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BEE PLANT INVENTORY AND THE POLLEN POTENTIALITY OF MENAGESHA SUBA STATE FOREST FOR BEEKEEPING UTILIZATION

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ABSTRACT: The study was designed with the objectives of assessing the pollen yielding plant species and to establish, the flowering phenology of bee plants. Pollen was collected from the zander beehives using the pollen trap fitted to the entrance of beehives for two years. The pollen was identified using light microscope with a 400x magnification. The nutritive analysis was made for total nitrogen, protein and mineral for bee collected pollen at Holeta Agricultural Research Center soil and plants laboratory. Fifty eight plant species were identified as a source of nectar and pollen or pollen, of which 27 plant species were the major pollen source plants in the area. Nutritional analysis indicated that pollen from *Andropogon abyssinicus*, *Cyanotis barbata*, *Eucalyptus camaldulensis, Eucalyptus globulus, Justicia ladanoides, Justicia schimperiana*, and *Trifolium* spp. were high in protein. Menagesha Suba State Forest was found to be rich in pollen and nectar source plants and therefore integration of beekeeping with forest conservation program is highly recommended for sustainable utilization of this forest.

Key words/phrases: Menagesha, Pollen, Protein, Vegetation

INTRODUCTION

Forests provide a wide range of economic, social, environmental and cultural benefits particularly in a country like Ethiopia, which has a predominantly traditional society with rural structures. Ethiopia has diverse climate and topography which favors the growth of wide range of plants. There are about 6000-7000 species of flowering plants (Edwards, 1976) of which the majority are bee plants. These mainly comprise forest trees, shrubs, weeds and cultivated crops. The existence of diverse floral resources coupled with variable climate, and edaphic factors enable the country to sustain around ten million honeybee colonies that belong to five geographical races (Amssalu Bezabeh *et al.*, 2003).

The country stands first in Africa in honeybee population which would be an evidence for the enormous potential of the country for apiculture development (Reinhard and Admassu, 1994). The annual production of honey in Ethiopia is estimated at 30,000 tones (MoARD, 2003) and significant proportion of the honey comes from natural forests. With this

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amount, Ethiopia is the largest honey producing country in Africa and worldwide, it ranks tenth (Demel Teketay, 2004).

The analysis of bee plant pollen loads and palynological analysis of honey samples can provide a true picture of honeybee flora of the area that provides food for honeybees and other pollinators in the ecosystem (Hepburn *et al*., 1998). Due to high content of proteins, amino acids and minerals, pollen has many applications as basic nutrition for honeybees and as a nutritional complement for humans.

Pollen provides honeybees with a 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 honeybees (Pernal and Currie, 2001).

The Menagesha Suba State Forest is one of a few protected forest batches in the central parts of the country. The area is part of the central plateau covering an altitudinal range from 2200-3385 m a.s.l. This natural forest covers about 2500 ha and is described by Friis (1992) as one of the undifferentiated afromontane forests. The floristic composition of this forest was surveyed by Breitenbach (1962), Gilbert (1970), Henry (1973) and Sebsebe Demissew (1980, 1988). The Forest has a great potential for beekeeping development and thus may contribute to improving the livelihood of the surrounding communities (Reinhard and Admassu Addi, 1994; Debissa Lamessa, 2006). However, the Forest is under continuous threat by expansion of human population pressure from all sides. Owing to such a human pressure, trees and under-story plants used for honey production are under threat resulting in loss of biodiversity. In this study, an attempt was made to assess the species composition, pollen potentiality of bee plants and their contribution for honey production. Therefore, the aim of this study was to identify the dominant pollen source plants, document seasonal flowering phenology and analyse the quality of bee collected pollen.

MATERIALS AND METHODS

The study was conducted in Menagesha Suba State Forest, which is located in central Ethiopia, about 43 km southwest of Addis Ababa between longitudes $38^0 30'$ to $38^0 39'$ east and Latitudes 08^0 55' to 09^o 04' north in Oromia Regional State. It experiences seven months of rain from March to September with the highest concentration in July and August (Daniel Gamachu, 1977). The mean annual rainfall is about 1150 mm and the mean

annual temperatures varies from 11-22^{0}C with lower temperatures at higher altitudes.

