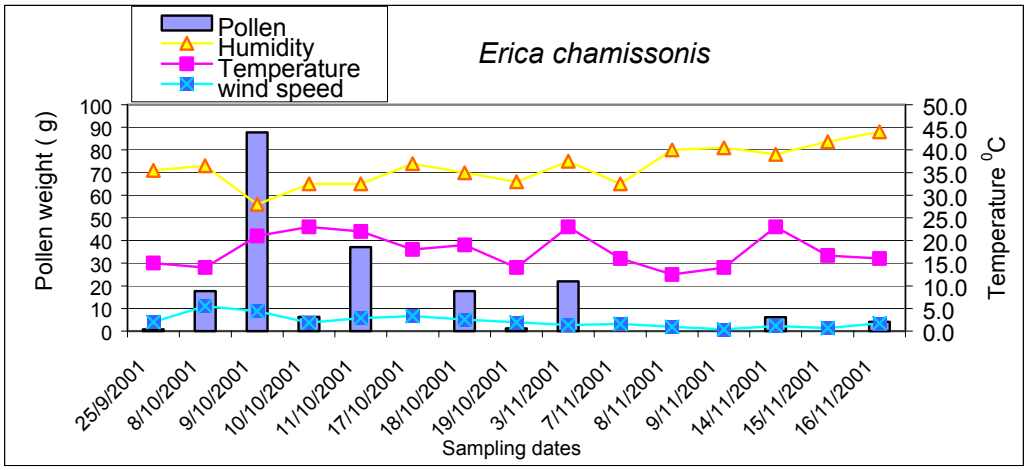

Figure 4.5b The effect of temperature, relative humidity and wind speed on daily pollen collection of *Erica chamissonis*.

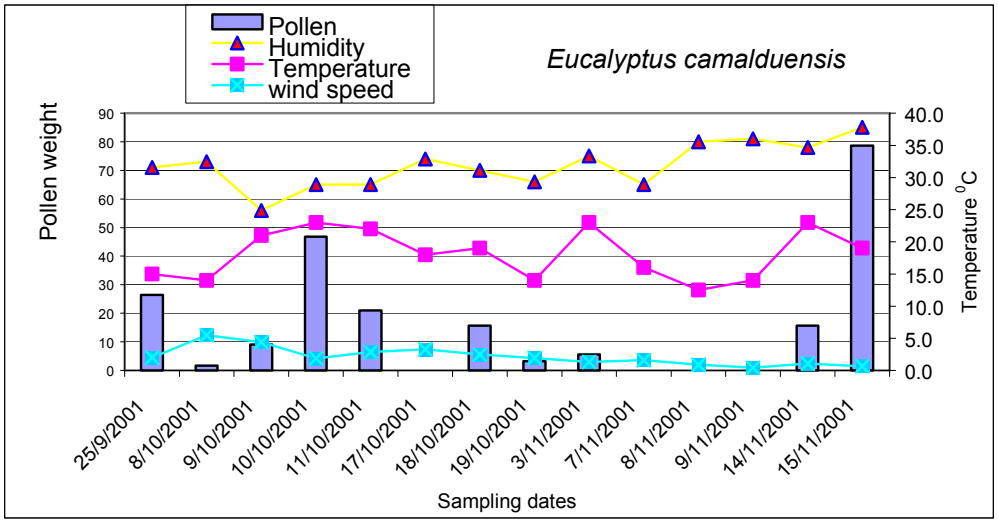

Figure 4.5c The effect of temperature, relative humidity and wind speed on daily pollen collection of *Eucalyptus camaldunesis*.

Peak flight activity of honeybees was recorded at temperatures of 24°C and 30°C and a slight decrease of flight activity was observed above these temperatures. Temperatures below 10°C decreased flight activity From field observations was noted that Cape honeybees fly from 05:00 to 19:00 in spring and summer, while, in autumn and winter, honeybees did not fly before 09:00 or after 17:00 because warm temperature and light intensity.

The regression analysis of temperature, humidity and wind speed on flight activity was analysed and temperature reveals strong positive correlation but humidity and wind speed has significant influence on flight activity of bees and the correlation is negative (Fig 4.6)

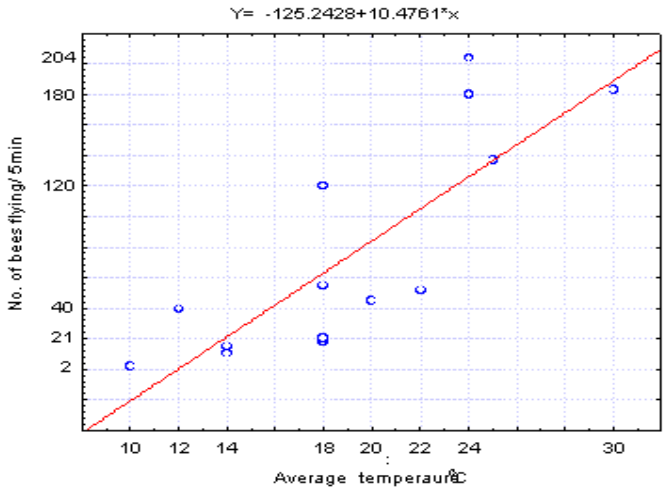

Figure 4.6a The correlation between flight activity and temperature

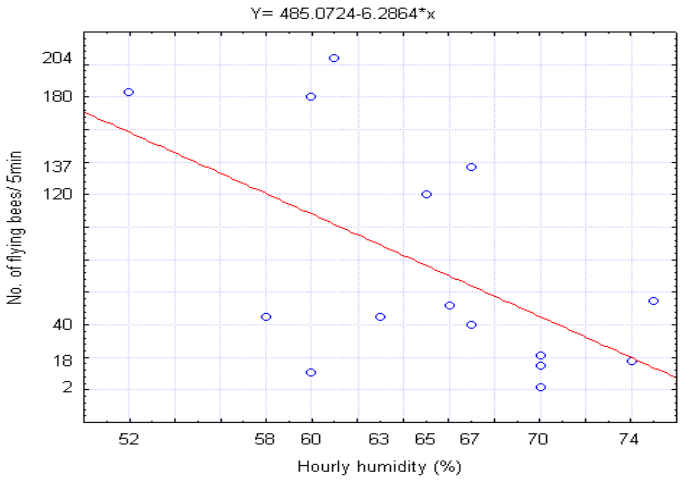

Figure 4.6b The correlation between flight activity humidity

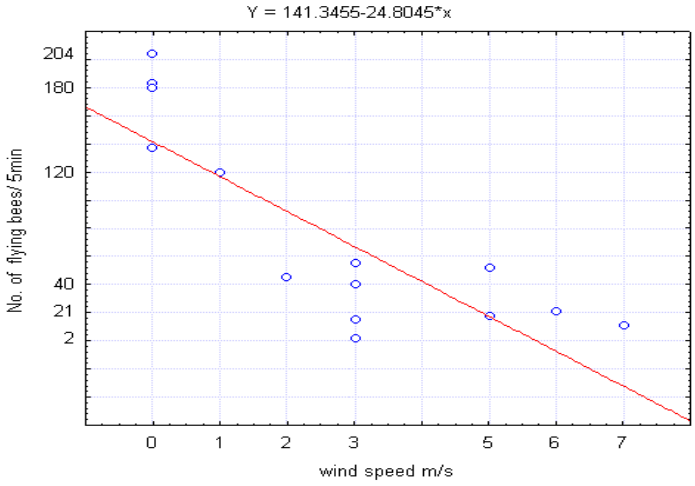

Figure 4.6c The correlation between flight activity and wind speed

4.3.3 Flowering intensity and rainfall

Flowering intensity is positively correlated with rainfall (r = 0.46, *P* = 0.009), but negatively correlated with temperature (r = 0.05, *P*= 0.53), which is shown, by plus and minus signs for each month in Table 5.2. In standardized phenological data, the plus sign indicates values above the mean and a positive correlation while a minus sign indicates that the measured variables are below the mean and that the correlation is negative. Flowering intensity, brood rearing, and pollen collection increased from August to January, peaking in September and November. Brood rearing and pollen collection continued until February. Flowering intensity decreased from late summer to winter (March to July).

Table 4.1 Standardised Phenological data for rainfall (mm), temperature (°C), flowering plant, brood (cm^2) and pollen weight (g) at Rivendell Farm in the Eastern Cape.

Parameters	Spring (Sept-Nov)			Summer (Dec- Feb)			Autumn (Mar–May)			Winter (June-Aug)			Mean ± Sd
	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	
Rainfall (mm)	22.5	70	153	120	38	-85	15	44.25	107.7	-105	-106	50	68 ± 40
Temperature (^{o}c)	-33	166.6	66.6	100	133.3	233.3	266.6	-33	-133	-100	-100	0	18 ± 3
Flowering bee plant (No.)	30	100	150	140	30	-60	-80	-100	140	-70	-40	20	21 ± 10
Total flowering (No)	74.2	111	162	125.7	54.2	-82	-94	-114	108	-82	-37	-2.85	51 ± 35
Brood (cm^2)	74.34	0	103.2	107.9.	97.8	152.17	-71.5	-97.8	103.7	-68.5	-39.68	-10.68	11 ± 6.9
Pollen (gm)	1.11	20.7	51.26	86.92	68	213.2	-11.3	-94.3	114.5	-104	-49.4	26.22	65 ± 53.

4.4 Discussion

4.4.1 Effect of weather on pollen collection

The significant positive correlation between pollen weight, maximum and minimum temperature (Fig. 4.2 & 4.3) reveals that pollen collection activity by honeybees is affected by the fluctuations of the ambient temperature.

Temperatures below 10° C and above 26° C are found to substantially reduce pollen collection. This could be due to by extreme temperatures influencing flight activity and the dehiscence of the anthers of the flowers. This result is in agreement with the findings of Ribbands (1953) and Percival (1955) who show that temperature appears to be an important factor affecting the amount of pollen collected. Lower temperatures may reduce pollen collection by retarding pollen ripening and delaying the dehiscence of anthers. Synge (1947) found a positive correlation between daily maximum air temperature and the number of loads of red clover pollen collected due to the acceleration of anther dehiscence at higher temperatures.

The non-significant correlation between relative humidity and pollen collection shows that the recorded humidity ranges were 52-78% are all suitable for pollen collection, a finding that agrees with Goodman (1994). Goodman stated that relative humidity independently or in isolation is not an important factor in bee activity or pollen collection. However in combination with variation in temperature are important for the ripening and dehiscence of anthers and therefore the availability of pollen for honeybees. This is supported by the combined effects of temperature and humidity on pollen collection from *Erica chamissonis*, *Eucalyptus camalduensis* and *Metalasia muricata*.

The climate of the Grahamstown area is mild the temperature and humidity is not very high as compared to those of tropical climates. Relative humidity has a strong influence on pollen collection in tropical conditions when temperature, followed by high evapo-transpiration, creates high relative humidity, thus preventing honeybees from flying and indirectly influencing the pollen collection.

The negative correlation between wind speed and pollen collection shows that wind speeds from 0-4m/s were found to be optimal for pollen collection and did not affect honeybee's activities. This result corresponds with the findings of Giovannini & Fonseca (1985) who found that wind speeds of 3-4 m/s did not restrict the flying activity of honeybees. However wind speeds of 5 m/s (18 Km/hr) or more did.

The positive correlation between temperature and flight activity of *Apis mellifera capensis* indicates that temperature is a limiting factor in the flight activity of honeybees. A decline in flight activity was observed for temperatures above 30°C and below 10° C. Temperatures above 30° C honeybees remained at their hive entrance presumably ventilating the hives to reduce the hive temperatures. At temperatures below 10°C the flight activity of Cape honeybees is severely reduced and honeybees clustered around the brood area to keep a constant brood temperature in the hives.

4.4.2 The relationship between flowering intensity, rainfall and. temperature

The significant positive correlation between flowering intensity and rainfall during spring flowering and the negative correlation between temperature and flowering intensity during the summer and winter both show that temperature and moisture conditions during the spring are favourable for plant growth, which stimulates flowering. During the winter, low temperatures possibly inhibit growth and flowering whereas the combined effects of high temperature and water deficiency during the summer inhibit plant growth and flowering. This finding is in agreement with Hepburn and Radloff (1995), who showed that rainfall ultimately stimulates flowering, hence intensity of flowering is directly related to intensity of rainfall. The flowering intensity of plants used by bees and total flowering decreases from the end of January to July.

4.4.3 The relationship between flowering intensity and brood production

There was also a close correspondence between monthly bee flowering intensity and that of brood production. Brood production across the months is directly correlated with increased flowering intensity through availability of pollen. Bee plant flowering and total flowering intensity decreased at the beginning of February. The brood and pollen production extended until the end of February due to intensive pollen flow from *Metalasia muricata* and *Eucalyptus grandis*, which provided an influx of pollen for brood production.

4.5 Conclusions

Temperature is a limiting factor in pollen collection activity of *Apis mellifera capensis*. The maximum temperature ranges between 17 – 26°C and minimum temperature 14–19°C were found to be optimum for pollen collection. Extreme temperatures below 10° C and above 26° C were found to reduce pollen collection.

Relative humidity has no a strong influence on the pollen collection activity of Cape honeybees in the study area since the climate of which is relatively mild. When temperature is mild there is less evapo-transpiration, which might explain the low humidity.

There is a significant positive correlation between rainfall and the flowering intensity of plants. Rainfall stimulates the flowering plant species, resulting in the availability of pollen for brood rearing and accounting of high brood population in spring.

CHAPTER 5 STUDY ON NECTAR OF MELLIFEROUS PLANT SPECIES

5.1. Introduction

In this study, an attempt was made to investigate nectar secretion times and the amount of nectar available for the pollinators during 24-hour periods and the influence of weather on nectar secretion of Cape honeybee visited plants.

Nectar is a product of photosynthesis derived from the phloem tissue (Faegeri & Van der Pijl 1979) and is available for reward of different pollinators for pollination. Honeybees collect nectar from flowering plants and is brought back to the hive and used in the nourishment of larvae and for preparing honey.

Percival (1946), Lack (1982) and Shuel (1992) have studied the nectar secretion and concentration of various plants and they found that the flowers of each species differ considerably in the amount and concentration of nectar they produce. Some plant species may produce large quantities of nectar to attract more pollinators or large pollinators such as birds or mammals while others produce little. The nectar secretion of plants varies with time of day and from plant to plant depending on environmental factors. Most of the diurnal plants produce nectar during the daytime, which is an adaptation to day visitors, while nocturnal plants secrete nectar during the night for the nocturnal visitors.

The frequencies of visitors for nectar collection have been strongly correlated with the quantity of sugar concentration and chemical constituents of nectar (Cruden *et al.,* 1983*).* Understanding nectar secretion rate and its influence on different visitors is crucial to the understanding of plant reproductive strategies and more specifically the understanding of effective pollination mechanisms for that specific plant (Faegri and Van der Pijl*,* 1979).

