REPRODUCTIVE BIOLOGY AND UTILISATION OF *Berchemia discolor* (Klotzsch) Hemsley (RHAMNACEAE)

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Thesis presented in partial fulfilment of the requirements for the degree of M.Sc. in Forestry Sciences at the University of Stellenbosch.

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Declaration

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in it's entirety or in part submitted it at any other university for a degree.

Date: 12/11/99

SUMMARY

Berchemia discolor is an indigenous African fruit tree species with potential in terms of commercialisation and domestication. Indigenous fruit tree species play a role in the socio-economic well being of small-scale farmers and rural communities. To facilitate the process of domestication and commercialisation of *B. discolor*, it is important to learn more about the biology of the species, nutritional value of the fruit, and if potential markets exist for the fruit.

Fieldwork was carried out in Caprivi and Omusati in northern Namibia in order to study the reproductive phenology and the floral and pollination biology of the species. Analysis of the nutritional value of the fruit was carried out on the dry fruit pulp to assess the nutrients, minerals and vitamins contained in the fruit. In addition to this a socio-economic survey was carried out to assess the current trade in fruit and the utilisation of the tree and its products.

The length of the reproductive phase during the 1996-97 season extended from mid October to end of March in Caprivi and from beginning of November to early April in Omusati. Vegetative growth and flower bud formation in Omusati occurred just after the onset of the first rain whereas in Caprivi it occurred two weeks prior to the onset of the rain.

The flowers of *B. discolor* are dichogamous and protandrous. Pollinators are probably attracted to the flowers by olfactory stimuli, however visual stimuli also play a role as the flowers are greenish-yellowish in colour and several flowers are borne together in the inflorescence. Insect visitors to the flowers were identified as belonging to four different orders (Hymenoptera, Diptera, Coleoptera and Heterophera). Three of these orders have genera which may represent potential pollinators of *B. discolor*. Stigma receptivity probably occurred only after the elongation of the pistil subsequent to the presentation of pollen.

The dry fruit pulp of *B. discolor* is rich in carbohydrates, calcium, sodium, iron, magnesium and potassium, but it is not a good source of phosphorus, fat, protein and ascorbic acid. The fruit trade is important for generating income, which is used to acquire other goods and services by the rural people. *B. discolor* could, subject to improvements on fruit quality and marketing become one of the commercial fruit in northern Namibia.

OPSOMMING

Berchemia discolor is `n vrugteboom inheems aan Afrika met kommersiële en ander gebruikerspotensiaal. Inheemse vrugtebome speel 'n belangrike rol in die sosio-ekonomiese welvaart van klein-boere en die landelike gemeenskappe. Vir die benutting van *B. discolor* is dit nodig dat die spesie bestudeer word in terme van die biologie, die voedingswaarde van die vrugte en die bemarkingspotensiaal.

Veldstudies is in Caprivi en Omsusati in Owamboland in die noorde van Namibië uitgevoer om die voortplantings-fenologie, die blom- en die bestuiwings-biologie van die spesie te bestudeer. Die voedingswaarde van die vrugte is bepaal deur die vlees van die vrugte te verpulp, te droog en te analiseer vir die teenwoordigheid van voedingstowwe, minerale en vitamiene. 'n Sosio-ekonomiese opname is gedoen om die grootte van die verkoopsmark vir die produkte van die boom (hout en vrugte) te bepaal.

Die voortplantingsfase van die spesie gedurende die 1996-97 seisoen het gestrek van die middel van Oktober tot die einde van Maart in die Caprivi en van die begin van November tot die begin van April in die Omusati. Vegetatiewe groei en blomknopvorming in Omusati neem in aanvang net na die eerste reëns terwyl dit in die Caprivi twee weke voor die eerste reëns begin het.

Die blomme van *B. discolor* is digogaam en protandries. Bestuiwers word waarskynlik na die blomme gelok deur reuk stimuli, maar visuele stimuli kan ook 'n rol speel deurdat die blomme, `n groen-geel kleur het en verskeie blomme saam in `n bloeiwyse voorkom. Insekte wat moentlik vir die bestuiwings verantwoordelike is, behoort tot vier ordes (Hymenoptera, Diptera, Coleoptera en Heteroptera). Drie van hierdie ordes bevat genera wat kan dien as potensiële bestuiwers vir die spesie. Die stempel word ontvanklik eers nadat die stamper ten volle verleng het en nadat die stuifmeel vrygestel is.

Die droë pulp van die vrugte bevat 'n groot hoeveelheid koolhidrate, kalsium, natrium, yster, magnesium en kalium, maar is nie ryk aan fosfate, vette, proteiene en askorbiensuur nie. Die vrugte word deur die plaaslike inwoners versamel en vekoop, wat dien as bron van inkomste vir die verkryging van ander bestaansgoedere en dienste. *B. discolor* besit die potensiaal om

met verbeterings in vrug-kwaliteit en bemarking, een van die belangrikste kommersiële vrugte in die noorde van Namibië te word.

DEDICATION

This thesis is dedicated to the rural people of Namibia for the following reason:

During the last dasain (biggest Hindu festival) I had the goat I needed at home to slaughter but no money to buy spices. A local shop-owner supplied me with spices I needed in exchange for the fruit from my lapsi tree.

My daughter took about a dhwang (18 litres) of lapsi fruit to market and bought six notebooks for her studies.