Colony establishment and pollen collection

Two representative sites were selected based on vegetation condition and altitude. Honeybee colonies were established at selected sites in the Forest. Plants in various plant communities visited by honeybees were observed within a one kilometre radius of the honeybee colonies. Field observations were used to record the type of food source offered by plants, their flowering periods and type of habitat.

Pollen trapping

Pollen loads were collected from four established honeybee colonies for 12 months from February 2005 to February 2006 using a pollen trap having 16% pollen trapping efficiency fitted at the entrances of hives (Synge, 1947). The pollen trap efficiency was measured during October when the major plant species were in flower by counting 100 bees entering the hives with pollen loads on their legs. The trap was 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 were scrapped off from the legs of honeybees to the collecting tray.

Analysis of pollen and reference pollen preparation

A total of 1008 pollen samples were analyzed and trapped pellets were collected, weighed, and dried overnight at room temperature and then sorted by color and size. Representative pellets of each color were washed with ether and mounted on glycerin jelly for microscopic examination. To identify the pollen pellets collected by the honeybees, a sample of ripe pollen grains were collected from mature flower buds directly from the field and flower samples were kept in individual envelopes to avoid contamination with the pollen grains of other species. 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 covered with a cover slip and examined under a light microscope with 400x magnification.

Pollen analysis of honey

The honey pollen analysis protocol developed by Louveaux *et al*. (1970) was used for the preparation of slides and identification of pollen grains in honey samples. From each sample 10 gm of honey was dissolved in 20 ml of distilled water, the solution was centrifuged for 10–15 minutes at 3000 rpm and repeated when necessary; the sediment was transferred to a microscopic slide and examined under a light microscope with a 400X magnification.

Analysis of pollen for Nitrogen, Phosphorus and Potassium (NPK)

Analysis was made for crude protein, nitrogen, phosphorus and potassium contents at Holeta Agricultural Research Center soil and plants laboratory. A Kjeldahl method (Tekalign Tadesse *et al.,* 1991) for determining nitrogen was used; crude protein is calculated by multiplying 6.25 by %N. This is based on %N in 100 g protein. Dry ashing and wet digestion procedures were used for determining P and K contents in pollen following Sahlemedhin and Taye Bekele (2000).

Brood measurement and honey flow period

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 into units. 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 was recorded and the brood populations were calculated from the total area occupied by the brood. For the determination of honey flow period, eight honeybee colonies were established and honey yield and time of honey harvest were recorded. In addition, the beekeepers in the area were interviewed for the right honey flow period of the area.

RESULTS

Bee flora observation

Fifty eight plant species in 34 families were identified being visited by honeybees that were collecting either pollen or nectar or both (Appendix 1). Only a few plant species such as *Podocarpus falcatus* and ferns were not visited by honey bees. It was also observed that honey bees collected a sugary substance from *Cupressus lusitanica,* probably honeydew excreted by aphids.

Identification of pollen source plants

A total of 27 pollen source plant species were identified from different sites within the Menagesha-Suba State Forest (Table1). Most of the pollen grains collected by bees (74.7%) came comparatively from a few plant species: *Echinops macrochaetus, Eucalyptus globulus*, *Plantago lanceolata, Guizotia scabra*, *Hypoeste*s spp., *Croton macrostachyus,* and *Trifolium* spp. It was interesting to find pine pollen in pollen traps, thus indicating that pine plantations are sources of food for honeybees or the pollen grains of pine fell into the trays while being transported by wind.

Table1. Bee plant pollen on dry weight basis in weight/gm.