5.2. Materials and methods

Five plant species (*Burchellia bubaline*, *Leonotis leonurus*, *Callistemon citrinus*, *Syzygium cordatum* and *Psychotria capensis)* were selected based on their abundance near the study area and by virtue of being visited by Cape honeybees at the study site. There were two main reasons for including *Leonotis leonurus* in the list.even though it is primarly designed for bird pollination. a) on preliminary visit to the site it was observed that Cape honeybees observed collecting from *Leonotis leonurus* and despite it being primarly designed for bird pollination, b) thus if bee visited , the chance of transfer of pollen from anthers to stigma might be occurring (Confirmation of the possible pollination of the plants did not form part of the study). Observations were made hourly throughout 24 hour periods. The flowers of these plant species were labelled and bagged in nylon mesh before sampling, in order to prevent nectar removal by honeybees. Nectar was collected from 10 fully opened flowers at hourly intervals for 24-hour periods using 100 disposable 10µl capacity micropipettes purchased from the Laboratory and Scientific Equipment Company, Cape Town. The volume of nectar for each hour was measured from the length of the fluid column in the microcapillary tube. Hourly temperatures and relative humidity in the vicinity of the flowers were recorded using the Temperature Monitor II Data Logger.

5.3 Results: Nectar producing plant species

Data were analysed to show the peak time of nectar secretion of each plant species in order to predict the pollination syndrome of plants and their adaptation to different pollinators. Also the relations between the volume of nectar secreted, relative humidity and ambient temperature were also investigated. The plant species were *Callistemon viminalis*, *Burchellia bubalina, Leonotis leonurus*, *Psychotria capensis*, and *Syzygium cordatum*. The nectars of *Burchellia bubalina* and *Leonotis leonurus* are protected by a long tubular corolla and in both plants the nectar is concealed at the base of the style.

The peak time of nectar secretion of *Burchellia bubalina* was between 06h:00 and 14:00. Nectar production declined steadily over this period from a 6h:00 to 14h:00 high. After 14h:00 the volume of nectar produced decreased completely stopping at midnight and started to rise about 04:00 (Fig. 5.1). Honeybees were observed collecting nectar from

Burchellia bubalina by going deep into the tubular corolla. They came in contact with the anthers, which are located on the side of the corolla tube.

The pattern of nectar secretion in *Leonotis leonurus* was similar to that in *Burchellia bubalina*. The peak time of nectar secretion was between 06h:00 and 16h:00 (Fig. 6.1). After 16h:00 there was a steadily decline in volume until 11h:00 and it rise again to the next morning.
The corolla of *Leonotis leonurus* is very long and surrounded by the fused sepals. It can be reached by pricing the corolla tube. Thus nectar is only accessible to birds with long beaks, which can easily suck the nectar from deep in the corolla. Honeybees were observed collecting pollen from exerted anthers.

Callistemon vimalis has exposed nectar; it was secreted between 06h:00 and 11h:00. Secretion completely stopped around midday and rose again around 04:00 (Fig 5.1). Early in the morning birds were observed feeding on nectar from *Callistemon viminalis* and when the day was getting warmer, honeybees were observed collecting nectar.

The nectar of *Psychotria capensis*, and *Syzygium cordatum* is partially protected due to short corolla tubes. The nectar is accessible to honeybees as was confirmed by the many bees collecting nectar from the flowers.

The volume of nectar secreted from *Psychotria capensis* and *Syzygium cordatum* was less than to that of the other plant species studied. Nectar secretion declines towards evening in both plant species (Fig. 5.1a, b, c).

It was found that an individual plant species vary in the volume of nectar produced during a 24 hour period. The highest nectar yields were recorded for *Leonotis leonurus, Callistemon vimimalis*, and *Burchellia bubalina*. Much smaller volumes of nectar were recorded for *Psychotria capensis* and *Syzygium cordatum*. The mean nectar volumes with standard deviations for each plant species are shown (Fig. 5.2).

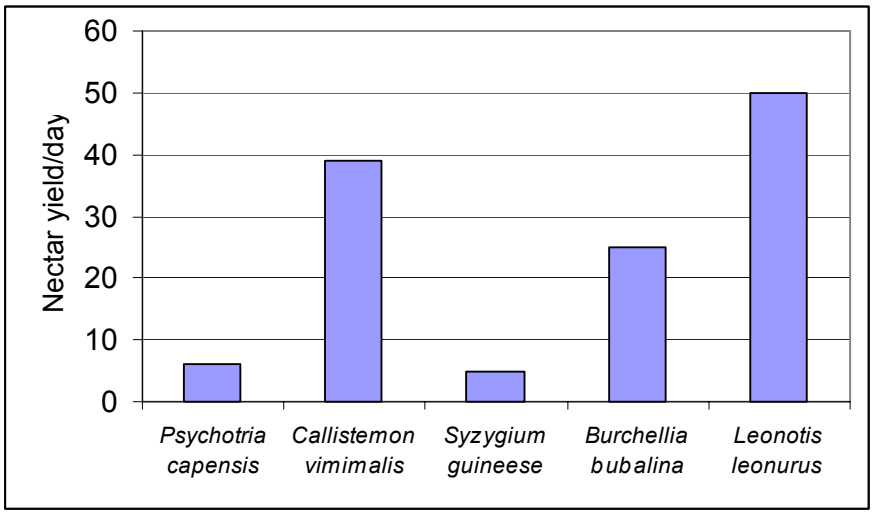

Figure 5.2 The volume of nectar yield measured for a 24 hours period for five selected plant species

Individual flowers of each plant species also differed considerably in the amount of nectar they produced as indicated by high standard deviation for the nectar samples from the different flowers. Some flowers took a long time to secrete nectar after it had been sampled.

A variation in available nectar was also observed for all sampled plant species depending on prevailing temperature and relative humidity. There was increase in the volume of nectar during the early morning with increasing relative humidity, which corresponded with a decrease in temperature.

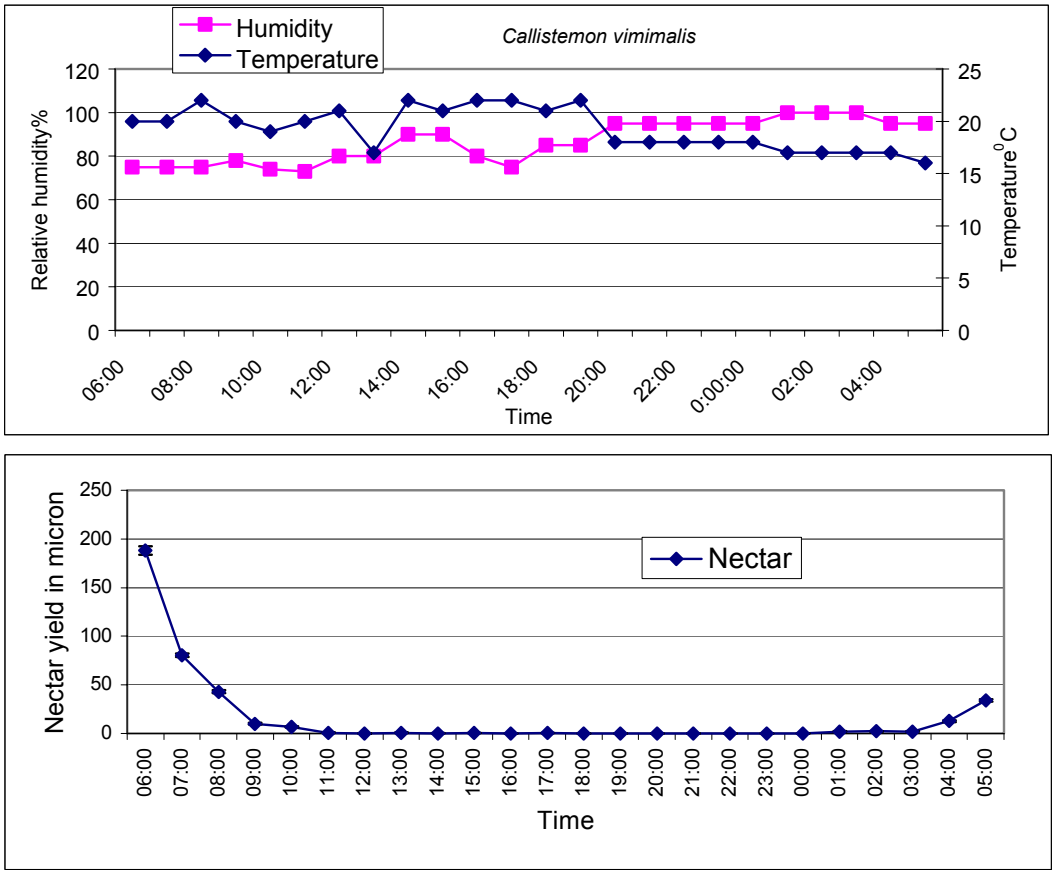

Figure 5.1a .The relationship between nectar volume and temperature and relative humidity at the different times of the day for *Callistemon viminalis*

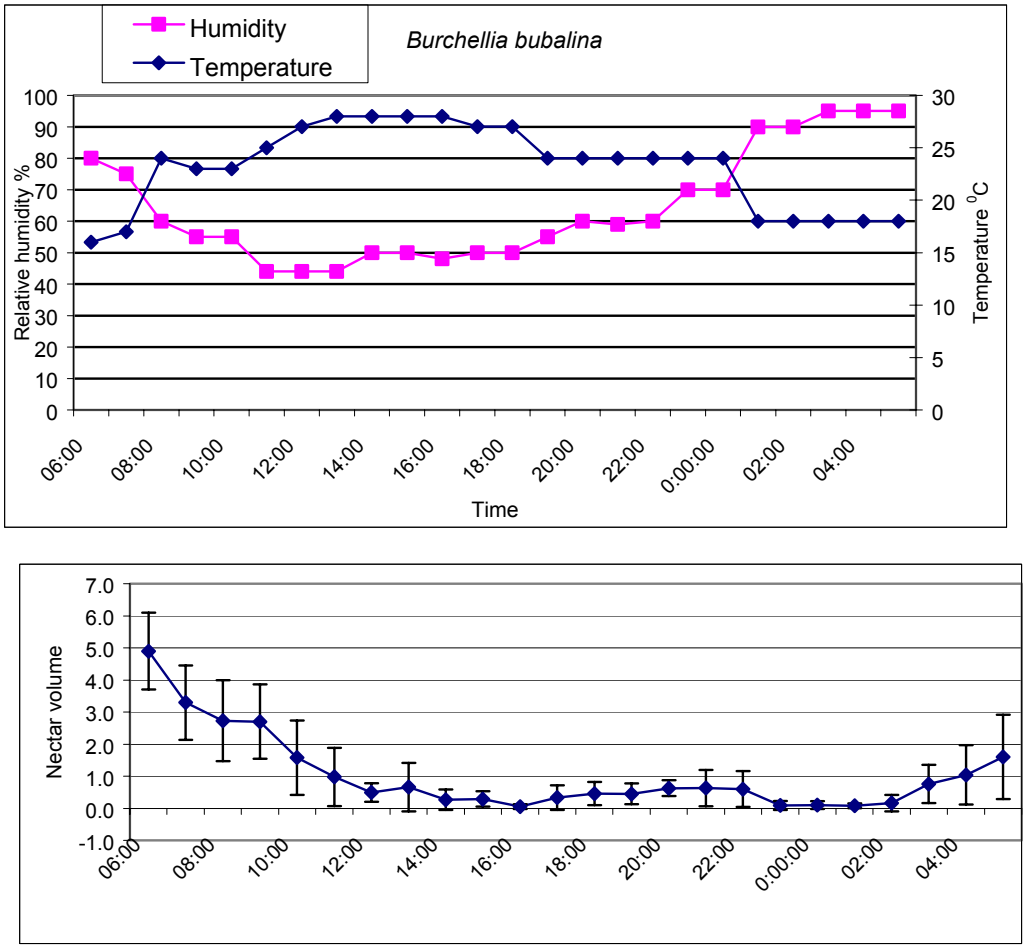

Figure 5.1b The relationship between nectar volume and temperature and relative humidity at the different times of the day for *Burchellia bubaline.*

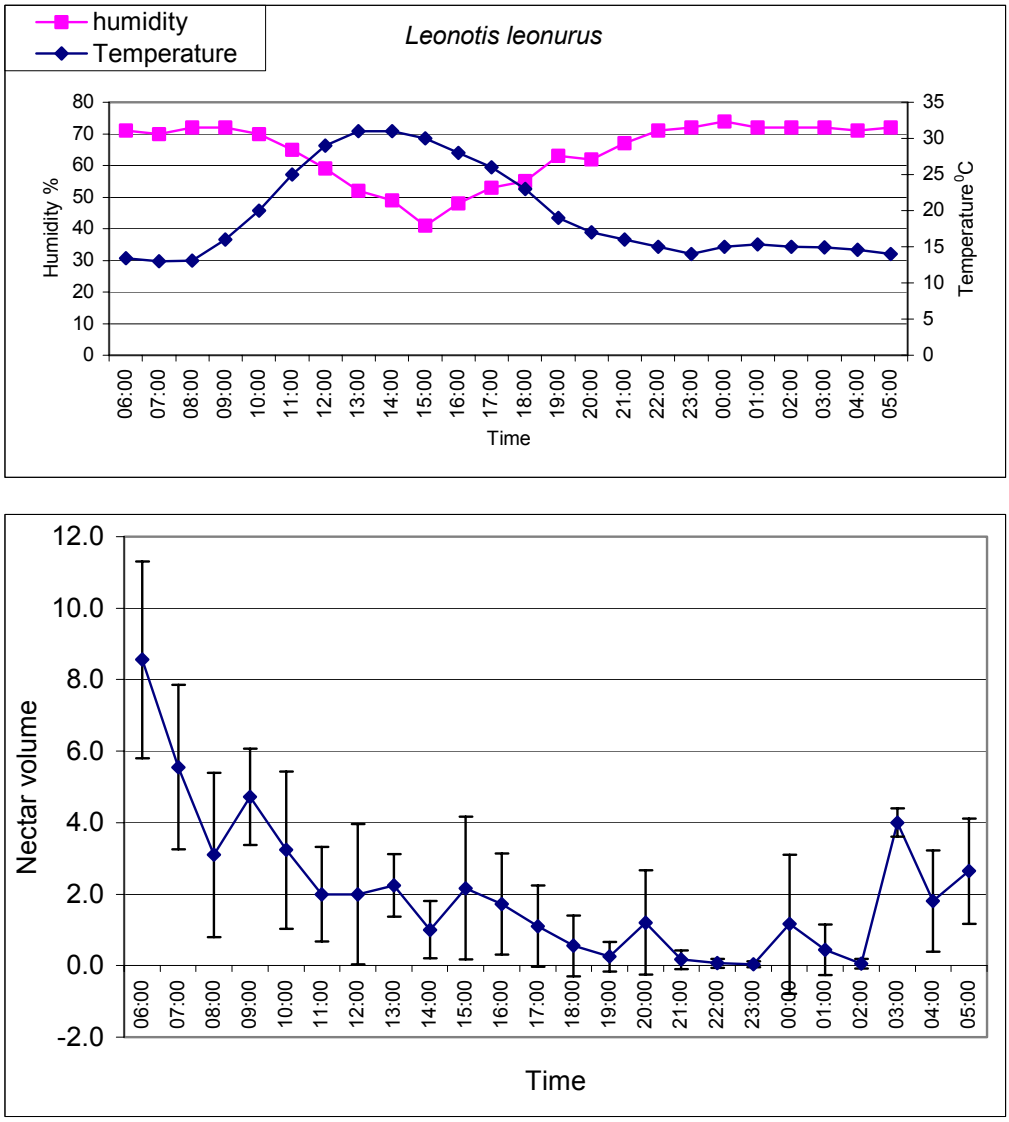

Figure 5.1c The relationship between nectar volume and temperature and relative humidity at the different times of the day for *Leonotis leonurus*.