As I had no money to pay the school fees for two of my children, I asked them to collect lapsi fruit on Saturday and take them to the market on their way to school. They took a small bag each and sold them so that they could pay their fees at school.

______________________________Krishna H. Gautam 1997

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INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Berchemia discolor (Klotzsch) Hemsley (Rhamnaceae) is an indigenous southern African fruit tree species of Namibia with economic potential. It has a rather wide distribution in northern, eastern, central and southern Africa. Other economically important indigenous species in southern Africa are *Sclerocarya birrea* (A. Rich.) Hochst., *Uapaca kirkiana* Muell. Arg., *Azanza garckeana* F. Hoffm. Exell & Hillcoat, and *Strychnos cocculoides* Baker (Taylor & Kwerepe 1995).

In various parts of southern Africa research programs have been launched with the aim of domesticating indigenous fruit tree species with economic importance. In Botswana a non-governmental organisation (NGO), Veld Products Research is working towards the domestication of *Sclerocarya birrea, Vangueria infausta* Burch., *Strychnos cocculoides, Azanza garckeana* and *Schinziophyton rautanenii* Schinz. (Taylor & Kwerepe 1995). In Zambia extensive research has been carried out on *Uapaca kirkiana* which has already established itself commercially (Mwamba 1989; Packham 1993). In Malawi the International Centre for Research in Agroforestry (ICRAF) has established field trials of various indigenous fruit tree species (Maghembe 1995). These research projects are carried out with the realisation of the following:

- There is a recent interest in the commercial utilisation of indigenous species. At the same time the current rate of deforestation requires that people ought to cultivate commercially valuable tree species (Leakey 1995).
- Indigenous trees are adapted to the local climate and therefore could offer a far better investment in terms of commercialisation and domestication (Kwesiga & Mwanza 1995).
- The value that rural people put on indigenous fruit can still be seen during land clearing for cultivation. Usually most of the trees will be cleared while fruit trees will be left on cultivated land (Maghembe 1995).
- Unlike urban people most rural people do not have direct access to exotic fruit like oranges, apples, pineapples and apricots. This is because the fruit are perishable and rural

areas are usually far away from the urban markets. Therefore indigenous fruit remain an important addition to the diet of rural people as they diversify the diet of these people and provide them with essential minerals and vitamins (Packman 1993).

So far very little work has been done towards domesticating indigenous fruit trees. Various reasons account for this:

- The high density of most indigenous trees in the woodlands has made it unnecessary for further tree planting to be carried out. However due to deforestation of woodlands it is no longer the case (Leach & Mearns 1988; Kwesiga & Mwanza 1995).
- Indigenous fruit trees are regarded as slow growers as well as being slow in reaching reproductive maturity. However the contrary has been proved for several species studied in Malawi (Maghembe 1995). These indigenous fruit tree species bore flowers and fruit within the ages of two to five years.
- The availability of exotic fruit on the local market has to some extent decreased the trade in indigenous fruit in urban areas. This is because in most cases exotic fruit are sold at higher prices in comparison to indigenous fruit. Fruit sellers prefer to sell a profitable product rather than a non-profitable one (Kwesiga & Mwanza 1995). The low market value of indigenous fruit is probably due to the fruit quality and it will only improve with improvements to the fruit quality.
- Commercialisation of indigenous species in general is being hampered by poor access to the markets as most rural areas do not have an effective transport infrastructure (Kwesiga & Mwanza 1995).
- Current land and tree tenure in some areas can discourage rural people from engaging in cultivation of indigenous fruit trees (Kwesiga & Mwanza 1995). In some cases although fruit trees are individually owned they are still accessed by the public.
- Commercialisation of indigenous species in general is being hampered by poor access to the markets as most rural areas do not have an effective transport infrastructure (Kwesiga & Mwanza 1995)

This is the first attempt to study the reproductive biology of *B. discolor*. Other work carried out on this species was mainly by Coates Palgrave (1984) concerning the description and general phenology. However Zietsman *et al.* (1989) worked on the reproductive biology of

Ziziphus mucronata subsp. *mucronata* Willd., a member of the Rhamnaceae family and also occurring in southern Africa.

1.2 Species characteristics

B. discolor belongs to the family *Rhamnaceae,* a family consisting of 55 genera and about 900 species (Cronquist 1981 cited in Zietsman 1988) and occurring in tropical and temperate regions (Johnston 1972). In southern Africa the family is mainly represented as trees and shrubs, while in other parts of the world the growth form ranges from herbs, shrubs to trees. The genus *Berchemia* is named after the French botanist, M. Berchemia (Palmer & Pitman 1972).

In Africa the genus is represented by only two species, both yielding edible fruit. *B. discolor* occurs from southern Africa to north Africa probably to Ethiopia, whereas *B. zeyheri* is confined to southern Africa. In South Africa *B. discolor* occurs in the north-eastern provinces (previously part of Transvaal) and Kwazulu-Natal. It is also found in Namibia, Mozambique, Swaziland, Botswana, Zimbabwe and Zambia (Palmer & Pitman 1972).

The specific epithet *discolor,* meaning different colours, refers to the different colours of the leaves. The leaves have a shiny dark green colour on the adaxial (upper) side and a pale green colour on the abaxial (lower) side (Palmer & Pitman 1972).