Plant species	Family	Pollen Sample weight (gm)	% Weight
Acacia abyssinica	Fabaceae	1.6	0.165
Indet.Acanthaceae	Acanthaceae	8.9	1.815
Indet.Asteraceae	Asteraceae	0.2	0.0204
Andropogon abyssinicus	Poaceae	6.0	0.614
Apodytes dimidiata	Icacinaceae	1.4	0.143
Bidens spp.	Asteraceae	24.0	2.462
Caesalpinia decapetala	Fabaceae	.0.0043	0.04
Croton macrostachyus	Euphorbiaceae	19.8	2.028
Cyanotis barbata	Commelinaceae	16.4	1.686
Cyperus spp.	Cyperaceae	25.7	0.026
Echinops macrochaetus	Asteraceae	158.5	16.24
Eucalyptus camaldulensis	Myrtaceae	52.8	5
Eucalyptus globulus	Myrtaceae	138.3	14.17
Grevillea robusta	Proteaceae	7.5	0.772
Guizotia scabra	Asteraceae	105.0	10.76
Hypoestes spp.	Acanthaceae	58.3	5.014
Justicica ladanoiides	Acanthaceae	8.8	0.903
Justicia schimperiana	Acanthaceae	13.5	1.386
Olea europaea subsp.*cuspidata*	Oleaceae	2.0	0.2
Pinus patula	Pinaceae	7.4	0.757
Plantago lanceolata	Plantaginaceae	215.1	22.044
Indet.grass Poaceae	Poaceae	0.4	0.04
Senecio spp.	Asteraaceae	9.6	0.984
Silybum marianum	Asteraaceae	5.2	5.329
Trifolium spp.	Fabaceae	65.8	6.75
Unknown pollen	-	6.3	0.634
Vernonia amygdalina	Asteraceae	7.9	0.809

According to registration of flowering period of plant species and analysis of seasonal pollen load collection, the majority of bee plant species flowered

from the end of August through September and reached peak in October and November. Approximately 58.06% bee plant species flowered during the active season (September to November), 22.58% during the dry season (December to February), 11.29% during the small rainy season (March-May) and 8.67% during the big rainy season (June-August). The flowering pattern of the plants across the months is given in Fig.1. There was considerable variation among the plant species with respect to time of flowering. It was interesting to note that the majority of plant species flowered during September–October but no honey flow was recorded. Even though the number of flowering plant species during December to January was small, it was one of the honey flow periods in the area.

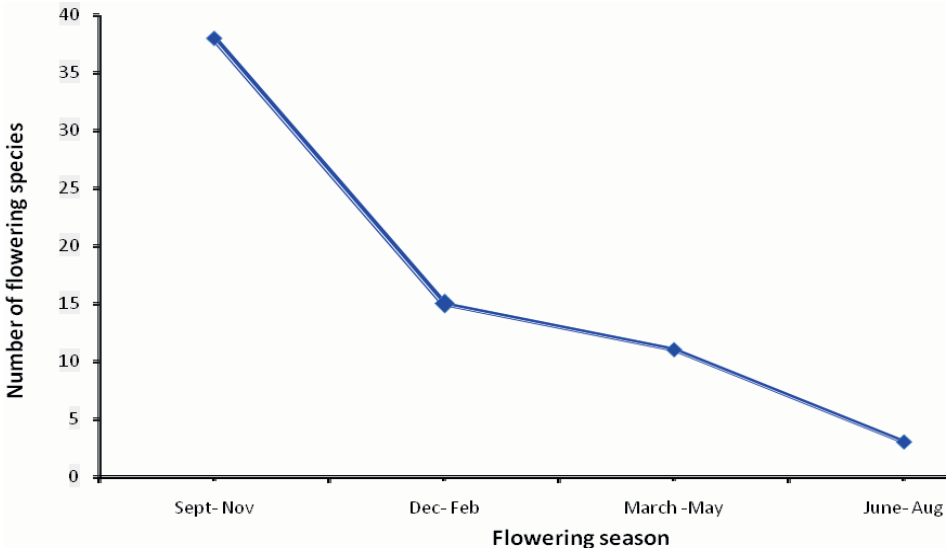

Fig 1. The flowering intensity of bee plants in the study area.

Bee pollen nutritional analysis

Pollen protein and mineral analysis were made for the major pollen source plants of 17 species as presented in Table 2. The content of crude protein varied from 14% to 29% for pollen source plants while it was lower for *Pinus patula* (8%). The total nitrogen content ranged from 2% to 5%. The K content of the bee pollen also varied from 0.6% to 6.4% and the P content of analyzed bee pollen of the plant species was generally low when compared

to the other mineral contents. Pollen from *Andropogon abyssinicus*, *Cyanotis barbata*, *Eucalyptus camaldulensis, Eucalyptus globulus, Justicia ladanoides, Justicia schimperiana* and *Trifolium* spp. were found to be high in protein content (Table 2). However, the protein content of identified plant species was not positively correlated with the quantity of pollen collected.

Table 2. Bee pollen protein and mineral content.