5.4 Discussion

The data analysis from five nectar producing plants species shows that nectar volume varies with time of day due to a change of prevailing temperature, relative humidity and plants own biorhythms.

The peak of nectar secretion in tubular flowers of *Burchellia bubalina, Leonotis leonurus* and *Callistemon viminalis* in the morning. This together with colour and structure of the flowers suggests an adaptation to an avian pollination syndrome. This finding is in agreement with Rebelo (1987) who showed that extensive production of nectar by the plants in the morning is characteristics of the bird pollination syndrome.

The decreasing trend of the volume of nectar towards midday in almost all species of plants may be due to evaporation of water from the nectar. This is would result in increased sugar concentration of nectar.

The nectar secretion rates of *Callistemon viminalis*, *Burchellia bubalina,* and *Leonotis leonurus* decreased or completely ceased during the night due to an adaptation of plants to their legitimate pollinators. It is known that plants pollinated by diurnal visitors produce more nectar when their pollinators are active during the day time otherwise plants may lose their nectar to non-pollinating visitors, drying by evaporation or washed by the rain (Carpenter, 1983).

Dilute nectar in the morning does not attract or offer enough reward in terms of energy for foraging honeybees. Therefore honeybees were observed collecting nectar from *Callistemon viminalis* around 09h :00 because at this time of the day nectar may become concentrated due to evaporation of water from nectar. It would have been useful if nectar sugar concentrations were measured with a field refractometer which can provide the actual amount of sugar in the nectar at various times of the day, however due to the non availability an appropriate field refractometer, which can measure very small volumes of nectar sugar concentration, we decided not to measure nectar sugar concentration of the study pants.

Honeybees collected pollen from exerted anthers of *Leonotis leonurus* and both pollen and nectar from *Callistemon viminalis* during warm days suggesting that honeybees may

contribute in the transfer of pollen grains for effective pollination even though they are primarily adapted for bird pollination. This observation correlates with the finding of Coetzee and Giliome (1985), which showed that honeybees and beetles pollinate the brush flowers of bird-pollinated plants, even though birds appear to be legitimate pollinators.

Moreover Stiles (1981) has also shown that even though birds are legitimate pollinators of the particular plants, these plants maybe pollinated by different arrays of insect visitors.

The morphological adaptation of flowers: such as exposed nectar, short corolla tube and limited nectar production in flowers of *Psychotria capensis* and *Syzygium cordatum* revealed strong adaptation to insect pollination in general and suited to honeybee pollination. According to Faegri and Van der Pijl, (1979) and Percival, (1955) flowers with short corolla tubes and white and yellow flowers, which are within a range of colour vision of honeybees, are characteristics of the bee-pollinated flowers.

The exposed nectar in *Psychotria capensis* and *Syzygium cordatum* nectar have high concentrations of sugar due to evaporation of water, which coincides with energy demands of honeybees. It was stated by Free (1970) that plants with a lower nectar secretion have greater chances of being pollinated by honeybees because in order to satisfy their energy requirement, they visit many flowers in a single visit and move from flower to flower. This increases the probability of pollen transfer from anthers to receptive stigma, which results in effective pollination and subsequent seed and fruit production.

Individual flowers in each plant species in the area vary in the nectar they produce during the day. Percival (1946), Shuel (1955) and Luck, 1982.have investigated this observation. This variation in nectar secretion within a plant species has been caused by a number of factors such as age of the flower, edaphic conditions and environmental conditions such as temperature and humidity.

Several studies have shown that temperature and relative humidity may influence the

volume of nectar produced by affecting the sugar concentration of nectar (for example Corbet 1978; Shuel 1992). It is a known fact that the sugar concentration of nectar increases during the day as temperature increases together with a decrease in humidity. This change of nectar volume by the local microclimate may influence the foraging rate of honeybees as it has been observed that the numbers of honeybees visiting on *Burchellia bubalina* and *Callistemon viminalis,* are low in the early morning. This observation is in agreement with Corbet, (1978) who stated that changes in volume and composition of nectar caused by the change in microclimate around flowers might influence visiting rate of honeybees.

5.5. Conclusion

The data clearly indicate that the volume of available nectar in these flowers of the study plants is affected by the time of the day, prevailing temperature, and relative humidity around the flowers.

High early morning nectar volumes were recorded in *Callistemon viminalis*, *Burchellia bubalina* and *Leonotis leonurus*. However pollen collection from exerted anthers of *Leonotis leonurus* and the intensive visitation of honeybees on *Callistemon viminalis* at later times of the day, indicate that honeybees may contribute to the pollination of plants even though the plants are primarily adapted for bird pollination.

The morphological features of flowers, peak time of nectar secretion and smaller nectar production in both *Psychotria capensis* and *Syzygium cordatum* are an adaptation for insect pollination and our study confirmed honeybees visit the flower of these plants.

CHAPTER 6: GENERAL DISCUSSION AND CONCLUSION

6.1 The research questions and summary of findings

The principal aim of this study was to test the hypothesis that the Cape honeybees utilize as the primary source of nectar and pollen, plant species limited to the Cape region or fynbos vegetation, in a study area where fynbos vegetation mingles with forest and grassland communities. Based on the overall hypothesis the study also aimed:

- to distinguish the vegetation communities in the area
- to determine the beeplants in the flora
- to determine which plants are likely pollen and nectar sources
- to identify predominant pollen source plants
- to examine the effect of metrological factors on pollen and nectar collection of honeybees.

In summary the highlights of the main finding of the study are presented below.
Based on pollen load analysis and identification of bee-visited plants, it was established that the Cape honeybees are generalist pollinators and visit a wide range of plant species both Cape endemic and non-Cape endemic plant species to fulfil their nutritional requirements. Therefore we reject the hypothesis that Cape honeybees selectively forage fynbos species as a preferred source of nectar and pollen.

Through direct field observation of the melliferous plant species in the mosaic vegetation of Grassy fynbos, Forest, Bush and Grassland of the study area vegetation we identified 54 pollen and nectar producing plants. Pollen load analysis of the bee collected pollen established that a few plant species, namely *Metalasia muricata*, *Eucalyptus grandis*, *Eucalyptus camaludensis*, *Erica chamissonis*, *Helichrysum odoratissimum*, *Helichrysum anomalum Crassula cultrata*, *Acacia longifolia*, *Hakea sericea* and *Cyperaceae* were found to be the dominant pollen source plants in the area

Temperature and wind speed were found to be limiting factors for the flight and subsequent pollen collection activity of honeybees but humidity was not. A temperature range from 17° C to 26° C were found to be optimum for pollen collection. Wind speed up to 4m/s did not affect the pollen collection but speeds over 5m/s were found to significantly reduce pollen collection.

The volume of available nectar is affected by the time of day, the prevailing temperature and the humidity around the flowers. The high nectar volume available early in the morning together with colour and structure of *Burchellia bubalina*, *Callistemon viminalis* and *leonotis leonurus* and nectar and pollen collection from *Callistemon vimimalis* by honeybees may contribute to the pollination of these plants even though plants are designed for bird pollination.

The TWINSPAN analysis classified the vegetation data into seven plant communities. These communities represent different phytochorological groups such as Afromontane forest, Cape fynbos, Tongaland- Pondoland and Karro- Namib.

This research established that the Cape honeybees are important for the pollination service in fynbos vegetation and offer practical beekeeping opportunities in this environment. Cape honeybees are more adapted to the flora through many years of interactions with fynbos biome than other African honeybees and therefore conservation of these bees important for the survival and reproduction of fynbos plants.

6.2 Analysis of the flora and vegetation of the area

Due to the small area of the farm, the number of species recorded was remarkably high compared to other areas near Grahamstown, which is an indication of the richness and diversity of the flora. The numbers of Albany endemic plant species are low when compared to other endemic centres in South Africa. The reasons for the low level of endemism in the Eastern Cape have been already investigated by Gibbs Russell and Robinson (1981) who pointed out that the selection pressure of the climate of the Eastern Cape, which has acted to produce a flora of a generalised genotype."Secondly the close proximity of the farm to different phytochoria of different evolutionary histories ensures that somewhere there is a species already present that can fill any new niches by migration.

6.3 Distribution of Cape honeybees

The study found that *Apis mellifera capensis* collect pollen from a wide range of plant species not only from Cape endemic taxa but also plants from different phytochoria occurring in the Eastern Cape. Earlier studies conclude that Cape honeybees distribution

coincides with fynbos biome and is strongly linked with the richness of the flora of the Cape region. But the study has shown that distribution of Cape honeybees is poorly correlated with Cape endemic flora. The distribution of Cape honeybees should be examined not only from floral perspective but also along a number of dimensions includes climate, soil, geology and exceptional floral diversity and endemism. One might suggest that one potentially useful line of research would be to explore the correlation of distribution of Cape honeybees along the more than one of this dimension

6.4 Flowering Phenology

We also observed that the sequential flowering patterns and overlapping of flowering different plant species. in the study area. These observations also coincide with those of Bond and Goldblatt (1984) who observed that many plant species in the fynbos biome of South Africa flower sequentially in any one month of a year. This sequential pattern may be due to fact that the study area is found in a transition zone between winter and summer rainfall that causes the variations in flowering.

6.5 Protein analysis of pollen load

The protein content is a reliable and direct measure of pollen quality in the diet of honeybees and a measure of nutritional input for the colony. Honeybees do *not* show a special preference for high protein content when there is abundance of pollen in the area.

Pernal and Currie (2001) found that honeybees respond to protein levels in the colony by increasing the gross amount of pollen rather than specializing in collecting pollen with high protein content during the flowering period. Our data indicated, that during the spring flowering season. A preference for pollen with a high protein content was not in evidence, but, an apparent preference for high protein yielding plants was found during the winter when bee forage was scarce. This may have been due to the limited choice available to the bees, as the more limited flowers available during this season were predominantly those with high protein content.

6.6 Conclusion

The botanical inventory of the Rivendell Farm produced a checklist of plant species providing essential baseline for future work such as rehabilitation and conservation of the flora of the area.

A TWINSPAN classification of the vegetation data was established seven main vegetation communities such as Forest, Bush clumps, or Thicket, Wooded grassland, Grassland Grassy fynbos, Fynbos and shrubland. These vegetation communities were subsequently identified and described. The species richness and total number of species and life forms was determined for each of the vegetation communities.

Direct field observation and pollen sample collection identified 54 plant species visited by the Cape honeybees. The majority of these plant species grow in fynbos. 66% of the identified plants were pollen yielders while 7.4% were nectar yielders and 26.6 % both pollen and nectar yielder. The availability of large number of pollen yielding plants may be an adaptation to produce more pollen as a floral reward for cross-pollination.

The majority of plant species flower during the spring. This is due to the winter rainfall, which occurs in the middle of August. The winter rainfall stimulates plants to flower, reaching their peak in October and November. Relatively few, but abundant, plant species flower in the summer and then flowering declined from the beginning of March throughout the winter.

The pollen analysis from bee-collected pollen loads established that 10 plant species were found to be the predominant pollen source plants in the area. These *Metalasia muricata*, *Erica chamissonis*, *Helichrysum odoratissimum*, *Helichrysum anomalum*, *Crassula cultrata*, *Acacia longifolia*, *Eucalyptus grandis*, *Eucalyptus camaludlensis*, *Hakea sericea* and *Cyperaceae*.

Examination of the pollen loads revealed that Cape honeybees are generalist pollinators and visit a wide range of plant species from both Cape endemic species and non-Cape endemic species. This disproves the hypothesis that Cape honeybees selectively forage fynbos species as their preferred source of pollen and nectar.

The protein content of pollen is a reliable and direct measurement of the quality of the pollen in the diet of honeybees and the nutritional input to the colony. However the data revealed that the Cape honeybee does not show a special preference for the plants with high protein content.

There was a significant positive correlation between pollen collection and brood population. The data also indicated that pollen collection and brood rearing were high during the spring and continued throughout the summer. This finding dose not seems to coincide with earlier findings of Hepburn and Radloff (1998) who found that for the entire Cape region brood rearing and flowering intensity decreases throughout the summer, autumn and winter. This difference in observed brood rearing pattern and pollen flow period maybe explained by the climatic complexity and mosaic nature of the vegetation in the Eastern Cape.

Temperature and wind speed were found to be limiting factors in the flight and thus pollen collection activity of Cape honeybees. The optimum temperatures range, as 14° C to 26 ^{o}c. Temperatures below 10° C and above 26° C. were found to reduced the flight and pollen collection. Hourly wind speeds above 5m/s significantly reduced flight activity and subsequent pollen collection. Relative humidity as it is has no significant influence on pollen collection but the effect of humidity own became pronounced when rainfall and cold temperatures accompanied it.

An exact evaluation of the pollination value and efficiency of *Apis mellifera capensis* on different plant species in the area was not possible on the basis of the data obtained from this study alone. However the observed foraging behaviour of the bees on the different melliferous species strongly points to the importance of Cape honeybees as pollinators of plants in the study area.

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APPENDIX I: LIST OF PLANT SPECIES ENDEMIC TO THE ALBANY HOTSPOT

THE ALBANY ENDEMIC PLANT SPECIES HAS BEEN COLLECTED FROM THE AREA AND CHEKED WITH PUBLISHED CHECKLIST OF EAVARD (1987), COWLING (1982) AND (VANWYK AND SMITH 2001).

CRASSULACEAE

Cotyledon velutina Hook. f.;

Crassula mesembryanthoides (Haw.) Dietr. subsp. *mesembryanthoi*

Crassula muscosa L. var. *muscosa*; AAM 1291; rel. 128;

Crassula perfoliata L. var. *coccinea* (Sweet) Rowley ; AAM 1133

Crassula pellucida L.

Crassula multicava Lem.

MESEMBRYANTHMACEAE

Lampranthus spectabilis (Haw.) N. E. Br.

Delosperma ecklonis (Salm – Dyck) Schwant.

ASPHODELACEAE

Bulbine frutescens (L.) Willd.

SANTALACEAE

Rhoiacarpos capensis (Harv.) A.

ERICACEAE

Erica chamissonis Klotzsch ex Benth. var. chamissonis

Erica glumiflora Klotzsch ex Benth

ASTERACEAE

Oldenburgia grandis (Thunb.) Baill.

Gerbera cordata (Thunb.)

Helichrysum subglomeratum Less

Pteronia teretifolia (Thunb.) Fourc.

IRIDACEAE

Watsonia longifolia J.W. Mathews & L. Bol.

EUPHORBIACEAE

Euphorbia polygona Haw.

ORCHIDACEAE

Satyrium membranaceum Swartz.

THYMELACEAE

Struthiola argentea Lehm.

FABACEAE

Indigofera stenophylla Eckl. & Zeyh.