In older taxonomic revisions *B. discolor* was placed in the genus *Phyllogeiton*. Other synonyms for the species include *Scutia discolor* Klotzsch., *Adolia discolor* (Klotzsch) Kuntze, *Araliorhamnus punctata* H. Perr. and *Araliorhamnus vaginata* H. Perr. (Johnston 1972). Common names given to this species include brown ivory or bird plum in English, bruin ivoor in Afrikaans, muzinzila in Lozi, omuve in Oshiwambo, munyee in Shona and mosintsila in Tswana (Coates Palgrave 1984).

Several authors (Johnston 1972; Palmer & Pitman 1972; Van Wyk 1972; Palmer 1977; Fox &Young 1982; Coates Palgrave 1984) describe the tree as ranging from 7 —25 m tall. It is an erect deciduous tree, with a dense round crown (Fig.1.1). Van Wyk (1972) gives the stem diameter of a 14 m tall tree as being about 0.6 m. The bark is rough and fissured (Coates Palgrave 1984), with a colour-range of light grey to dark brown (Palmer & Pitman 1972).

25—80 mm and a width of about 15—50 mm (Van Wyk 1972). Leaves are opposite at the tip of the twig but become alternate away from the tip (Palmer & Pitman 1972).

Figure. 1.1 *B. discolor* tree on cultivated land in northern Namibia.

The small, bisexual, yellow to green flowers are borne in axillary cymes in groups of 1—4 (Fig. 1.2). The flowers give rise to oval-shaped fruit with an average length of 17 mm and a diameter of 8 mm. The fruit has a thin flesh surrounding a hard stone which contains two seeds. The fruit is green when unripe, becomes pale yellow when ripe and dark brown when dried (Van Wyk 1972). The fleshy part of the fruit is edible.

1.3 Ecology of the species

Distribution

In southern Africa *B. discolor* occurs in Namibia, Angola, Zimbabwe, Mozambique, Zambia and South Africa (Fig.1.3). In northern Namibia, the species occurs in areas around Otavi,

Figure 1.2 *B. discolor*: 1. Flowers and leaves. 2. Fruit and leaves. 3. Seed. (Coates Palgrave 1956).

Tsumeb, Oshakati, Ruacana, Grootfontein, Rundu and Katima Mulilo. In South Africa it is confined to areas of the north-eastern provinces (previously part of Transvaal) and Kwa-Zulu Natal. In east Africa it occurs in Uganda, Kenya and Tanzania (Johnston 1972). It also occurs in north Africa probably all the way to Ethiopia (Van Wyk 1972).

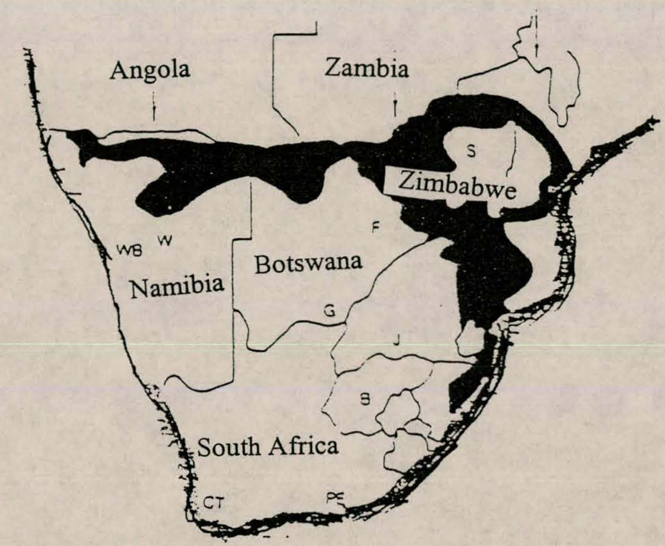


Figure 1.3 Distribution map of *B. discolor* in southern Africa (Coates Palgrave 1984) adapted to show country names.

Climate

Information on the climatic conditions for the natural range of *B. discolor* in literature could only be located for Namibia. In Namibia, *B. discolor* is confined to the northern parts of the country where the rainfall ranges from 400—700 mm per annum from the far north west to north east respectively. The maximum temperature during October and November which are the hottest months of the year is between 34—36^0 C. The average daily minimum temperature in winter in these areas is between 2—10^0 C (Erkillä & Siiskonen 1992).

Habitat

B. discolor is generally known to grow in semi-desert grasslands, wooded grasslands, riverine forests, rocky hillsides and on termite mounds (Johnston 1972; FAO 1983). In Namibia it is found in woodlands (tree savanna and riverine woodlands) and is usually associated with *Baikiaea plurijuga* Harms., *Colophospermum mopane* Kirk ex Berth., *Sclerocarya birrea,* *Hyphaene petersiana* Gaertn. and *Diospyros mespiliformis* Hochst.ex A.DC (Personal observation). It is almost semi-domesticated and is found growing on cropland in northern Namibia (Personal observation).

Phenology

Limited studies have been done on the phenology of *B. discolor*. The published information on phenology is mostly about flowering and fruiting periods. The species flowers from October to January and fruit from January to May (Coates Palgrave 1984). The flowering and fruiting periods mentioned here includes the site to site variation and the year to year variation per site. No information is available on leaf flush, shoot growth and leaf fall.