Plant species	Family	Pollen weight proportion (%)	Crude protein (%)	N (%)	P (%)	K (%)
Hypoestes triflora	Acanthaceae	1.71	18.44	2.95	0.34	2.44
Bidens prestinaria	Asteraceae	2.91	13.94	2.23	0.25	2.09
Trifolium sp.	Fabaceae	13.73	20.68	3.31	0.40	3.78
Eucalyptus globulus	Myrtaceae	7.77	23.56	3.77	0.54	4.33
Eucalyptus camldulensis	Myrtaceae	7.19	18.75	3.00	0.56	3.81
Croton macrostachyus	Euphorbiaceae	2.39	17.50	2.80	0.69	4.59
Acacia abyssinica	Mimosoidae	0.12	16.06	2.57	0.37	4.81
Olea europaea subsp.*cuspidata*	Oleaceae	0.50	13.25	2.12	0.29	3.97
Guizotia scabra	Asteraceae	2.91	15.50	2.48	0.24	2.32
Pinus patula	Pinaceae	7.39	7.87	1.26	0.23	2.73
Justicia ladanoides	Acanthaceae	0.17	19.06	3.05	0.42	4.56
Justicia schimperiana	Acanthaceae	2.67	28.68	4.59	0.65	5.99
Cyanotis barbata	Commelinaceae	4.17	26.31	4.21	0.55	4.68
Eucalyptus grandis	Myrtaceae	7.40	14.69	2.35	0.38	5.17
Andropogon abyssinicus	Poaceae	0.92	19.87	3.18	0.45	6.38
Echinops macrochaetus	Asteraceae	13.54	14.50	2.32	0.10	0.65
Plantago lanceolata	Plantaginaceae	16.15	16.12	2.58	0.35	5.51
Vernonia amygdalina	Asteraceae	7.50	15.40	2.47	0.47	3.99
Apodytes dimidiata	Icacinaceae	6.51	16.18	2.59	0.64	4.90

Brood population

The brood rearing pattern of honeybees (*Apis melleifera bandasi*) positively correlated with monthly pollen weight ($r=0.58$; $P<0.001$). Both brood population and the incoming pollen weight were highest between September-October and April-May and lowest in December-January (Fig.2). There was fluctuation in both pollen flow and brood rearing pattern depending on the weather.

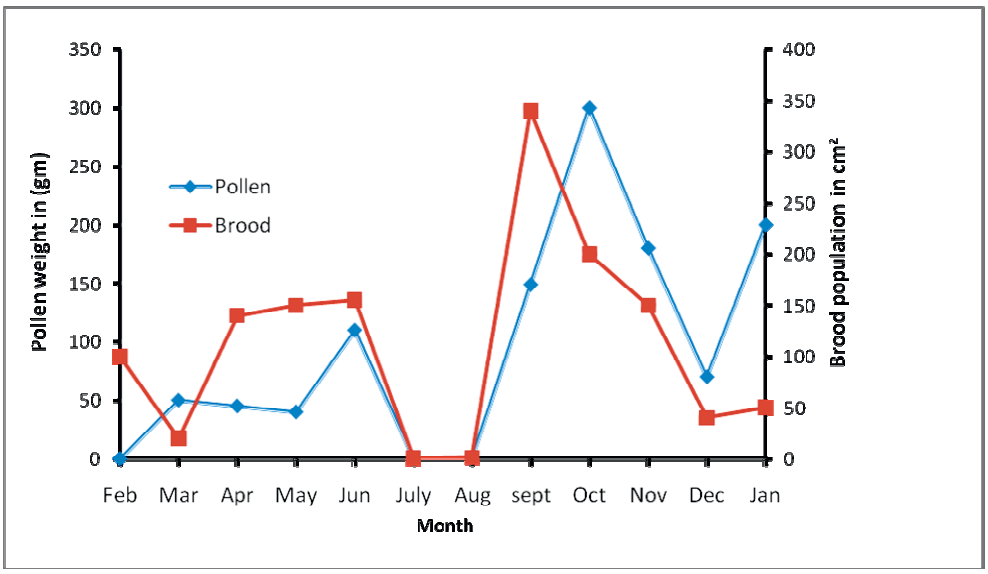

Fig. 2. The relation between the monthly pollen weight and brood population of the study area.