APPENDIX II: SPECIES CHECKLIST OF THE RIVENDELL FARM

This species list consists of specimen, which has been collected from the Rivendell farm. For all specimen collection number and releve number was given for each species. . All the specimens are housed in the Rhodes University Schnoland herbarium (GRA) The Checklist of plant species .The list of Albany endemic plant species is also presented.

CRASSULACEAE

Cotyledon velutina Hook. f.;

Crassula mesembryanthoides (Haw.) Dietr. subsp. *mesembryanthoides*

Crassula muscosa L. var. *muscosa*; AAM 1291; rel. 128;

Crassula perfoliata L. var. *coccinea* (Sweet) Rowley ; AAM 1133

Crassula pellucida L.

Crassula multicava Lem.

MESEMBRYANTHMACEAE

Lampranthus spectabilis (Haw.) N. E. Br.

Delosperma ecklonis (Salm – Dyck) Schwant.

ASPHODELACEAE

Bulbine frutescens (L.) Willd.

SANTALACEAE

Rhoiacarpos capensis (Harv.) A.

ERICACEAE

Erica chamissonis Klotzsch ex Benth. var. chamissonis

Erica glumiflora Klotzsch ex Benth

ASTERACEAE

Oldenburgia grandis (Thunb.) Baill.

Gerbera cordata (Thunb.)

Helichrysum subglomeratum Less

Pteronia teretifolia (Thunb.) Fourc.

IRIDACEAE

Watsonia longifolia J.W. Mathews & L. Bol.

EUPHORBIACEAE

Euphorbia polygona Haw.

ORCHIDACEAE

Satyrium membranaceum Swartz.

THYMELACEAE

Struthiola argentea Lehm.

FABACEAE

Indigofera stenophylla Eckl. & Zeyh.

LYCOPODIACEAE

Lycopodium clavatum L.; AAM 1388;

SCHIZAEACEAE

Mohria caffrorum (L.) Desv. var. *caffrorum* ; rel. 080; rel. 130; rel. 131; rel. 132; rel. 138; rel. 142; rel. 143;

Schizaea pectinata (L.) Swartz ; AAM 1127; rel. 042; rel. 045; rel. 049; rel. 061;

DENNSTAEDTIACEAE

Pteridium aquilinum (L.) Kuhn ; rel. 006; rel. 040;

ADIANTACEAE

Adiantum vogelii Keys ; rel. 117; rel. 118; rel. 119; rel. 130; rel. 131; rel. 135;

Cheilanthes hirta Swartz ; rel. 013; rel. 020; rel. 021; rel. 023; rel. 044;

Pellaea calomelanos (Swartz) Link var. *calomelanos* ; AAM 1076; rel. 002; rel. 137; rel. 138; rel. 140; rel. 141; rel. 142;

Pellaea viridis (Forssk.) Prantl var. *viridis*; AAM 1035; rel. 004;

DAVALLIACEAE

Nephrolepis undulata (Sw.) J.Sm. ; AAM 1431; rel. 007; rel. 008;

ASPIDIACEAE

Dryopteris athamantica (Kuntze) Kuntze ; rel. 008; rel. 010; rel. 011;

Rumohra adiantiformis (G. Forst.) Ching; AAM 1084;

HEDWIGIACEAE

Rhacocarpus purpurascens (Brid.) Par.; AAM 1096;

THUIDIACEAE

Drimia abietina (Hedw.) Fleisch. ; AAM 1335;

PODOCARPACEAE

Podocarpus falcatus (Thunb.) R. Br. ex Mirb. ; AAM 1357; rel. 001; rel. 002; rel. 003; rel. 005; rel. 006; rel. 007; rel. 008; rel. 010; rel. 011;

PINACEAE

Pinus patula Schlechtd. & Cham. ; rel. 154;

CYPERACEAE

Ascolepis capensis (Kunth) Ridley ; AAM 1209; AAM 1399;

Cyperus albostriatus Schrad. ; AAM 1087; rel. 001; rel. 002; rel. 004; rel. 007; rel. 008; rel. 009; rel. 011;

Cyperus tenellus L. f. var. *tenellus*; AAM 1187; rel. 006; rel. 050; rel. 084; rel. 085; rel. 087;

Pycreus polystachyos (Rottb.) Beauv. var. *polystachyos* ; AAM 1333; AAM 1334;

Cladium mariscus (L.) Pohl subsp. jamaicense ; AAM 1151;

Tetraria cf. cuspidata (Rottb.) C.B. Cl.; AAM 1114; rel. 035; rel. 036;

Carex zuluensis C.B. Cl. ; AAM 1086; rel. 007; rel. 009; rel. 103;

RESTIONACEAE

Elegia stipularis Mast. ; AAM 1323; AAM 1367; rel. 031; rel. 032; rel. 034; rel. 037; rel. 045; rel. 046; rel. 051; rel. 055; rel. 056; rel. 057; rel. 058; rel. 059; rel. 060; rel. 091; rel. 092; rel. 093; rel. 094; rel. 095; rel. 102; rel. 104; rel. 105; rel. 106; rel. 107; rel. 108;

Restio filicaulis Pillans; rel. 021; rel. 022; rel. 023; rel. 024; rel. 027; rel. 028; rel. 029; rel. 033; rel. 035; rel. 036; rel. 037; rel. 038; rel. 042; rel. 043; rel. 044; rel. 047; rel. 049; rel. 050; rel. 052; rel. 053; rel. 057; rel. 060; rel. 061; rel. 063; rel. 065; rel. 067; rel. 068; rel. 069; rel. 070; rel. 071; rel. 072; rel. 073; rel. 074; rel. 075; rel. 076; rel. 079; rel. 080; rel. 081; rel. 083; rel. 086; rel. 090; rel. 091; rel. 092; rel. 093; rel. 094; rel. 097; rel. 098; rel. 100; rel. 106; rel. 110; rel. 116; rel. 117; rel. 118; rel. 119; rel. 120; rel. 125; rel. 126; rel. 127; rel. 128; rel. 130; rel. 131;

Restio filiformis Poir. ; AAM 1148;

Rhodocoma capensis Nees ex Steud. ; PP 5288; PP 5289; AAM 1107; AAM 1142; rel. 025; rel. 028; rel. 029; rel. 030; rel. 031; rel. 032; rel. 036; rel. 038; rel. 045; rel. 049; rel. 051; rel. 054; rel. 055; rel. 056; rel. 057; rel. 059; rel. 060; rel. 066; rel. 067; rel. 070; rel. 071; rel. 073; rel. 074; rel. 075; rel. 076; rel. 080; rel. 081; rel. 083; rel. 090; rel. 091; rel. 092; rel. 093; rel. 100; rel. 105; rel. 106; rel. 107; rel. 108; rel. 109; rel. 110; rel. 116; rel. 125; rel. 126; rel. 130; rel. 132;

COMMELINACEAE

Commelina africana L. var. *africana* ; rel. 001; rel. 010; rel. 014; rel. 027; rel. 029; rel. 058; rel. 117; rel. 146;

Commelina diffusa Burm. f.; AAM 1237; rel. 042; rel. 043;

JUNCACEAE

Juncus lomatophyllus Spreng. ; AAM 1023; AAM 1243; rel. 083;

ASPHODELACEAE

Bulbine capitata V. Poelln. ; AAM 1255; rel. 120; rel. 123;

Aloe ciliaris Haw. var. *ciliaris* ; rel. 001; rel. 032;

Aloe ecklonis Salm-Dyck ; AAM 1404; AAM 1403; rel. 058; rel. 073; rel. 117; rel. 152;

HYACINTHACEAE

Scilla firmifolia Bak. ; AAM 1341; AAM 1395;

Ornithogalum tenuifolium Delaroche subsp. *tenuifolium*; AAM 1257;

Ledebouria cooperi (Hook. f.) Jessop; AAM 1353;

DRACAENACEAE

Dracaena aletriformis (Haw.) Bos; AAM 1095; rel. 001; rel. 003; rel. 004; rel. 005; rel. 006; rel. 007; rel. 008; rel. 010;

ASPARAGACEAE

Asparagus asparagoides W.Wight ; rel. 006; rel. 007; rel. 009; rel. 010; rel. 011;

Asparagus plumosus Baker ;

Asparagus wildermanii Weim.; AAM 1272;

Asparagus densiflora Kunth; AAM 1405; rel. 143;

LUZURIAGACEAE

Behnia reticulata (Thunb.) Didr.; AAM 1092;

AMARYLLIDACEAE

Haemanthus albiflos Jacq. ; AAM 1432;

HYPOXIDACEAE

Hypoxis hemerocallidea Fisch. & C.A. Mey. ; AAM 1247; rel. 026; rel. 039; rel. 077; rel. 083; rel. 084; rel. 100;

Hypoxis villosa L. f. var. *obliqua* (Jacq.) Bak. ; AAM 1162; rel. 012; rel. 013; rel. 014; rel. 019; rel. 027; rel. 029; rel. 030; rel. 031; rel. 034; rel. 036; rel. 047; rel. 048; rel. 051; rel. 054; rel. 056; rel. 058; rel. 059; rel. 061; rel. 069; rel. 071; rel. 072; rel. 073; rel. 074; rel. 077; rel. 082; rel. 096; rel. 101; rel. 107; rel. 108; rel. 109; rel. 153;

IRIDACEAE

Moraea polystachya (Thunb.) Ker-Gawl. ; AAM 1046; rel. 017; rel. 018; rel. 019; rel. 054;

Dietes bicolor (Steud.) Sweet ex Klatt; rel. 002; rel. 003; rel. 005;

Dietes iridioides (L.) Sweet ex Klatt ; AAM 1083;

Bobartia gracilis Bak. ; rel. 022; rel. 023; rel. 029; rel. 033; rel. 035; rel. 037; rel. 038; rel. 040; rel. 042; rel. 043; rel. 047; rel. 048; rel. 050; rel. 070; rel. 071; rel. 074; rel. 076;

rel. 078; rel. 079; rel. 080; rel. 081; rel. 082; rel. 083; rel. 085; rel. 088; rel. 094; rel. 095; rel. 117; rel. 139; rel. 140; rel. 160;

Aristea anceps Eckl. ex Klatt ; AAM 1164; rel. 020; rel. 029; rel. 032; rel. 038; rel. 065; rel. 078; rel. 080; rel. 082; rel. 124; rel. 127; rel. 128; rel. 129; rel. 130;

Hesperantha candida Bak. ; AAM 1143;

Dierama pendulum (L. f.) Bak. ; AAM 1032; rel. 007; rel. 055;

Anapalina caffra (Ker-Gawl. ex Bak.) G.J. Lewis; AAM 1109;

Watsonia longifolia J.W. Mathews & L. Bol.; AAM 1169; rel. 026; rel. 083;

ORCHIDACEAE

Holothrix burchellii (Lindl.) Reichb. f.: Helen James (1993);;

Holothrix parviflora (Lindl.) Reichb. f.: Helen James(1993) ;;

Habenaria anguiceps H. Bol. :Helen James;;(1993)

Habenaria arenaria Lindl. : Helen James;

Habenaria falcicornis (Burch. ex Lindl.) H. Bol.: Helen James (1993) ;;

Habenaria laevigata Lindl. : Helen James (1993);

Bonatea speciosa (L. f.) Willd. Var. *speciosa*: Helen James (1993);

Satyrium acuminatum Lindl. : Helen James; (1993)

Satyrium longicolle Lindl. : Helen James (1993);

Satyrium membranaceum Swartz: Helen James;;(1993)

Satyrium parviflorum Swartz: Helen James;; (1993)

Brownleea coerulea Harv. Ex Lindl. : Helen James (1993);

Brownleea recurvata Sond. : rel. 006;

Disa aconitoides Sond. : Helen James (1993);

Disa polygonoides Lindl. : Helen James (1993);

Disa racemosa L. f.: Helen James (1993);

Disa sagittalis (L. f.) Swartz: Helen James (1993);

Monadenia bracteata (Swartz) Dur. & Schinz: Helen James (1993);

Monadenia brevicornis Lindl. : Helen James (1993);;

Disperis micrantha Lindl. : Helen James;;(1993)

Disperis micrantha Lindl. : Helen James;; (1993)

Ceratandra grandiflora Lindl. : Helen James (1993);;

Polystachya pubescens Reichb. f.; Helen James (1993)

Eulophia aculeata (L. f.) Spreng. subsp. *aculeata* :Helen James(1993);;

Eulophia foliosa (Lindl.) H. Bol. :);; AAM 1309;

Eulophia parviflora (Lindl.) A.V. Hall: Helen James;(1993);

Eulophia tenella Reichb. f.: Helen James;;(1993)

Eulophia clavicornis Lindl. var. *inaequalis* (Schltr.) A.V. Hall :Helen James(1993);;

PIPERACEAE

Peperomia retusa (L. f.) A. Dietr. var. *bachmannii* (; AAM 1101; rel. 010;

MYRICACEAE

Myrica brevifolia E. Mey. ex C. DC. ; AAM 1147; rel. 046;

Myrica serrata Lam. ; AAM 1022; rel. 021;

MORACEAE

Ficus natalensis Hochst. ; rel. 003; rel. 008;

Ficus sur Forssk. ; AAM 1287; AAM 1337; rel. 002; rel. 007; rel. 009;

PROTEACEAE

Protea neriifolia R. Br. ; AAM 1397;

Protea simplex Phill. ; AAM 1292; rel. 041; rel. 042; rel. 055; rel. 065; rel. 066; rel. 067; rel. 068; rel. 073; rel. 086; rel. 109;

Leucadendron salignum Berg. ; AAM 1036; rel. 042; rel. 043; rel. 067; rel. 068; rel. 071; rel. 072; rel. 073; rel. 074; rel. 075; rel. 076; rel. 077; rel. 092; rel. 105; rel. 128; rel. 129;

Hakea sericea Schrad. ; AAM 1034; PP 5284; rel. 019; rel. 129;

LORANTHACEAE

Tapinanthus kraussianus (Meisn.) V. Tieghem subsp. *kraussia* ; AAM 1355;

VISCACEAE

Viscum rotundifolium L. f. ; AAM 1111; AAM 1347;

SANTALACEAE

Colpoon compressum Berg. ; AAM 1039;

Rhoiacarpos capensis (Harv.) A. DC. ; rel. 007; rel. 009; rel. 010;

Osyris lanceolata Hochst. & Steud. ; rel. 146; rel. 152;

Thesium acutissimum A. DC. ; AAM 1246;

POLYGONACEAE

Rumex cordatus Poiret ; AAM 1207; rel. 154;

AMARANTHACEAE

Hermbstaedtia odorata (Burch.) T. Cooke var. *aurantiaca* (Suesseng.) C.C. Townsend; AAM 1321;

Achyranthes aspera L. var. *aspera*; rel. 004;

MESEMBRYANTHEMACEAE

Carpobrotus edulis (L.) L.Bol.; AAM 1144;

Delosperma ecklonis (Salm-Dyck) Schwant. var. *ecklonis* ; AAM 1078;

Delosperma klinghardtianum (Dinter) Schwant ; AAM 1134;

RANUNCULACEAE

Knowltonia vesicatora (L.f.) Sims; AAM 1378; rel. 071;

Clematis simensis Fresen. ; rel. 009; rel. 011;

Ranunculus multifidus Forssk. ; AAM 1242; rel. 002;