Reproductive biology

Since the species is not under cultivation, there is a big gap in the knowledge of the reproductive biology. Very little could be found in literature on seed production, seed dispersal, seed viability and longevity, vegetative regeneration and growth. According to Van Wyk (1972) no problems have been encountered with the germination of seeds, the only pre-treatment he recommended was to soak the seeds in hot water before germination. The seedlings are known to be very slow growers under natural conditions (Van Wyk 1972). It is not known how they perform under cultivation.

Uses

The fruit is used in several ways. It is eaten raw as fresh fruit, or dried to be kept in storage for longer. Fruit are also fermented to make a wine, from which a brandy can be distilled. The fruit is used as a dye in the basket making industry. This is done by boiling the fruit together with Makalani palm (*Hyphaene petersiana*) leaves, it dyes the leaves an orange colour. The bark of the tree is also used in the dyeing process and changes the leaves of the Makalani palm to a dark brown colour (Rodin 1985).

The timber is hard and heavy, the sapwood is light yellow and the heartwood has a reddish tinge. Presently there is not a high demand for the wood, probably because of the value of the fruit. In the past it was used for furniture carvings and door frames (Storrs 1995).

1.4 Objectives

Although indigenous fruit trees are important as a source of food and as a source of income to rural people, their future in the natural woodlands remains bleak as a result of clearing of natural vegetation. This resulted from increased population pressure, land use practices such as shifting cultivation and development of road and town infrastructure (Okafor & Lamb 1994). Therefore it is essential to embark on conservation strategies such as domestication, which will help indigenous fruit trees to persist as deforestation continues.

The objectives of the study are as follows:

- To investigate the reproductive phenology, fruit production, floral and pollination biology of *B. discolor*. This baseline information will facilitate improvement of the fruit of *B. discolor*.
- To determine the nutritional value of the fruit. There is no detailed information about the nutritional value of *B. discolor*, although Van Wyk (1972) mentioned that the fruit is rich in vitamin C. An analysis of the nutritional content of the fruit will give an indication of its role in the diet of rural people.
- To assess the socio-economic importance of *B. discolor* to the rural people of northern Namibia. Information on the utilisation and demand for the fruit and also the identification of a significant potential market in the trade of the fruit is necessary to justify its commercialisation and domestication at a larger scale.

Berchemia discolor can be successfully domesticated only after acquiring a better understanding of the reproductive biology. This will enable us to manipulate its production for our future needs. Geneticists carrying out further experiments on crossings and selection of superior phenotypes and genotypes can use knowledge of reproductive biology of the species. It is hoped that the work presented here may become a basis, which will encourage future studies on the species.

CHAPTER 2

PRELIMINARY SOCIO-ECONOMIC SURVEY ON THE UTILIZATION AND MARKETING OF *B. discolor* TREE AND FRUIT IN NORTHERN NAMIBIA

2.1 Introduction

Despite the progress in developing countries, a high number of people in rural areas still live in absolute poverty (Chambers 1989). Many rural people are entirely dependent on subsistence agriculture for their day to day survival, which is supplemented by forestry products such as indigenous fruit, honey, wild animals, fish, mushrooms and leaves (Campbell *et al.* 1996). Rural poverty is a result of fluctuations in agricultural production due to unproductive soils or recurrent droughts, the decline in non-timber forest products due to deforestation and increase in the rural population (Okafor & Lamb 1994).

To alleviate the conditions under which rural people find themselves, it is necessary for researchers to take the initiative in enabling the rural people to help themselves (Chambers 1989). To help rural people effectively, their needs have to be realised and projects must be designed addressing these issues. The planning of projects should include adequate information about conditions in rural communities.

Initially when researchers started investigating the needs of rural people they administered questionnaires, thereafter they designed research projects according to what they perceived as problems facing rural people. This approach failed in some cases because the perception of the researchers did not always reflect the reality of the situation with which rural people were faced with (Davis-Case 1989). In the next stage researchers, started consulting rural people about what they perceived as major problems and then they tried to provide solutions for them. During this stage it was realised that rural people sometimes already have their own solutions, which when intermingled with the technology of the researchers, could result in real changes in their situation. This gave rise to the current situation where researchers and rural people try to work in partnership to ensure the success of projects (Davis-Case 1989).

Although no documentation of the trade of *Berchemia discolor* in Namibia was found, the trade in the fruit has been going on for some years throughout the northern parts of the country. Initial observation show that the fruit is almost semi domesticated throughout northern Namibia as it is being maintained together with the other important tree species on the fields (pers. obs.). So far it is not yet known how important the income gained from the sale of fruit is to the people involved, who is involved in neither the trade nor the magnitude of the trade.

A study of the socio-economic significance of *B. discolor* was motivated because it is not only important as a fruit tree species but it has cash generating opportunities for rural people. The study aimed at providing an overview of the utilisation of the tree and fruit as well as the trade in the fruit. The information collected could then be used as a basis for recommendations that might have a positive impact on rural development.

The objectives of the study are four fold:

- To determine how important the sale of *B. discolor* fruit is to the rural communities of northern Namibia.
- To identify if a potential commercial market exists for the fruit and it's products.
- To determine how *B. discolor* fruit compare in importance to other indigenous and alien fruit trees consumed in the communities.
- To assess the applicability of Participatory Rural Appraisal (PRA) and Rapid Rural Appraisal (RRA) methods for the valuation of indigenous fruit trees.