DISCUSSION

Fifty eight honeybee nectar and pollen source plants were identified within a one kilometre radius of the foraging area of the bees. The number of major bee plant species identified was relatively small compared with the floral richness of the forest, probably due to the floral preference of honeybees.

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 27 plant species identified from the pollen trap, the bulk of pollen came from only a few plant species. This is because the pollen yielding potential of an area depends not only on the number of plant species but also their relative abundance and floral preference of the honeybees. This result is also supported by findings of Free (1970), Heinrich (1975) and Percival (1955), who have suggested that honeybees forage on more productive and profitable plants that provide necessary nutrition nearby their hives.

Even though the identification of *Pinus patula* pollen in pollen trap indicates that pine plantations may be considered a source of bee forage, the proportion of collected pollen is insignificant. The reason for the low proportion of pollen loads may be due to accidental mixing of windborne pollen of pine with other pollen grains since honeybees were not observed collecting the pollen from pine species.

The positive correlation of monthly pollen weight and brood population revealed that honeybees require an influx of fresh pollen to raise their brood. Pollen affects the performance of the bee colony because pollen storage level reflects the potential for rapid growth in brood production. The pollen collection was highest during September-October and April-May due to increased need of pollen in the hive for brood rearing but there was a slight decline of pollen collection during November and June due to switching of honeybees from pollen collection to nectar collection for storing honey to be used during the rainy season (Kiremt).

Pollen quality has a considerable influence on aspects of colony performance such as brood rearing, growth and longevity. The determination of crude protein and N content of bee pollen from plant species showed a wide range of variation. The plant species identified with dominant pollen weights had lower protein and N content (*Echinops macrochaetus, Plantago lanceolata* and *Trifolium* spp. while plant species with lower pollen weights were found to be higher in protein content (*Acacia abyssinica, Andropogon abyssinicus, Croton macrostachyus, Hypoestes triflora, Justicia ladanoides, Justicia schimperiana* and *Olea europaea* subsp.*cuspidata).* Therefore, the preference of honeybees for protein may not depend on quantity of pollen collected but availability of the resource and their needs in the hives. This indicates that the pollen collection by honeybees is not based on the quantity of N, P and K found in pollen. Generally, when comparing with the existing literature (Somerville, 2001; cited in Debissa Lamessa, 2006) on average basis the protein and N content is optimum while P and K content of the bee pollen of the identified plants is low. This might be related with the soil condition of the area.

According to field records of the flowering period, the majority of bee plant species flowered from September through October and May to June following the rainy seasons. It is remarkable to note that although the majority of plant species flowered during September-October, this bloom period doesn't overlap with honey flow period in the area which might be due to most of the herbaceous flora including the weeds and under-story plants, finishing flowering earlier before the main honey flow period (October-November). Furthermore, the absence of field crops such as oil crops, pulses and others near the forest also affects the honey flow period of the area.

The number of plant species flowering during December to January is small, but December-January is one of the minor honey flow periods in the area

due to the availability of a few plant species which are able to provide abundant nectar that can be converted to honey by bees. According to honey pollen analysis: *Hypoestes* spp., *Vernonia amygdalina, Eucalyptus camaldulensis, Justicia schimperiana* and *Guizotia scabra* were the major sources of honey during minor honey flow (January–February) accounting for 25.9%, 23.5% 16.8%, 6.4% and 3.8% pollen frequency, respectively. These plant species are also found in pollen loads of bee collected pollen and verified in field observation, signifying that they are important pollen and nectar source plants for honey production.

CONCLUSION AND RECOMMENDATION

Both pollen load collection and field observation showed that Menagesha Suba State Forest is rich in floral diversity, which included many species used by honeybees for pollen forage such as *Echinops macrochaetus, Eucalyptus* spp., *Hypoestes triflora, Justicia* spp., *Trifolium* spp., *Plantago lanceolata, Guizotia scabra, Vernonia amygdalina* and *Croton macrostachyus*. The protein content of identified plant species was only weakly correlated with the quantity of pollen collected and thus the protein value of the pollen does not appear to play a major role in pollen preference. Honey flow was greatest in December to January and May to June although the majority of plant species flowered during September–October. The Mengesha Suba State Forest has potential for beekeeping development due to the availability of rich pollen and nectar source plants. Integration of beekeeping with the forest management program is recommended for sustainable honey production and conservation of the remaining forest.