BRASSICACEAE

Lepidium africanum (Burm. f.) DC. subsp. *africanum* ; AAM 1315;

CAPPARACEAE

Cadaba aphylla (Thunb.) Wild ; AAM 1282;

Maerua racemulosa (A. DC.) Gilg & Ben. ; AAM 1094;

CRASSULACEAE

Cotyledon velutina Hook. f. ; AAM 1369; AAM 1385;

Crassula alba Forssk. ; AAM 1137; rel. 089;

Crassula cotyledonis Thunb. ; AAM 1338;

Crassula lactea Soland. ; AAM 1077; rel. 140; rel. 143;

Crassula mesembryanthoides (Haw.) Dietr. subsp. *mesembryanthoi* ; AAM 1316;

Crassula muscosa L. var. *muscosa* ; AAM 1291; rel. 128;

Crassula nemorosa (Eckl. & Zeyh.) Endl. ex Walp. ; AAM 1374; rel. 125; rel. 126;

Crassula nudicaulis L. var. *nudicaulis* ; rel. 141; rel. 152;

Crassula perfoliata L. var. *coccinea* (Sweet) Rowley ; AAM 1133;

Crassula vaginata Eckl. & Zeyh. subsp. *vaginata* ; rel. 024; rel. 030; rel. 092; rel. 104;

Crassula atropurpurea (Haw.) Dietr. var. *anomala* (Schonl. & Bak. f.) Toelken ; AAM 1319;

Crassula cultrata L. x *C. nudicaulis L. var. nud* ; rel. 130;

MONTINIACEAE

Montinia caryophyllacea Thunb. ; AAM 1157; AAM 1391;

PITTOSPORACEAE

Pittosporum viridiflorum Sims ; rel. 004;

CUNONIACEAE

Cunonia capensis L. ; AAM 1056;

BRUNIACEAE

Berzelia intermedia (Dietr.) Schlechtd. ; AAM 1141; rel. 032; rel. 055; rel. 056; rel. 057;

rel. 071; rel. 094; rel. 106; rel. 109; rel. 128; rel. 129; rel. 131;

ROSACEAE

Pyracantha angustifolia (Franch.) Schneid.; AAM 1424;

Rubus pinnatus Willd. ; AAM 1043; rel. 002; rel. 006; rel. 008; rel. 074; rel. 138; rel. 142; rel. 143;

Cliffortia linearifolia Eckl. & Zeyh. ; rel. 012; rel. 013; rel. 014; rel. 015; rel. 016; rel. 017; rel. 018; rel. 019; rel. 020; rel. 021; rel. 027; rel. 078; rel. 079; rel. 081; rel. 082; rel. 083; rel. 097; rel. 112; rel. 113; rel. 120; rel. 124; rel. 129; rel. 137; rel. 138;

Cliffortia paucistaminea Weim. ; AAM 1423;

Cliffortia graminea L. f. var. *convoluta* Weim. ; AAM 1121; rel. 123; rel. 125;

FABACEAE

Acacia longifolia (Andr.) Willd. ; AAM 1000; rel. 147;

Schotia latifolia Jacq. ; AAM 1300; AAM 1392;

Bauhinia petersiana Bolle subsp. *petersiana* ; AAM 1102;

Chamaecrista mimosoides (L.) Greene ; AAM 1231; AAM 1253;

Rafnia elliptica Thunb. ; AAM 1308;

Aspalathus abietina Thunb. ; AAM 1123; rel. 001; rel. 075; rel. 123; rel. 124; rel. 128;

Aspalathus chortophila Eckl. & Zeyh. ; AAM 1245; AAM 1254; rel. 048; rel. 129;

Aspalathus frankenioides DC. ; AAM 1194; AAM 1342;

Aspalathus pedunculata Houtt. ;

Aspalathus recurva Benth. ; rel. 039;

Aspalathus setacea Eckl. & Zeyh. ; AAM 1195; AAM 1271; AAM 1387; rel. 002; rel. 003; rel. 004; rel. 062;

Argyrolobium collinum Eckl. & Zeyh. ; AAM 1128; rel. 071; rel. 091; rel. 125;

Argyrolobium transvaalense Schinz ; AAM 1182;

Trifolium burchellianum Ser. subsp. *burchellianum* ; AAM 1221; rel. 106;

Indigofera hedyantha Eckl. & Zeyh. ; rel. 064; rel. 065; rel. 081; rel. 089; rel. 101; rel. 147;

Indigofera stenophylla Eckl. & Zeyh., AAM 1259;

Indigofera zeyheri Spreng. ex Eckl. & Zeyh. ; AAM 1024; AAM 1421; rel. 012; rel. 013; rel. 014; rel. 018; rel. 027; rel. 039; rel. 063; rel. 079; rel. 080; rel. 082; rel. 111;

Psoralea aphylla L; AAM 1402;

Psoralea pinnata L. ; AAM 1014; rel. 012; rel. 013; rel. 034; rel. 051; rel. 061; rel. 080;

Tephrosia angulata E. Mey. ; AAM 1071; rel. 018; rel. 023; rel. 026; rel. 027; rel. 035;

rel. 036; rel. 047; rel. 113; rel. 118; rel. 132; rel. 151;

Tephrosia diffusa (E. Mey.) Harv. ; AAM 1390;

Tephrosia grandiflora (Ait.) Pers. ; AAM 1112; rel. 029; rel. 156;

Tephrosia pallens (Ait.) Pers. ; rel. 012; rel. 013; rel. 014; rel. 016; rel. 020; rel. 021; rel. 022; rel. 025; rel. 028; rel. 040; rel. 043; rel. 048; rel. 050; rel. 052; rel. 076; rel. 078; rel. 079; rel. 080; rel. 081; rel. 082; rel. 085; rel. 087; rel. 088; rel. 111; rel. 112; rel. 114; rel. 116; rel. 146; rel. 151;

Tephrosia polystachya E. Mey. var. *longidens* H. M. Forbes ; AAM 1223; AAM 1417; rel. 041; rel. 042; rel. 144; rel. 148; rel. 156; rel. 160;

Tephrosia villosa (L.) Pers. ; rel. 007; rel. 083;

Zornia capensis Pers. ; AAM 1220; AAM 1376;

Erythrina lysistemon Hutch. ; AAM 1159; rel. 022; rel. 023; rel. 026;

Rhynchosia capensis (Burm.) Schinz ; AAM 1170; AAM 1317;

Eriosema salignum E. Mey. ; AAM 1258;

Eriosema burkei Benth. ; rel. 038; rel. 075; rel. 076; rel. 077; rel. 088; rel. 089; rel. 096;

Vigna angustifoliolata Verdc. ; rel. 109;

Dipogon lignosus (L.) Verdc. ; AAM 1007; AAM 1186;

GERANIACEAE

Monsonia ovata (Knuth) Bowden subsp. *glauca* T.Müll. ; AAM 1031; rel. 036; rel. 088;

Pelargonium capitatum (L.) L'Herit. ; AAM 1190; rel. 001; rel. 006; rel. 007; rel. 008; rel. 009; rel. 011; rel. 012; rel. 013; rel. 016; rel. 017; rel. 018; rel. 020; rel. 021; rel. 027; rel. 122; rel. 133; rel. 136; rel. 143; rel. 144; rel. 145; rel. 154;

Pelargonium odoratissimum (L.) L'H,rit. ; AAM 1238;

Pelargonium radens H.E. Moore ; AAM 1304;

Pelargonium zonale (L.) L'H,rit. ; AAM 1037; AAM 1154; AAM 1188; rel. 061;

OXALIDACEAE

Oxalis comosa E. Mey. ex Sond. ; rel. 153; rel. 154; rel. 155;

Oxalis latifolia H.B.K. ; rel. 055; rel. 092; rel. 107; rel. 156; rel. 159; rel. 160;

Oxalis semiloba Sond. ; rel. 013; rel. 019; rel. 027;

Oxalis smithiana Eckl. & Zeyh. ; rel. 019; rel. 100;

RUTACEAE

Zanthoxylum capense (Thunb.) Harv. ; AAM 1053; rel. 004; rel. 005; rel. 006; rel. 007; rel. 009; rel. 011; rel. 141; rel. 142;

Calodendrum capense (L. f.) Thunb. ; rel. 005;

Agathosma ovata (Thunb.) Pillans ; AAM 1019; PP 5285; rel. 022; rel. 044; rel. 045; rel. 046; rel. 047; rel. 048; rel. 050; rel. 051;

Agathosma pegleriae D□mmer ; AAM 1244; rel. 036; rel. 053; rel. 067;

Vepris lanceolata (Lam.) G. Don ; rel. 002; rel. 003;

MELIACEAE

Ekebergia capensis Sparrm. ; rel. 002; rel. 004; rel. 009; rel. 011;

POLYGALACEAE

Muraltia alopecuroides (L.) DC. ; AAM 1180; rel. 100; rel. 127; rel. 128; rel. 129;

Muraltia stenophylla Levyns ; AAM 1263;

EUPHORBIACEAE

Croton rivularis Muell. Arg. ; AAM 1089; rel. 009; rel. 118; rel. 119;

Acalypha peduncularis E. Mey. ex Meisn. ; AAM 1222; rel. 013; rel. 016; rel. 026; rel. 027; rel. 036; rel. 040; rel. 043; rel. 054; rel. 072; rel. 078; rel. 081; rel. 087; rel. 088;

Tragia collina Prain. ; rel. 007; rel. 008; rel. 011;

Clutia affinis Sond. ; PP 5286; PP 5287; AAM 1252; rel. 042; rel. 054; rel. 055; rel. 061; rel. 062; rel. 063; rel. 064; rel. 067; rel. 068; rel. 069; rel. 070; rel. 074; rel. 076; rel. 084; rel. 085; rel. 087; rel. 088;

Clutia pulchella L.; AAM 1008; AAM 1339; rel. 003; rel. 006; rel. 008; rel. 010; rel. 011;

Clutia rubicaulis Eckl. ex Sond. ; AAM 1386;

Euphorbia polygona Haw. ; rel. 121; rel. 152;

Euphorbia striata Thumb. var. cuspidata (Boiss.) N.E. ; AAM 1429; rel. 057; rel. 061; rel. 097; rel. 109; rel. 115;

ANACARDIACEAE

Harpephyllum caffrum Bernh. ex Krauss ; rel. 007; rel. 008;

Rhus chirindensis Bak. f. ; rel. 003; rel. 004; rel. 005; rel. 006; rel. 007; rel. 008;

Rhus crenata Thunb. ; AAM 1167; rel. 120; rel. 145; rel. 146; rel. 147; rel. 149; rel. 151;

Rhus dentata Thunb. ; AAM 1166; rel. 013; rel. 015; rel. 017; rel. 027; rel. 126; rel. 132; rel. 138; rel. 140; rel. 141; rel. 142; rel. 143; rel. 144;

Rhus lancea L. f. ; AAM 1104; rel. 123;

Rhus pallens Eckl. & Zeyh. ; AAM 1051; rel. 015; rel. 016;

Rhus pallens Eckl. & Zeyh. ; rel. 131; rel. 134; rel. 135; rel. 136; rel. 138; rel. 139; rel. 140; rel. 141; rel. 142; rel. 143;

Rhus rigida Mill. ; AAM 1299; AAM 1401;

Rhus tomentosa L. ; AAM 1152; AAM 1330; rel. 001;

AQUIFOLIACEAE

Ilex mitis (L.) Radlk. var. *mitis* ; AAM 1285; AAM 1298; AAM 1418;

CELASTRACEAE

Maytenus acuminata (L. f.) Loes. var. *acuminata* ; AAM 1075; AAM 1412; rel. 001; rel. 002; rel. 006; rel. 007; rel. 008; rel. 009; rel. 010; rel. 011;

Maytenus heterophylla (Eckl. & Zeyh.) N.K.B. Robson ; AAM 1020; AAM 1120; AAM 1192; AAM 1279; rel. 001; rel. 002; rel. 003; rel. 004; rel. 005; rel. 007; rel. 008; rel. 009; rel. 010; rel. 011; rel. 139; rel. 142; rel. 143;

Maytenus peduncularis (Sond.) Loes. ; AAM 1352; AAM 1411; rel. 006;

Maytenus undata (Thunb.) Blakelock ; AAM 1428; AAM 1273; rel. 004; rel. 005; rel. 007; rel. 009; rel. 010; rel. 011;

Pterocelastrus tricuspidatus (Lam.) Sond. ; AAM 1155;

Cassine cf. peragua L. ; AAM 1098;

Cassine peragua L. subsp. *peragua* ; AAM 1318; AAM 1394; rel. 004; rel. 152;

Mystroxylon aethiopicum (Thunb.) Loes. ; AAM 1074;

Pleurostylia capensis (Turcz.) Loes. ; AAM 1415;

ICACINACEAE

Cassinopsis ilicifolia (Hochst.) Kuntze ; AAM 1302;

Apodytes dimidiata Arn. var. *dimidiata* ; rel. 001; rel. 003; rel. 004; rel. 005; rel. 006; rel. 007; rel. 008; rel. 009; rel. 010; rel. 144; rel. 145;

SAPINDACEAE

Hippobromus pauciflorus (L. f.) Radlk. ; rel. 001; rel. 002; rel. 003; rel. 006; rel. 009;

Hippobromus pauciflorus (L. f.) Radlk. ; AAM 1430;

MELIANTHACEAE

Bersama lucens (Hochst.) Szyszyl. ; rel. 002;

RHAMNACEAE

Scutia myrtina (Burm. f.) Kurz ; AAM 1050; AAM 1275; AAM 1306; rel. 002; rel. 006; rel. 010; rel. 011; rel. 134; rel. 138; rel. 139; rel. 140; rel. 141; rel. 142; rel. 143; rel. 144; rel. 145;

Rhamnus prinoides L'H,rit. ; rel. 003; rel. 141;

Phylica axillaris Lam. var. *axillaris* ; AAM 1026; rel. 013; rel. 021; rel. 028; rel. 029; rel. 031; rel. 032; rel. 033; rel. 035; rel. 036; rel. 037; rel. 040; rel. 042; rel. 043; rel. 044; rel. 045; rel. 047; rel. 049; rel. 051; rel. 053; rel. 055; rel. 056; rel. 057; rel. 058; rel. 065; rel.