2.2 Literature review

Natural forests provide goods and services such as food, fuel, and wood for construction and medicine, which are essential to the well being of rural communities (Campbell *et al.* 1996). In the past these goods and services have been considered free commodities but, increasingly due to their scarcity, they are no longer free and thus cost money (Muthoo 1991). In the past it was largely timber products which were assigned economic values. This is because the timber industry is a high income generating activity with an established market unlike most non-timber products like fruit, fuelwood, honey, medicines and mushrooms. However in terms of the well being of rural people the non-timber forest products are the most valuable ones (Muthoo 1991).

Indigenous fruit trees have a history of being a free commodity because they are not cultivated. Commercialisation of indigenous fruit trees is a recent development as rural societies move from a subsistence economy to a cash economy (McElwee 1994). Commercialisation is still in it's initial stages and it is affected by a number of factors such as the lack of policy, a lack of transport to the markets, low market values, insecure tenurial rights. These issues need to be resolved so that the indigenous fruit market can develop. (McElwee 1994).

Forests are rich in variety and quantity of fruit (Okafor & Lamb 1994). These fruit are not a major component of the diet of rural people but are an important supplement. Indigenous fruit also provide minerals and nutrients to the diet. Although the importance of indigenous fruit has been realised, so far their domestication is limited, but existing trees are managed for fruit production (Sinclair *et al.* 1994). Indigenous fruit trees are protected as they provide alternative food sources especially during the dry season when agricultural harvests are diminishing. Grundy *et al.* (1993) cite an example of rural people in Zimbabwe who leave indigenous fruit trees on their land during land clearing for cultivation. Secondly, the fruit can be easily converted into cash in order to buy other goods and services. The fruit trees that occur on common land also offer an advantage to the poor and landless people in rural areas as they gain easy access to them and can generate income to support them. In most societies rural women take up the collection and marketing of indigenous fruit as a means to generate some income to take care of their households (McElwee 1994). This is a result of the high percentage of unemployment of rural women as compared to the men who often go to seek jobs in the cities.

However the picture for commercialisation of indigenous fruit trees is not as vague as it seems because there are societies which have success stories. An example of successful commercialisation of indigenous fruit trees that occurs in the southern province of Zambia where the local brewery brews a wine from the fruit of *Uapaca kirkiana* known as "Musuku". Local people pick the fruit and the brewery organises the transport from the rural area to the brewery (Packham 1993).

In the past, rural people believed that tree planting of indigenous species was the work of God. This attitude has changed and presently rural people are more inclined to engage in tree planting activities. This could be attributed to the cash incentives, which tree planting activities, offer. Stimulatory efforts by Governments and Non-Governmental Organisations (NGO) have led to an increase in tree planting activities in the rural areas throughout southern African region (Baker & Taylor 1992 cited in Taylor & Kwerepe 1995).

In the past, rural people believed that tree planting of indigenous species was the work of God. This attitude has changed and presently rural people are more inclined to engage in tree planting activities. This could be attributed to the cash incentives, which tree planting activities offer. Stimulatory efforts by Governments and Non-Governmental Organisations (NGO) have led to an increase in tree planting activities in the rural areas throughout southern African region (Baker & Taylor 1992 cited in Taylor & Kwerepe 1995).

2.3 Study areas

The selection of study areas was done according to the distribution of *B. discolor* fruit trees in northern Namibia. There are about four major areas (former Owamboland, Kavango, Caprivi and Grootfontein) where the fruit tree is distributed, the current scope of the study could only encompass two areas (Caprivi and former Owamboland) due to time limitations.