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Appendix 1. Nectar and pollen source plant species identified in the study area.

Plant species	Family	Food source	Flowering period
Bidens prestinaria	Asteracaeae	N and P	Sept-Oct
Senecio spp.	Asteracaeae	N and P	Sept-Oct
Glycine wightii	Fabaceae	N and P	Sept-Oct
Cirsium schimperi	Asteracaeae	P	Sept-Oct
Tagetes minuta	Asteracaeae	P	Sept-Oct
Trichodesma africana	Boraginaceae	N and P	Sept-Oct
Caylusea abyssinica	Resedaceae	N and P	Dec-Jan
Solanecio gigias	Asteracaeae	P	Sept-Oct
Solanum spp.	Solanaceae	N and P	Sept-Oct
Croton macrostachyus	Euphoprbiaceae	N and P	Feb-May
Hypoestes triflora	Acanthaceae	N and P	Feb-Oct
Geranium spp.	Geranaceae	N and P	Sept-Oct
Achyranthes aspera	Amaranthaceae	P	All year
Pennisetum sphacelatum	Poaceae	P	Sept-Oct
Galinsoga parviflora	Asteraceae	N and P	Sept-Oct
Commelina spp.	Commelinaceae	P	Sept-Oct
Epilobium hirsutum	Onagraceae	N	Sept-Oct
Thunbergia alata	Acanthaceae	N	Sept-Oct
Saturja paradoxa	Lamiaceae	N and P	Sept-Oct
Trifolium semiplosum	Fabaceae	N and P	Sept-Oct
Trifoium rupellianum	Fabaceae	N and P	Sept-Oct
Datura stramonium	Solanaceae	N	Sept-Oct
Salvia leucantha	Lamiaceae	N	Sept-Oct
Clausena anisata	Rutaceae	N and P	May-June
Cyanotis barbata	Commelinaceae	P	Sept-Oct
Saturja punctata	Lamiaceae	N and P	Sept-Oct
Hibiscus spp.	Malvaceae	P	Sept-Oct
Rumex nepalense	Polygonaceae	P	Sept-Oct
Urtica simensis	Urticaceae	P	Sept-Oct
Solanium nigrum	Solanaceae	N and P	Sept-Oct
Caealpinia decapetala	Fabaceae	N and P	Sept-Oct
Justicia schimperiana	Acanthaceae	N and P	Dec-Jan
Rumex nervosus	Polygonaceae	P	Sept-Oct
Grevillea robusta	Proteaceae	N	Nov-Jan
Cucurbita pepo	Cucurbitaceae	N and P	Sept-Oct
Impatiens rothii	Balasiminaceae	N	Sept-Oct
Plectranthus punctata	Lamiaceae	N and P	Dec-Jan
Laggera crispata	Asteraceae	P	Dec-Jan
Echionops macrochaetus	Asteraceae	P	Dec-Jan
Vernonia amygdalina	Asteraceae	N and P	Dec-Jan
Olea europaea subsp.cuspidata	Oleaceae	N and P	April-June
Bersama abyssinica	Melianthaceae	N and P	Sept-Oct
Calpurea aurea	Fabaceae	N and P	Sept-Oct

Appendix 1. contd.

Sideroxylon oxyacanthum	Sapotaceae	N and P	Dec-Jan
Olinia rochetiana	Oliniaceae	N and P	Dec-Jan
Carrisa spinarum	Apocynaceae	N	Dec-Jan
Kalancho petitiana	Crassulaceae	N	Sept-Oct
Eucalyptus spp.	Myrtaceae	N and P	March-June
Scadoxus multiflora	Amaryllidaceae	P	March-June
Hagenia abyssinica	Roseaceae	N and P	Sept-Oct
Rhus glutinosa	Anacardiaceae	N and P	Sept-Oct
Albizia gummifera	Fabaceae	N andP	Nov-Jan
Acacia abyssinica	Fabaceae	N and P	Nov-Jan
Erica arborea	Ericaceae	N and P	March-May
Phytolacca dodcandra	Phytolacaceae	N and P	Sept-Oct
Ekebergia capensis	Meliaceae	N and P	Nov-May
Cupressus lusitanica	Cuperaceae	P	-
Pinus patula	Pinaceae	P	-