067; rel. 068; rel. 070; rel. 071; rel. 072; rel. 075; rel. 076; rel. 077; rel. 107; rel. 110; rel. 122;

Helinus integrifolius (Lam.) Kuntze ; AAM 1274;

VITACEAE

Rhoicissus digitata (L. f.) Gilg & Brandt ; AAM 1041;

Rhoicissus tomentosa (Lam.) Wild & R. B. Drumm. ; rel. 002; rel. 003; rel. 006; rel. 007; rel. 008; rel. 009; rel. 010;

Rhoicissus tridentata (L.f.) Wild & R. B. Drumm. subsp. *cuneifo* ; AAM 1091; rel. 001; rel. 007; rel. 008; rel. 010; rel. 011; rel. 013; rel. 134; rel. 138;

TILIACEAE

Grewia occidentalis L. f. var. *occidentalis* ; AAM 1191; rel. 003; rel. 004; rel. 005; rel. 011; rel. 139; rel. 142; rel. 145;

MALVACEAE

Pavonia praemorsa (L. f.) Cav.; AAM 1225;

Hibiscus aethiopicus L. var. *aethiopicus* ; rel. 085;

OCHNACEAE

Ochna serrulata (Hochst.) Walp. ; AAM 1165; rel. 001; rel. 003; rel. 004; rel. 005; rel. 009; rel. 010; rel. 011;

CLUSIACEAE

Hypericum wilmsii R. Keller ;

FLACOURTIACEAE

Scolopia zeyheri (Nees) Harv. ; rel. 004; rel. 008; rel. 121;

Dovyalis rhamnoides (Burch. ex DC.) Harv. ; rel. 005; rel. 008; rel. 009; rel. 011; rel. 134; rel. 141; rel. 144; rel. 145;

PASSIFLORACEAE

Passiflora coerulea L. ; AAM 1234; rel. 135;

ACHARIACEAE

Ceratiosicyos laevis (Thunb.) A. Meeuse; AAM 1427;

OLINIACEAE

Olinia ventosa (L.) Cufod. ; AAM 1158;

THYMELAEACEAE

Gnidia anthylloides (L. f.) Gilg ; rel. 087; rel. 088; rel. 110; rel. 125; rel. 130; rel. 132;

Gnidia nodiflora Meisn. ; AAM 1119; AAM 1239; AAM 1365; rel. 037; rel. 052; rel. 055; rel. 057; rel. 059;

Gnidia thesioides Meisn. var. *thesioides* ; rel. 021; rel. 025; rel. 036; rel. 037; rel. 038; rel. 043; rel. 050; rel. 054; rel. 056; rel. 060; rel. 061; rel. 062; rel. 063; rel. 064; rel. 065; rel. 066; rel. 067; rel. 068; rel. 070; rel. 085; rel. 102;

Struthiola argentea Lehm. ; AAM 1115; rel. 029; rel. 032; rel. 037; rel. 051; rel. 054; rel. 055; rel. 068; rel. 105; rel. 118; rel. 119;

Struthiola ciliata (L.) Lam. subsp. schlechteri ; AAM 1383;

Struthiola dodecandra (L.) Druce ; AAM 1145;

Passerina vulgaris Thoday ; AAM 1193; rel. 124; rel. 146; rel. 147; rel. 148; rel. 149; rel. 150; rel. 151;

MYRTACEAE

Syzygium cordatum Hochst. ; AAM 1161;

Eucalyptus camaldulensis Dehnh. ; AAM 1267; AAM 1422;

Callistemon rigidus R. Br. ; AAM 1199;

MELASTOMATACEAE

Memecylon bachmannii Engl. ; rel. 006;

ARALIACEAE

Cussonia spicata Thunb. ; AAM 1297; AAM 1294; rel. 004; rel. 006; rel. 123; rel. 141;

APIACEAE

Centella affinis (Eckl. & Zeyh.) Adamson var. *affini* ; AAM 1327;

Centella coriacea Nannfd. ; rel. 012; rel. 013; rel. 014; rel. 016; rel. 017; rel. 018; rel. 023; rel. 026; rel. 040; rel. 078; rel. 081; rel. 082; rel. 083; rel. 097; rel. 099; rel. 111; rel. 112; rel. 113; rel. 114; rel. 115; rel. 133; rel. 134; rel. 136; rel. 137; rel. 139; rel. 140; rel. 141; rel. 142; rel. 143; rel. 144; rel. 145; rel. 154; rel. 155; rel. 156; rel. 157; rel. 158; rel. 159; rel. 160;

Alepidea acutidens Weim. var. *acutidens* ; AAM 1377; rel. 057; rel. 058; rel. 069; rel. 070; rel. 076; rel. 092; rel. 096; rel. 108;

Heteromorpha arborescens (Thunb.) Cham. & Schlechtd ; rel. 010;

Anginon difforme (L.) B.L. Burtt ; AAM 1198; rel. 035; rel. 044;

Peucedanum caffrum (Meisn.) Phill. ; rel. 061;

CORNACEAE

Curtisia dentata (Burm. f.) C.A. Sm. ; AAM 1307; rel. 001; rel. 002; rel. 003; rel. 004; rel. 007; rel. 008; rel. 009; rel. 010; rel. 011;

ERICACEAE

Erica caffra L. ; AAM 1108; AAM 1001;

Erica cerinthoides L. ; AAM 1027; AAM 1263a; rel. 023; rel. 024; rel. 039; rel. 051; rel. 059; rel. 061; rel. 070; rel. 074; rel. 095; rel. 097; rel. 102; rel. 125; rel. 126; rel. 128; rel. 131; rel. 132;

Erica chamissonis Klotzsch ex Benth. var. *chamissonis* ; AAM 1138; rel. 046; rel. 048; rel. 051; rel. 125; rel. 129; rel. 131;

Erica demissa Klotzsch ex Benth. var. *demissa* ; AAM 1173; rel. 016; rel. 017; rel. 019; rel. 027; rel. 051; rel. 150;

Erica glumiflora Klotzsch ex Benth. ; AAM 1028; rel. 021; rel. 022; rel. 024; rel. 025; rel. 026; rel. 028; rel. 036; rel. 042; rel. 044; rel. 047; rel. 048; rel. 053; rel. 055; rel. 057; rel. 060; rel. 072; rel. 073; rel. 074; rel. 075; rel. 097; rel. 102; rel. 103; rel. 105; rel. 107; rel. 108; rel. 112; rel. 127; rel. 131; rel. 132;

Erica nemorosa Klotzsch ex Benth. ; AAM 1013; AAM 1015; AAM 1382;

MYRSINACEAE

Rapanea melanophloeos (L.) Mez ; rel. 004; rel. 006; rel. 007; rel. 008; rel. 009; rel. 010; rel. 011; rel. 131; rel. 141; rel. 145; rel. 152;

PRIMULACEAE

Anagallis arvensis L. ; AAM 1303; rel. 038; rel. 063; rel. 084;

SAPOTACEAE

Sideroxylon inerme L. subsp. *inerme* ; rel. 006;

EBENACEAE

Euclea natalensis A.DC. subsp. *natalensis* ; AAM 1040; rel. 088; rel. 141; rel. 142; rel. 143; rel. 152;

Diospyros dichrophylla (Gand.) De Winter ; AAM 1054; rel. 138; rel. 145;

Diospyros lycioides Desf. subsp. *guerkii* (Kuntze) De Winter ; rel. 002; rel. 003; rel. 139;

Diospyros whyteana (Hiern) F. White ; rel. 007; rel. 008; rel. 009; rel. 011;

Diospyros scabrida (Harv. ex Hiern) De Winter var. *scabrida* ; AAM 1346;

OLEACEAE

Olea capensis L. subsp. *capensis* ; AAM 1345; AAM 1361; rel. 006; rel. 007; rel. 008; rel. 009; rel. 010; rel. 011;

LOGANIACEAE

Nuxia floribunda Benth. ; AAM 1009; rel. 001; rel. 004; rel. 005; rel. 007; rel. 008; rel. 009; rel. 010; rel. 011; rel. 013; rel. 141;

GENTIANACEAE

Sebaea hymenosepala Gilg ; AAM 1163; rel. 018; rel. 036;

Chironia tetragona L. f. ; AAM 1012; AAM 1201; rel. 029; rel. 031; rel. 034; rel. 044; rel. 047; rel. 048; rel. 051; rel. 053; rel. 054; rel. 057; rel. 059; rel. 060; rel. 069; rel. 105; rel. 109; rel. 117; rel. 153;

MENYANTHACEAE

Nymphoides indica (L.) Kuntze subsp. occidentalis ; AAM 1249;

APOCYNACEAE

Carissa bispinosa (L.) Desf. ex Brenan subsp. *bispino* ; AAM 1179; rel. 001; rel. 002; rel. 003; rel. 004; rel. 005; rel. 006; rel. 007; rel. 009; rel. 010; rel. 011; rel. 134; rel. 139; rel. 145;

ASCLEPIADACEAE

Pachycarpus appendiculatus E. Mey. ; rel. 087; rel. 099;

Pachycarpus grandiflorus (L. f.) E. Mey. var. *grandiflorus* ; AAM 1410;

Secamone alpini Schultes ; AAM 1426; rel. 007; rel. 009; rel. 120; rel. 121;

Secamone filiformis (L. f.) J.H. Ross; AAM 1425; rel. 002; rel. 003; rel. 008;

Ceropegia africana R. Br. ; rel. 004;

CONVOLVULACEAE

Cuscuta appendiculata Engelm. ; rel. 131;

Falkia repens L. f. ; AAM 1368;

BORAGINACEAE

Ehretia rigida (Thunb.) Druce; AAM 1266;

VERBENACEAE

Verbena bonariensis L. ; AAM 1072;

Lippia javanica (Burm. f.) Spreng. ; AAM 1277;

Lippia javanica (Burm. f.) Spreng. ; AAM 1373;

Clerodendrum caeruleum N.E. Br. ; rel. 003;

LAMIACEAE

Teucrium africanum Thunb. ; AAM 1281;

Leonotis leonurus (L.) R. Br. ; AAM 1350; AAM 1351; rel. 059; rel. 137;

Salvia triangularis Thunb. ; AAM 1276;

Plectranthus ecklonii Benth. ; AAM 1396; AAM 1400; rel. 002; rel. 003; rel. 004; rel. 006; rel. 007; rel. 008; rel. 009; rel. 010;

Plectranthus fruticosus L'H,rit. ; rel. 001; rel. 002; rel. 005;

SOLANACEAE

Solanum capense L. ; AAM 1320;

Solanum linnaeanum Hepper & Jaeger ; AAM 1171; rel. 003; rel. 004;

Solanum rigescens Jacq. ; AAM 1284; rel. 134; rel. 139; rel. 159; rel. 160;

SCROPHULARIACEAE

Halleria lucida L. ; AAM 1005; rel. 001; rel. 013; rel. 142; rel. 143;

Sutera campanulata (Benth.) Kuntze ; AAM 1033; rel. 066; rel. 124; rel. 125; rel. 128; rel. 144; rel. 146; rel. 149;

Phyllopodium cuneifolium (L. f.) BENTH ; AAM 1269;

SELAGINACEAE

Selago corymbosa L. ; AAM 1240; rel. 025; rel. 037; rel. 040; rel. 082; rel. 095; rel. 120; rel. 130;

Selago corymbosa L. ; rel. 040; rel. 053;

Selago polystachya L. ; AAM 1029; rel. 030; rel. 036; rel. 042; rel. 043; rel. 050; rel. 078; rel. 111; rel. 112; rel. 144; rel. 146;

Selago punctata Rolfe ; rel. 114; rel. 134; rel. 137; rel. 139; rel. 142;

SCROPHULARIACEAE

Alectra orobanchoides Benth. ; AAM 1332; rel. 024; rel. 027; rel. 048; rel. 058; rel. 071; rel. 085; rel. 109;

Buchnera dura Benth. ; AAM 1331;

Striga asiatica (L.) Kuntze ; rel. 002;

GESNERIACEAE

Streptocarpus rexii (Hook.) Lindl. ; rel. 010;

Streptocarpus daviesii N.E. Br. ex C.B. Cl. ; rel. 003; rel. 004; rel. 007; rel. 008;

ACANTHACEAE

Thunbergia capensis Retz. ; rel. 036; rel. 064; rel. 066; rel. 070; rel. 120;

Thunbergia dregeana Nees ; rel. 062;

Thunbergia aurea N.E. Br. ; AAM 1370;

Chaetacanthus setiger (Pers.) Lindl. ; AAM 1217; rel. 038; rel. 039; rel. 052; rel. 060; rel. 062; rel. 063; rel. 064; rel. 066; rel. 068; rel. 078; rel. 093; rel. 096; rel. 117; rel. 118; rel. 119; rel. 120; rel. 124; rel. 126; rel. 129; rel. 130; rel. 131; rel. 144; rel. 151;

Ruellia cordata Thunb. ; rel. 090;

Hypoestes forskaolii (Vahl) R. Br. ; AAM 1100; rel. 001; rel. 003; rel. 004; rel. 005; rel. 006; rel. 007; rel. 134; rel. 141; rel. 145;

RUBIACEAE

Conostomium natalense (Hochst.) Brem. ; AAM 1349;

Burchellia bubalina (L. f.) Sims ; AAM 1002; rel. 001; rel. 004; rel. 006; rel. 007; rel. 008; rel. 009; rel. 011; rel. 013; rel. 015; rel. 019; rel. 023; rel. 027; rel. 118; rel. 120; rel. 131; rel. 132; rel. 134; rel. 138; rel. 139; rel. 140; rel. 141; rel. 143; rel. 144; rel. 147;

Catunaregam spinosa (Thunb.) Tirveng. subsp. *spinosa* ; rel. 134; rel. 139; rel. 141; rel. 142; rel. 143;

Gardenia thunbergia Thunb.; rel. 008; rel. 009; rel. 010; rel. 011;

Gardenia aqualla Stapf & Hutch. ; rel. 002; rel. 003;

Rothmannia capensis Thunb.; rel. 004; rel. 065;

Rytigynia monantha (K.Schum.) Robyns var. *monantha*; rel. 006;

Canthium ciliatum (Klotzsch) Kuntze ; AAM 1343; AAM 1414; rel. 002; rel. 003; rel. 004; rel. 007; rel. 008; rel. 009; rel. 010; rel. 011; rel. 120; rel. 121; rel. 141; rel. 144; rel. 145; rel. 160;

Canthium inerme (L. f.) Kuntze ; AAM 1356; AAM 1413; rel. 004; rel. 006; rel. 007; rel. 008; rel. 152;

Psydrax livida (Hiern) Bridson ; rel. 006;

Pavetta lanceolata Eckl. ; AAM 1090; AAM 1181; rel. 001; rel. 002; rel. 003; rel. 004; rel. 005; rel. 008; rel. 010; rel. 011;

Psychotria capensis (Eckl.) Vatke subsp. *capensis* ; AAM 1093; AAM 1010; rel. 001; rel. 002; rel. 003; rel. 004; rel. 006; rel. 007; rel. 008; rel. 009; rel. 010; rel. 011; rel. 141;

Galopina circaeoides Thunb. ; AAM 1085; rel. 001; rel. 002; rel. 003; rel. 004; rel. 006; rel. 007; rel. 008; rel. 061; rel. 064; rel. 076; rel. 078; rel. 083; rel. 086; rel. 087; rel. 094; rel. 098; rel. 099; rel. 128; rel. 129; rel. 134; rel. 138; rel. 139; rel. 140; rel. 141; rel. 142; rel. 143; rel. 145;

Anthospermum aethiopicum L ; AAM 1168; rel. 012; rel. 013; rel. 028; rel. 032; rel. 034; rel. 035; rel. 037; rel. 038; rel. 040; rel. 041; rel. 043; rel. 047; rel. 049; rel. 051; rel. 055; rel. 060; rel. 062; rel. 063; rel. 076; rel. 077; rel. 078; rel. 131; rel. 156;

Anthospermum herbaceum L. var. *herbaceum* ; rel. 012; rel. 013; rel. 014; rel. 015; rel. 016; rel. 018; rel. 019; rel. 022; rel. 023; rel. 029; rel. 030; rel. 031; rel. 036; rel. 097; rel. 099; rel. 101; rel. 103; rel. 104; rel. 105; rel. 106; rel. 130; rel. 132; rel. 143;