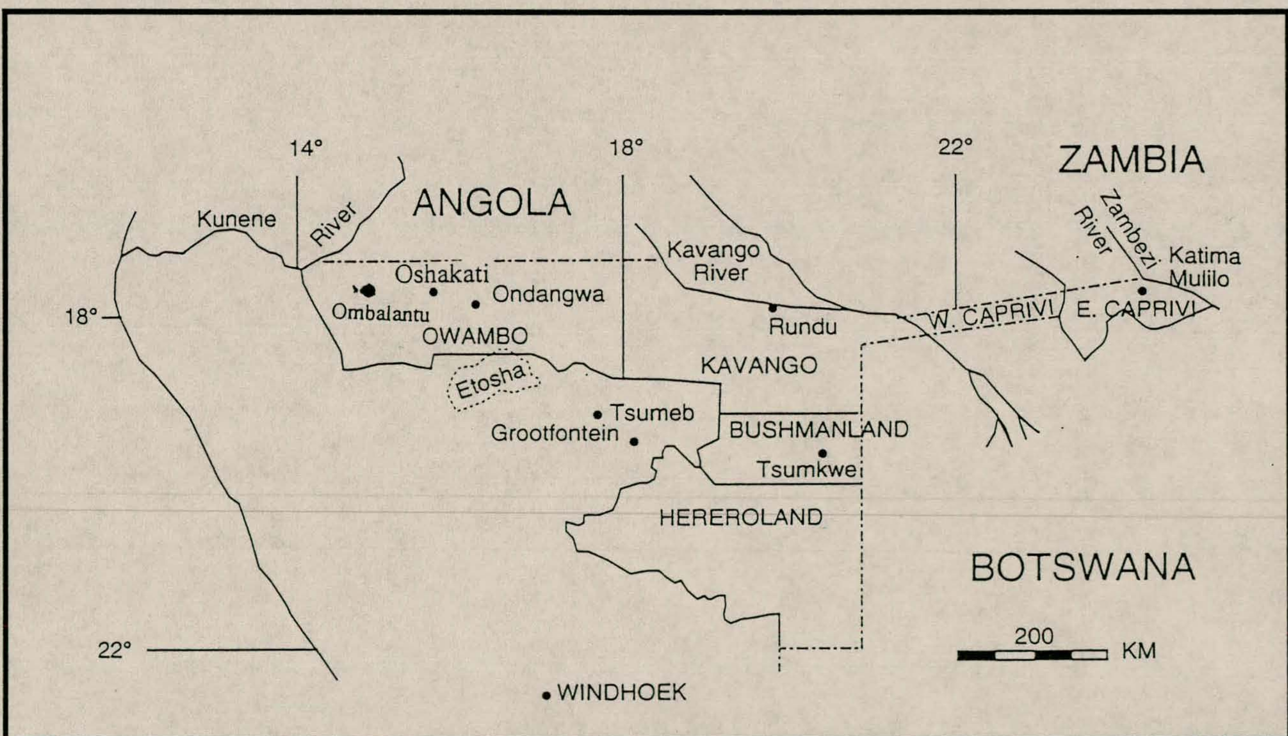


Figure 2.1 Map of northern Namibia (Erkillä & Siiskonen 1992) adapted to show study areas.

The final choice of which villages to include in the study was done randomly by choosing four villages from the total number of all villages that contain *B. discolor* trees. The description of the study areas below has been taken entirely from Erkillä & Siiskonen (1992), as it was the only source found with information on the two study areas.

2.3.1 Owamboland

Location and population

Owambo is a former name for the present four regions: Oshana, Omusati, Ohangwena and Oshikoto, which are located in north-central Namibia (Fig. 2.1). The four regions together cover an area estimated at 5.2 million hectares. Owamboland has the highest population density in Namibia. Out of the 1.3 million population of Namibia in 1992, 600 000 lived in Owambo.

Eengolo village is situated in the Omusati Region near the town settlement Outapi. Outapi is approximately 80 km west of Oshakati, which is the major town in the former Owamboland.

Onuuno village is located on the Ondangwa-Oshikango road, which leads to the border between Namibia and Angola

Climate

The climate in Owambo was described as being continental. In winter a minimum temperature of 7°C in the night may be recorded while the maximum temperature may reach higher than 27°C during the day. In summer temperatures as high as 36°C can be recorded. The mean annual rainfall ranges from 350 mm in some parts to 550 mm in other places.

Soils

The soils are derivatives from Kalahari soils of the group arenosols. The soils are infertile, lacking humus and plant nutrients.

Vegetation

The western part of Owambo is a mopane savanna with *Colophospermum mopane* as the main dominant species. Other species occurring in the mopane Savanna are *Acacia* sp.

Adansonia digitata, Combretum sp., *Diospyros mespiliformis, Terminalia sericea, Sclerocarya birrea, Berchemia discolor* and *Hyphaene petersiana.*

The eastern part is tree and woodland savanna, which includes species like *Baikiaea plurijuga, Burkea africana, Pterocarpus angolensis, Schinziophyton rautanenii, Acacia erioloba, Combretum* sp., *Guibourtia coleosperma* and *Terminalia sericea.*

2.3.2 Caprivi

Location and population

Caprivi Region is situated in the north-eastern part of Namibia. The region is clearly subdivided into West and East Caprivi, it borders Zambia and Angola in the north, Botswana in the south and Kavango in the west (Fig. 2.1). East Caprivi where the villages included in the study are situated covers an area of 1.2 million ha. The population of east Caprivi is reported to have been 60 000 inhabitants in 1992.

Bito village is found in the Caprivi Region. It is situated on the Katima Mulilo, Kongola road, 25 km away from Katima Mulilo, which is the main urban settlement in the region. Ibbu village is located in the lowlands of East-Caprivi on the edge of the floodplain of the Chobe River, with a population of approximately 1200 inhabitants (Reiss, unpublished). Lizauli village is located in western Caprivi close to the Mashi River, which forms the border with Botswana.

Climate

The climate of east Caprivi is described as being "subtropical, with mild dry winters (April to August) and hot wet summers (September to March). The hottest months are September and October and the coolest months are June and July. The average rainfall per annum is slightly below 700 mm.

Soils

The soils are mostly derivations of Kalahari sands and three types can be distinguished, these are aelioan red and yellow sands, loamy soils and shallow.

Vegetation

The vegetation of east Caprivi can be divided into three types, these are wooded areas characterised by *Baikiaea plurijuga*, aquatic plant communities of rivers, marshes and swamps characterised by the presence of *Colophospermum mopane, Phoenix reclinata* and *Piliostigma thonningii* and lastly cultivated land. Other species found in the region are *Terminalia sericea, Parinari curatelifolia, Acacia erioloba, Burkea africana, Adansonia digitata, Pterocarpus angolensis, Strychnos pungens* and *Combretum* sp.

2.4 Material and Methods

An Overview

The fieldwork was carried out in two phases, firstly from May to mid June 1997 and secondly from August to September 1998. The data were collected in two phases because two different methodologies were used i.e. rapid rural appraisal (RRA or interview method) and participatory rural appraisal (PRA). The interview method was used before the PRA method. This was done because it was later realised that interviews could be limiting in data collection therefore it was best to employ the PRA method as well. The two methods were used so that they could complement one another and help in giving a complete picture of the issues at hand.

In the time that was available in Owamboland two villages, Omwaandi and Okathimbi Eengolo and one market in Ombalantu were included in the RRA study. Data were collected with the help of a student from Ogongo Agricultural College, who acted as an interpreter. In the PRA study Okathimbi Eengolo was repeated and two other new villages were included i.e. Omundungilo and Onuuno village. Data were collected with the help a forest ranger from the local District Forestry Office (Ongwediva). The ranger was experienced in PRA exercises.

The fieldwork in Caprivi both for the RRA and PRA method was facilitated by some staff members at the District Forestry Office who are well known in the area. Areas with dense stands of *B. discolor* were targeted because it is in these areas where the trees and fruit are utilised and marketed. Interviews were conducted at the marketplace in Katima Mulilo, which is a small town and five other villages namely, Kasheshe, Lizauli, Ibbu, Bwara and Ngonga. In the PRA exercise, Lizauli and Ibbu were repeated and a new one Bito village was included.

2.5 Rapid rural appraisal

2.5.1 Material and methods

On arrival, interviewers introduced themselves as government forestry officials, who were collecting data about *B. discolor* trees. In the village, permission was asked from the village headmen before interviewing the women in that village. At the market in Katima Mulilo, permission was first asked from members of the town council, which runs the market. Individual consent was also asked of each interviewee before proceeding with the interviews. In the Caprivi interviewers were initially confused with forestry officials who were in the process of rounding up illegally cut timber in the community at the same time as the research was being done. Fortunately this did not affect access to the process in the end.

The research was planned for a team of two persons to conduct both the group interviews and the single person interviews, depending on the setting. The questionnaires prepared and used in conducting the interviews is attached (Appendix 2.1). The interviews were informal and the questions were not asked in chronological order as they appeared on the questionnaire. Questions in the questionnaire were primarily concerned with four issues, namely: the uses of the tree and fruit, the methods of fruit harvesting and storage, tree tenureship and the sale of fruit. Individual interviews were often carried out in marketplaces and households whereas group interviews were carried out in villages. In villages group interviews were performed because they were much quicker. The target group was mainly women of all ages because they are the main collectors, utilises and sellers of fruit.

The population of interest was mainly those people with *B. discolor* trees on their land, since not everybody owns trees. Interviews were drawn from people who were selling the fruit in the market as well as villages where dense stands of *B. discolor* trees occurred. Lastly the people who have some *B. discolor* trees on their land were interviewed.

The interviews were conducted in the local language in Caprivi and translated afterwards into English. In Owamboland, since the interviewer was not familiar with the local language, the services of an interpreter were engaged.

Transcription of the data collected in the field was done in the evenings when no interviews could be conducted. This involved audio typing of each interview and translating into English at the same time. The text was coded (Appendix 2.2 for code list) and analysed using a statistical package for analysing social science data (SPSS). Results are reported as percentages of the frequency of codes.

2.5.2 Data collection techniques

Data were collected with the aid of a tape recorder. This intimidated some of the respondents because they were worried that the recordings were for public broadcasting. However, after the reassurance that it would not be for that purpose, the respondents responded much more readily to the questions. Although collecting data with a tape recorder could have created an artificial environment during the interviews, the distraction caused by this was less than what it would be if data were entered by hand at the same time that the interviews were conducted.

2.5.3 Results

A total number of 17 interviews were obtained from both studies areas. This number however, does not include all the people involved in group interviews.

Uses of the tree and fruit

The results obtained during this study agree with work done by Rodin (1985) who documented the uses of the *Berchemia* fruit as eaten raw or the pulp being added to steamed millet bread or soft porridge. The fruit is used in the distillation of alcohol and the bark is used as a dye in the basket weaving industry. Of the uses mentioned by the respondents in Caprivi, the most important use of the fruit is as a snack. In former Owambo it is both as a snack and also for alcohol distillation. The uses of the timber mentioned by Storrs (1995) were not mentioned by any of the respondents. Only 29.4% of the respondents indicated that *B. discolor* is of some medicinal importance, whereas 70.6% were ignorant about its medicinal value.

In Ibbu village the women demonstrated how they collect the bark for dyeing palm leaves. They only collected the dark outer part of the bark. The women explained that at the beginning they always added wood charcoal to the bark in order to intensify the dark colour. They also recycled the dye mixture. The first leaves which are added to the mixture always turned a much darker colour, while for leaves which are added later they dye a much paler colour, tending to be brownish.

Fruit harvesting and storage

Respondents amounting up to 64.7% mentioned that the change in colour of the fruit from green to yellow is a good indication of the ripening of the fruit. The months of the year were also given by 14.3% respondents as a good indication of ripening fruit with fruit ripening from February to March. The remaining 7.1% mentioned that they notice that the fruit is ripe when children start to climb the trees for fruit. During harvesting the majority of the local people wait until the fruit fall to the ground before picking (75%), whereas 25% harvest the fruit directly from the tree, after which it is sun dried to a low moisture content before storage. The storage containers used range from hessian or polythene sacks (41.2%), claypots (35.3%), metal barrels or cylinders (11.8%), baskets (5.9%) and granaries (5.9%).