Spermacoce natalensis Hochst ; AAM 1344;

Spermacoce ruelliaie DC. ; AAM 1251; rel. 078; rel. 080; rel. 082; rel. 133; rel. 135; rel. 136; rel. 137; rel. 153; rel. 154; rel. 156; rel. 158; rel. 159;

DIPSACACEAE

Cephalaria oblongifolia (Kuntze) Szabo ; AAM 1393;

Scabiosa albanensis R.A. Dyer ; AAM 1213; rel. 023; rel. 029; rel. 032; rel. 035; rel. 036; rel. 048; rel. 050; rel. 068; rel. 071; rel. 097; rel. 121; rel. 126;

CAMPANULACEAE

Wahlenbergia sp. ; AAM 1206; rel. 038; rel. 153;

Wahlenbergia capillacea (L.f.) A.DC. subsp. *tenuior* (Engl.) Thulin ; AAM 1044; rel. 029;

LOBELIACEAE

Lobelia anceps L. f. ; rel. 156; rel. 157;

Lobelia neglecta Roem. & Schult. ; AAM 1018; rel. 032; rel. 033; rel. 040; rel. 113;

Lobelia tomentosa L. f. ; AAM 1131; rel. 026; rel. 064; rel. 065; rel. 089; rel. 124; rel. 126; rel. 128; rel. 130; rel. 147;

Monopsis unidentata (Dryand.) E.Wimm. subsp. *intermedia* Phillipson ; AAM 1208;

ASTERACEAE

Vernonia capensis (Houtt.) Druce ; AAM 1278; AAM 1286;

Vernonia mespilifolia Less. ; AAM 1270;

Corymbium glabrum L. var. *glabrum* ; AAM 1326;

Corymbium glabrum L. var. *glabrum* ; AAM 1329;

Mikania natalensis ; AAM 1184;

Mikania microptera DC. ; AAM 1160;

Aster bakeranus Burtt Davy ex C.A. Sm.; rel. 047; rel. 077; rel. 095; rel. 096; rel. 097; rel. 098; rel. 106;

Felicia filifolia (Vent.) Burtt Davy; AAM 1348; AAM 1372;

Conyza scabrida DC. ; AAM 1021;

Conyza ulmifolia (Burm. f.) Kuntze ; AAM 1048; AAM 1117; rel. 026;

Chrysocoma ciliata L. ; AAM 1122;

Brachylaena elliptica (Thunb.) DC.; AAM 1016; rel. 132;

Gnaphalium coarctatum Willd. ; AAM 1301;

Gnaphalium coarctatum Willd. ; AAM 1289;

Helipterum milleflorum (L.) Druce ; AAM 1364; rel. 065;

Helichrysum anomalum Less. ; rel. 020; rel. 021; rel. 022; rel. 024; rel. 029; rel. 032; rel. 033; rel. 037; rel. 038; rel. 041; rel. 043; rel. 049; rel. 050; rel. 052; rel. 060; rel. 062; rel. 063; rel. 064; rel. 065; rel. 066; rel. 067; rel. 070; rel. 077; rel. 078; rel. 087; rel. 089; rel. 093; rel. 095; rel. 096; rel. 097; rel. 098; rel. 099; rel. 100; rel. 104; rel. 113; rel. 115; rel. 118; rel. 121; rel. 123; rel. 124; rel. 125; rel. 127; rel. 128; rel. 129; rel. 130; rel. 131; rel.

135; rel. 137; rel. 142; rel. 147; rel. 148; rel. 149; rel. 150;

Helichrysum appendiculatum (L. f.) Less. ; AAM 1256; rel. 101;

Helichrysum cymosum (L.) D. Don ; AAM 1205; AAM 1283; rel. 012; rel. 014; rel. 015; rel. 016; rel. 017; rel. 018; rel. 019; rel. 020; rel. 021; rel. 027; rel. 045; rel. 046; rel. 047; rel. 051; rel. 058; rel. 073; rel. 134; rel. 138; rel. 140; rel. 142; rel. 143; rel. 145;

Helichrysum felinum Less. ; AAM 1172; rel. 030; rel. 031; rel. 032; rel. 034; rel. 035; rel. 036; rel. 037; rel. 046; rel. 047; rel. 055; rel. 063; rel. 065; rel. 067; rel. 074; rel. 082; rel. 085; rel. 094; rel. 095; rel. 099; rel. 100; rel. 104; rel. 109;

Helichrysum herbaceum (Andr.) Sweet ; AAM 1132; AAM 1420; rel. 012; rel. 014; rel. 022; rel. 023; rel. 025; rel. 026; rel. 029; rel. 030; rel. 031; rel. 035; rel. 044; rel. 045; rel. 046; rel. 049; rel. 051; rel. 057; rel. 058; rel. 065; rel. 068; rel. 071; rel. 072; rel. 075; rel. 076; rel. 077; rel. 078; rel. 079; rel. 081; rel. 082; rel. 083; rel. 090; rel. 094; rel. 097; rel. 098; rel. 099; rel. 107; rel. 108; rel. 109; rel. 130; rel. 142;

Helichrysum nudifolium (L.) Less. ; AAM 1389;

Helichrysum odoratissimum (L.) Sweet; AAM 1185; rel. 012; rel. 013; rel. 014; rel. 018; rel. 019; rel. 021; rel. 022; rel. 023; rel. 025; rel. 039; rel. 044; rel. 045; rel. 049; rel. 054; rel. 078; rel. 080; rel. 111; rel. 112; rel. 113; rel. 129; rel. 131;

Helichrysum spiralepis Hilliard & Burtt; AAM 1215; rel. 087; rel. 097;

Helichrysum subglomeratum Less. ; AAM 1017; AAM 1030; rel. 012; rel. 013; rel. 016; rel. 018; rel. 020; rel. 021; rel. 022; rel. 023; rel. 024; rel. 025; rel. 026; rel. 028; rel. 029; rel. 032; rel. 033; rel. 034; rel. 035; rel. 036; rel. 037; rel. 038; rel. 039; rel. 040; rel. 042; rel. 043; rel. 044; rel. 045; rel. 049; rel. 050; rel. 051; rel. 052; rel. 053; rel. 054; rel. 055; rel. 060; rel. 062; rel. 063; rel. 066; rel. 068; rel. 070; rel. 072; rel. 073; rel. 075; rel. 076; rel. 077; rel. 079; rel. 081; rel. 082; rel. 083; rel. 084; rel. 085; rel. 086; rel. 090; rel. 091; rel. 093; rel. 094; rel. 095; rel. 096; rel. 097; rel. 098; rel. 099; rel. 100; rel. 102; rel. 103; rel. 104; rel. 105; rel. 106; rel. 107; rel. 109; rel. 110; rel. 114; rel. 116; rel. 126; rel. 127; rel. 129; rel. 132;

Helichrysum teretifolium (L.) D. Don ; rel. 069;

Disparago tortilis (DC.) Sch. Bip. ; AAM 1103; AAM 1360; rel. 029; rel. 032; rel. 039; rel. 041; rel. 045; rel. 048; rel. 059; rel. 060; rel. 062; rel. 064; rel. 065; rel. 067; rel. 068; rel. 070; rel. 086; rel. 092; rel. 093; rel. 115; rel. 118; rel. 119; rel. 120; rel. 123; rel. 127; rel. 128; rel. 129; rel. 130; rel. 132; rel. 144; rel. 146; rel. 148;

Elytropappus rhinocerotis (L. f.) Less. ; AAM 1371;

Metalasia galpinii L. Bol. ; AAM 1340; rel. 149;

Metalasia muricata (L.) D. Don ; AAM 1011; rel. 013; rel. 022; rel. 023; rel. 025; rel. 028; rel. 030; rel. 033; rel. 034; rel. 035; rel. 037; rel. 047; rel. 048; rel. 049; rel. 051; rel. 053; rel. 060; rel. 067; rel. 069; rel. 070; rel. 075; rel. 076; rel. 077; rel. 081; rel. 082; rel. 093; rel. 097; rel. 107; rel. 117; rel. 118; rel. 119; rel. 120; rel. 122; rel. 123; rel. 125; rel. 126; rel. 127; rel. 128; rel. 129; rel. 130; rel. 131; rel. 132; rel. 146; rel. 147; rel. 150; rel. 151; rel. 152;

Relhania acerosa (DC.) Bremer; AAM 1197;

Arrowsmithia styphelioides DC. ; AAM 1293; rel. 128;

Athanasia dentata (L.) L. ; AAM 1042; AAM 1200; rel. 035; rel. 082; rel. 083; rel. 101;

Athanasia pinnata L. f. ; AAM 1140;

Cotula heterocarpa DC.; AAM 1049; AAM 1280;

Schistostephium flabelliforme Less.; AAM 1362;

Cineraria saxifraga DC. ; AAM 1073; rel. 120; rel. 121; rel. 122; rel. 123; rel. 124; rel. 146; rel. 152;

Senecio albanensis DC. var. *albanensis* ; AAM 1069; AAM 1290; rel. 017; rel. 018; rel. 019; rel. 035; rel. 036; rel. 038; rel. 039; rel. 041; rel. 063; rel. 064; rel. 067; rel. 068; rel. 069; rel. 070; rel. 075; rel. 077; rel. 085; rel. 089; rel. 096; rel. 099; rel. 100; rel. 112; rel. 115; rel. 118; rel. 128; rel. 129; rel. 130;

Senecio chrysocoma Meerb.; AAM 1230; rel. 126;

Senecio latifolius DC. ; rel. 025; rel. 027; rel. 043; rel. 047; rel. 153; rel. 154; rel. 158;

Senecio oxyriifolius DC.;

Senecio oxyriifolius DC.; AAM 1419;

Senecio petiolaris DC.; AAM 1201; rel. 024;

Senecio petiolaris DC.; AAM 1210;

Senecio retrorsus DC.; AAM 1211;

Senecio sisymbriifolus. ; AAM 1116;

Senecio skirrhodon DC.; AAM 1118;

Senecio speciosus Willd. ; AAM 1038; rel. 012; rel. 013; rel. 020; rel. 021; rel. 023; rel. 024; rel. 025; rel. 033; rel. 037; rel. 061; rel. 076; rel. 077; rel. 082; rel. 095; rel. 097; rel. 112; rel. 125;

Senecio macroglossoides Hilliard; rel. 140; rel. 144;

Euryops algoensis DC.; AAM 1233; rel. 115; rel. 124; rel. 125; rel. 127; rel. 146; rel. 152;

Osteospermum grandidentatum DC.; AAM 1175;

Chrysanthemoides monilifera (L.) T. Norl. ; AAM 1055; AAM 1196; rel. 048; rel. 069;
Ursinia abrotanifolia (R.Br.) Spreng. ; AAM 1174; rel. 046; rel. 048; rel. 051; rel. 057; rel. 059; rel. 125; rel. 128;
Haplocarpha scaposa Harv.; AAM 1288;
Gazania krebsiana Less. subsp. *arctotoides* (Less.) Ro ; rel. 013; rel. 020; rel. 021; rel. 022; rel. 028; rel. 047; rel. 051; rel. 052; rel. 078; rel. 127;
Berkheya heterophylla (Thunb.) O. Hoffm. var. *radiata* (DC ; AAM 1045; rel. 012; rel. 013; rel. 014; rel. 016; rel. 018; rel. 023; rel. 026; rel. 027; rel. 032; rel. 034; rel. 035; rel. 036; rel. 037; rel. 039; rel. 040; rel. 042; rel. 044; rel. 045; rel. 047; rel. 051; rel. 056; rel. 066; rel. 067; rel. 068; rel. 071; rel. 072; rel. 075; rel. 077; rel. 079; rel. 087; rel. 088; rel. 095; rel. 096; rel. 097; rel. 107; rel. 113; rel. 114; rel. 128; rel. 129; rel. 131; rel. 132; rel. 141; rel. 142; rel. 158;
Berkheya sphaerocephala (DC.) Roessl. ; AAM 1113; rel. 013; rel. 016; rel. 017; rel. 018; rel. 026; rel. 029; rel. 030; rel. 031; rel. 054; rel. 075; rel. 080; rel. 140; rel. 143;
Cirsium vulgare (Savi) Ten. ; rel. 158;
Oldenburgia grandis (Thunb.) Baill. ; rel. 117; rel. 120; rel. 121; rel. 123; rel. 124; rel. 125; rel. 126; rel. 130;
Gerbera cordata (Thunb.) Less. ; AAM 1082; rel. 007; rel. 025; rel. 078; rel. 090; rel. 115; rel. 116; rel. 142; rel. 145; rel. 151;
Hypochoeris radicata L. ; AAM 1260; rel. 133; rel. 136; rel. 137; rel. 154;
Sonchus asper (L.) Hill subsp. asper ; AAM 1129; rel. 015; rel. 151;
Sonchus dregeanus DC.; AAM 1325;
Sonchus schweinfurthii Oliv. & Hiern ; AAM 1380;
Crepis rueppellii Sch.Bip. ; AAM 1305;

SOLANACEAE

Browallia viscosa "Humb., Bonpl. & Kunth": Helen James(1993);; rel. 002;

POACEAE

Miscanthus capensis (Nees) Anderss. ; AAM 1067; AAM 1359; AAM 1310; rel. 030; rel. 031; rel. 034; rel. 046; rel. 047; rel. 048; rel. 051; rel. 057; rel. 058; rel. 060; rel. 072; rel. 074; rel. 096; rel. 097; rel. 098; rel. 101; rel. 102; rel. 103; rel. 105; rel. 106; rel. 107; rel. 108; rel. 109; rel. 118;
Eulalia villosa (Thunb.) Nees; rel. 039; rel. 125; rel. 127;
Andropogon abyssinicus Fresen. ; rel. 124;
Cymbopogon marginatus (Steud.) Stapf ex Burtt Davy; rel. 014; rel. 015; rel. 016; rel.

017; rel. 034; rel. 058; rel. 090; rel. 152;

Hyparrhenia anamesa Clayton ; AAM 1060;

Themeda triandra Forssk. ; AAM 1062; rel. 012; rel. 013; rel. 014; rel. 016; rel. 017; rel. 018; rel. 019; rel. 049; rel. 052; rel. 053; rel. 060; rel. 065; rel. 071; rel. 078; rel. 079; rel. 082; rel. 083; rel. 094; rel. 095; rel. 097; rel. 099; rel. 107; rel. 112; rel. 114; rel. 115; rel. 116; rel. 126; rel. 129; rel. 130; rel. 132; rel. 144; rel. 145; rel. 147; rel. 149; rel. 154; rel. 155; rel. 157; rel. 158; rel. 159; rel. 160;

Digitaria eriantha Steud. ; AAM 1057; AAM 1057; rel. 012; rel. 014; rel. 017; rel. 019; rel. 073; rel. 154;

Alloteropsis semialata (R. Br.) Hitchc. subsp. *eckloniana* (Nees) Gibbs Russell ; AAM 1066; AAM 1126; rel. 016; rel. 017; rel. 018; rel. 021; rel. 022; rel. 023; rel. 030; rel. 031; rel. 032; rel. 033; rel. 034; rel. 035; rel. 036; rel. 037; rel. 038; rel. 039; rel. 040; rel. 041; rel. 042; rel. 043; rel. 044; rel. 045; rel. 046; rel. 047; rel. 048; rel. 049; rel. 050; rel. 051; rel. 053; rel. 054; rel. 055; rel. 056; rel. 057; rel. 058; rel. 059; rel. 060; rel. 062; rel. 063; rel. 064; rel. 065; rel. 066; rel. 067; rel. 068; rel. 069; rel. 070; rel. 071; rel. 072; rel. 073; rel. 074; rel. 075; rel. 076; rel. 077; rel. 078; rel. 079; rel. 080; rel. 083; rel. 084; rel. 086; rel. 087; rel. 088; rel. 089; rel. 090; rel. 091; rel. 092; rel. 093; rel. 094; rel. 095; rel. 096; rel. 097; rel. 099; rel. 100; rel. 101; rel. 102; rel. 104; rel. 105; rel. 107; rel. 108; rel. 109; rel. 110; rel. 118; rel. 119; rel. 123; rel. 125; rel. 126; rel. 128; rel. 129; rel. 148; rel. 151;

Paspalidium geminatum (Forssk.) Stapf ; AAM 1061; rel. 012;

Oplismenus hirtellus (L.) Beauv. ; AAM 1099; rel. 001; rel. 002; rel. 003; rel. 004; rel. 006; rel. 007; rel. 008; rel. 009; rel. 011;

Panicum aequinerve Nees ; AAM 1312;

Panicum maximum Jacq. ; rel. 012; rel. 015; rel. 017; rel. 018; rel. 019; rel. 027; rel. 082; rel. 099; rel. 134; rel. 140; rel. 141;

Setaria sphacelata (Schumach.) Moss var. *sericea* (Stap ; AAM 1070; rel. 007;

Melinis nerviglumis (Franch.) Zizka ; AAM 1079; rel. 157;

Melinis repens (Willd.) C.E.Hubb. subsp. *grandiflora* (Hochst.) Zizka; rel. 130;

Ehrharta calycina J.E. Sm. var. *angustifolia* Kunth ; AAM 1311a;

Tristachya leucothrix Nees ; AAM 1064; AAM 1124; rel. 021; rel. 022; rel. 023; rel. 024; rel. 025; rel. 028; rel. 029; rel. 033; rel. 036; rel. 038; rel. 039; rel. 040; rel. 041; rel. 042; rel. 043; rel. 050; rel. 051; rel. 052; rel. 062; rel. 064; rel. 065; rel. 066; rel. 068; rel. 070; rel. 078; rel. 079; rel. 081; rel. 085; rel. 087; rel. 088; rel. 089; rel. 111; rel. 113; rel.

116; rel. 117; rel. 120; rel. 121; rel. 122; rel. 123; rel. 124; rel. 127; rel. 131; rel. 132; rel. 146; rel. 147; rel. 148; rel. 149; rel. 150; rel. 151;

Helictotrichon hirtulum (Steud.) Schweick. ; AAM 1059;

Merxmuellera disticha (Nees) Conert; AAM 1384;

Pentaschistis setifolia (Thunb.) Mcclean; rel. 130;

Agrostis lachnantha Nees var. *lachnantha* ; rel. 005; rel. 065; rel. 069;

Aristida junciformis Trin. & Rupr. ; AAM 1125;

Eragrostis capensis (Thunb.) Trin. ; AAM 1150; rel. 001; rel. 026; rel. 120; rel. 136;

Eragrostis curvula (Schrad.) Nees ; AAM 1366; AAM 1081; AAM 1149; AAM 1313; AAM 1311; rel. 026; rel. 037; rel. 039; rel. 082; rel. 083; rel. 111; rel. 112; rel. 113; rel. 114; rel. 115; rel. 126; rel. 128; rel. 130; rel. 133; rel. 134; rel. 135; rel. 136; rel. 137; rel. 138; rel. 139; rel. 140; rel. 142; rel. 143; rel. 144; rel. 145; rel. 152; rel. 153; rel. 154; rel. 155; rel. 156; rel. 157; rel. 158; rel. 159; rel. 160;

Eragrostis gummiflua Nees ; AAM 1314;

Eragrostis obtusa Munro ex Fical. & Hiern; AAM 1236;

Eragrostis plana Nees ; AAM 1068;

Eragrostis atrovirens (Desf.) Steud. ; AAM 1063;

Cynodon dactylon (L.) Pers. ; rel. 133; rel. 134; rel. 135; rel. 137;

Melica racemosa Thunb. ; AAM 1322;

Festuca costata Nees ; rel. 020; rel. 021; rel. 022; rel. 024; rel. 025; rel. 028; rel. 032; rel. 033; rel. 036; rel. 037; rel. 038; rel. 039; rel. 040; rel. 041; rel. 042; rel. 043; rel. 044; rel. 047; rel. 048; rel. 052; rel. 053; rel. 055; rel. 057; rel. 058; rel. 059; rel. 060; rel. 062; rel. 063; rel. 064; rel. 068; rel. 073; rel. 074; rel. 075; rel. 076; rel. 078; rel. 079; rel. 080; rel. 081; rel. 083; rel. 085; rel. 091; rel. 094; rel. 095; rel. 097; rel. 098; rel. 099; rel. 100; rel. 102; rel. 104; rel. 105; rel. 107; rel. 108; rel. 109; rel. 114; rel. 117; rel. 118; rel. 120; rel. 122; rel. 123; rel. 124; rel. 125; rel. 127; rel. 128; rel. 129; rel. 130; rel. 131; rel. 132; rel. 147; rel. 148; rel. 149; rel. 150; rel. 151;

APPENDIX III: SYNOPTIC TABLE OF PLANT SPECIES IDENTIFIED IN SEVEN IDENTIFIED PLANT COMMUNTIES

A synoptic table of common pant species in seven identified plant communities at Rivendell farm near Grhamstown: the digits are constancy values: 1 = 5- 20%: 2 = 21- 40 %: 3 = 41- 60 %: 5 = 81 – 100%

Plant species	Forest	Bush clump	Acacia savannah	Grassland	Grassy fynbos	Fynbos Shrubland
Burchellia bubalina	4	3				
Maytenus heterophylla	5	2				
Psychotria capensis	5					
Rapanea melanophloeos	5	1				
Podocarpus falcatus	4					
Carissa bispinosa	5					
Scutia myrtina	1	4	4			
Plectranthus ecklonii	5					
Curtisia dentate	5					
Canthium inerme	5	3	1			3
Oplismenus hirtellus	5	2				
Hypoestes forskaoli	4					
Galopina circaeoides	4					
Nuxia floribunda	4	1				
Zanthoxylum capens e	2					
Gerbera cordata	2		1	1		
Cyperus albostriatus	4		1			
Acacia karroo		3	5			
Senecio punctata				1		
Catunaregam spinosa		4	2			
Eragrostis curvula		4	5	5		
Grewia occidentalis		5				
Centella coriacea		3		5	2	2
Helichrysum cymosum		3				1
Berkheya heterophylla		2		2		

Plant species	Forest	Bush clump	Acacia savannah	Grassland	Grassy fynbos	Fynbos Shrubland
Rhus dentate 1	1					
Rhus pallens		4				2
Helichrysum anomalum		1	2	1	2	
Selago dolosa		2	3	1		
Helichrysum herbaceum		1		2	3	
Anthospermum herbaceum			3			
Asparagus setaceus	1					
Cynodon dactylon	1	1				1
Cliffortia linearifolia	1	3	3	1		1
Hypochoeris radicata		2				
Helichrysum odoratissimum				2	4	1
Tephrosia grandiflora			5	2	3	
Indigofera zeyheri		1				
Tristachya leucothrix		2		1	4	3
Erica brownleeae		1		2	1	
Senecio albanensis				2	2	
Themeda triandra		4		3		
Helichrysum subglomeratum		2		5	4	2
Disparago tortilis		1				2
Restio filiformis			1	3	3	2
Euphorbia striata		1				
Rhodocoma capensis		1		2	2	
Festuca costata			1	2	4	3
Pellaea calomelanos				1		
Gazania krebsiana				1		
Senecio speciosus				1	2	
Alloteropsis semialata				3	3	3
Agathosma ovata				1	1	
Anthospermum aethiopicum				2	3	2

Plant species	Forest	Bush clump	Acacia savannah	Grassland	Grassy fynbos	Fynbos	Shrubland
Metalasia muricata					1	2	4
Erica cerinthoides						1	1
Gnidia nodiflora					1	1	
Hypoxis villosa					1	1	
Cymbopogon marginatus					1	2	
Elegia stipularis							2
Athanasia dentata						1	2
Chironia tetragonal						1	
Eriosema burkei					1	1	
Phylica paniculata					1	3	
Berzelia intermedia					1	1	
Brachylaena elliptica					1	1	
Leucadendron salignum					1		
Commelina diffusa					1	1	
Wahlenbergia oppositifolia				1			
Chironia tetragona					1		
Crassula vaginata						1	
Miscanthus capensis					2	1	
Aloe ecklonis				1	1		
Lobelia neglecta				1			
Cyperus sp.				1		1	
Psoralea pinnata				1			
Monsonia ovata				1			
Thunbergia capensis					1		
Agathosma pegleriae						1	
Clutia affinis						2	
Chaetacanthus setige						1	

APPENDIX IV: THE CHECKLIST OF POLLEN GRAIN OF PREPARED REFERENCE SLIDES.

Plant species	Voucher number
Acacia longifolia (Andr.) Willd.;	AAM1000
Agathosma ovata (Thunb.) Pillans;	AAM1019
Agathosma pegleriae Dimmer;	AAM1244
Aloe ecklonis Salm-Dyck;	AAM 1404;
Apodytes dimidiata Arn. var. *dimidiata*	
Aspalathus frankenioides DC.;	AAM1194
Asparagus densiflora;	AAM1135
Athanasia dentata (L.) L.;	AAM 1042
Behnia reticulata (Thunb.) Didr.;	AAM 1092;
Berkheya heterophylla (Thunb.) O. Hoffm. Var	AAM1135
Berzelia intermedia (Dietr.) Schlechtd.;	AAM1141
Berzelia intermedia (Dietr.) Schlechtd.;	AAM1141
Bobartia gracilis Bak.	AAM1025
Burchellia bubalina (L. f.) Sims;	AAM1002
Callistemon rigidus R. Br.;	AAM1199
Carissa bispinosa (L.) Desf. ex Brenan subsp. bispinosa;	AAM1179
Cassine cf. peragua L.;	AAM1098
Chrysanthemoides monilifera (L.) T. Norl.	AAM 1055
Chrysocoma ciliata L.;	AAM 1122
Clutia pulchella L.;	AAM1008
Conyza ulmifolia (Burm. f.) Kuntze;	AAM1048
Cotula heterocarpa DC.;	AAM1049
Crassula cultrata L. x C. nudicaulis.	AAM1130
Crassula pellucida L	
Dipogon lignosus (L.) Verdc.	
Dipogon lignosus (L.) Verdc.;	AAM1007
Erica caffra L.;	AAM1001
Erica cerinthoides L.;	AAM1027
Erica chamissonis Klotzsch ex Benth;	AAM1138
Erica demissa Klotzsch ex Benth. var. demissa;	AAM1173
Erica glumiflora Klotzsch ex Benth.;	AAM1028
Erica nemorosa Klotzsch ex Benth.;	AAM1013
Erythrina lysistemon Hutch.;	AAM1159
Eucalyptus camaldulensis Dehnh.;	AAM1267
Gazania krebsiana Less. subsp. *arctotoides* (Less.) Robyns	
Gnidia nodiflora Meisn.;	AAM1119
Grewia occidentalis L. f. var. occidentalis;	AAM1191

Halleria lucida	AAM1035
Helichrysum cymosum (L.) D. Don	AAM 1205
Helichrysum odoratissimum (L.) Sweet;	AAM 1185
Helichrysum subglomeratum Less.	AAM 1017
Hypoestes forskaolii (Vahl) R. Br	AAM1100
Indigofera stenophylla Eckl. & Zeyh. ,	AAM1259
Leonotis leonurus (L.) R. Br.;;	AAM1350
Maytenus acuminata (L. f.) Loes.;	AAM1075
Maytenus heterophylla (Eckl. & Zeyh.) N.K.B. Robson;	AAM1020
Metalasia muricata (L.) D. Don	AAM 1011
Monopsis unidentata (Dryand) E.	AAM1208
Moraea polystachya (Thunb.) Ker-Gawl.;	AAM 1046
Nuxia floribunda Benth.;	AAM1009
Nymphoides indica (L.) Kuntze	AAM1249
Nyphaea sp	AAM1203
Olea capensis L. subsp. *capensis*	
Passerina vulgaris Thoday	AAM1193
Passiflora coerulea L.;	AAM1234
Pavetta lanceolata Eckl.;	AAM1090
Pelargonium capitatum (L.) L'Herit.;	AAM1190
Pelargonium zonale (L.) L'H,rit.;	AAM1037
Plectranthus ecklonii Benth.;	AAM1396;
Psoralea pinnata L.;	AAM1014
Psychotria capensis (Eckl.) Vatke	AAM1093
Restio filiformis Poir.;	AAM 1148
Rhus dentata Thunb.;	AAM1166
Rhus pallens	AAM1051
Rhus pallens Eckl. & Zeyh.;	AAM1051
Rhus tomentosa L.;	AAM1152
Scabiosa columbaria R.A. Dyer;	AAM1213
Scutia myrtina (Burm. f.) Kurz;	AAM1050
Sebaea hymenosepala Gilg;	AAM1163
Selago corymbosa L.;	AAM1240
Senecio chrysocoma Meerb.	AAM 1230
Senecio pterophorus	
Senecio speciosus Willd.;	AAM 1038
Sonchus asper (L.) Hill subsp. asper;	AA M 1129
Struthiola argentea Lehm.	AAM1115
Sutera cAAMpanulata (Benth.) Kuntze;	AAM1033
Syzygium cordatum	AAM1161
Syzygium cordatum Hochst.;	AAM1161
Tephrosia grandiflora (Ait.) Pers.;	AAM1112
Trifolium burchellianum Ser. subsp. burchellianum;	AAM1221

APPENDIX V: DETERMINATION OF PLOT SIZE USING THE MINIMAL AREA CURVE FOR DIFFERENT VEGETATION UNITS.

Vegetation type	**Quadrat size**
Fynbos	$4m^2$ (2mx2m)
Grassland	$1m^2$ (1mx1m)
Shrubland	$16m^2$ (4m x4m)
Forest	$100m^2$ (10mx10m)

APPENDIX VI: CALIBRATION CURVE OF SAMPLE REACTION OF PROTEIN DETERMINATION

I Preparation of stock solution.

1 mg of Bovine serum albumen (BSA) was dissolved in 1ml-distilled water to give a stock solution of 1mg/ml.

BSA concentration mg/ml	BSA (ml).	Distilled water (ml)	Bradford reagent (ml)	Abs. at 595nm
0	0	0	250	0
0.4	1	4	250	0.1155
0.8	2	3	250	0.2355
1.2	3	2	250	0.3775
1.6	4	1	250	0.462
2	5	0	250	0.609