More than half of the respondents reported that the fruit usually lasted less than one year in storage, while 11.8% said it lasted for up to one year and the same percentage said that it lasted for even more than one year. Some respondents (23.5%) said that they did not always have excess fruit to store for longer than a year. The respondents whose fruit were finished within a year could be associated with the selling of fruit or brewing of alcohol.

More than half of the respondents highlighted insect infestations mainly weevils as the main cause of fruit deterioration in storage. Ageing was also mentioned as the cause of fruit deterioration by 23.5% of the respondents. The remaining 23.5% was not very sure about the causes of deterioration. Fruit are sprinkled or covered with wood ash before storage to prevent insect infestations (41.2%). Cleaning of fruit by removing impurities like stones and sticks before storage also decreases insect attacks (35.3%) while 23.5% respondents did not take any precautions to prevent fruit deterioration.

Sale of fruit in general

Fruit are sold both at home (29.4%) and at the local market places (64.7%). However not everybody is engaged in fruit selling. About 6% of respondents did not sell the fruit. No records were kept about the income generated from the selling of fruit; thus no information about the amount of money gained from these sales could be gathered. Demand for fruit of *B. discolor* is quite high because no fruit are available on the markets six months after the fruiting season. However this demand could not be quantified because of the lack of records. Some of the goods mentioned which are bought using the money acquired from fruit sales are mainly blankets, clothes and groceries. Money is also used for paying school fees.

Sale of the fruit in Caprivi

In the rural areas, fruit are sold within households, or the rural people take the fruit to town and sell them to the market sellers. On occasions market sellers go to the rural areas to buy the fruit for sale in urban areas where they sell it for twice the price. In the rural areas 600g of fruit cost N$0.50.

A woman interviewed at the market in Katima Mulilo had started selling the fruit of *B. discolor* in 1992, and she said that since that time the prices of the fruit on the market has remained the same. In Lizauli village, a woman estimated that if she sells a 50 kilogram sack of *B. discolor* she gets an amount of N$200.00.

Sale of the fruit in Ombalantu

The fruit is sold from the houses and at local marketplaces. Rural people sell their own fruit, as there are no middleman involved. The measure for sale is a 500 ml engine oil can, which when filled with fruit, costs N$2.00. Alcohol distilled from the fruit is also sold locally in the area. A 200 ml bottle filled with alcohol costs about N$3.00.

Tree tenure

In general, for villages in former Owamboland, trees occurring on cultivated land are individually owned while those occurring on communal land are communally owned. However the public could still access some of the trees on cultivated land, sometimes by invitation from the owners while others have to ask for permission to gain access.

In Caprivi, although the general scenario was that everybody accesses trees on both communal and cultivated land there are deviations depending on individuals.

In Kasheshe village the trees occurring on cultivated land are accessible to all the village people and the owner of the land. The owners of the cultivated land with *B. discolor* trees on them expressed dissatisfaction to this state of affairs. Although *B. discolor* trees occur on the village common land, they are not being utilised by the village people since nobody cleans under the trees to enable the fruit pickers to pick the fruit from the ground. Village people preferred picking the fruit on cultivated land where the landowner cleans under the trees.

In Lizauli village, the women mentioned that they only shared the fruit in the forest while the trees on cultivated land are only accessed by the landowner.

2.5.4 Discussion

The utilisation of the fruit as a snack improves the nutrition of rural people. This contribution to the rural people's diet cannot be underestimated because of the lack of other sources of fruit in rural areas. The fruit also provides the local people with an income. The income generated from the sale of fruit is used to acquire other goods and services, which are otherwise inaccessible. The income generated from the fruit selling means a lot to people in rural areas where there are only a few formal employment opportunities for the generation of cash.

The production of and trade in alcohol is also a significant income generating activity. However, comparisons in terms of fruit volume between income from alcohol and raw fruit trade were not drawn

In Ibbu village, the use of the bark in the colouring process in the basket weaving industry is sustainable and offers no obvious threat to the tree's health. Only the outer parts of the bark are used, which is not harmful to the tree. This activity only adds to the importance of the tree to the rural people. There are no major medicinal uses of the tree and for this purpose the significance of the tree is limited.

The reason for the decline in the utilisation of *B. discolor* as a timber species could stem from its use as a fruit tree species, which is more important. There are also alternative timber species available in these areas such as *Baikiaea plurijuga, Pterocarpus angolensis* and *Colophospermum mopane,* which produce superior timber.

A variety of containers are used in the storage of fruit. The effect of the different containers in prolonging the fruit during storage was not investigated. However, weevils were identified as the main insects, which cause fruit deterioration in storage. Mixing the fruit with ash was mentioned as the most effective way of preventing insect attack in fruit during storage. At this stage it cannot be speculated as to why the ash controls the insect attacks and further investigations are recommended to verify and assess the finding. The other method mentioned was cleaning fruit of all impurities, like stones and debris, before storage. Cleaning impurities from fruit is effective in preventing fruit deterioration since some of these impurities might contain fungal spores, which might later infect the fruit.

In Caprivi an informal market infrastructure exists for the selling of the fruit. This has been established between the rural settlements and the town settlement of Katima Mulilo. The fruit is produced in the rural areas and transported to the town for sale at a profit. This market is however faced with problems like fruit pricing, transport and quality. The prices of the fruit have not changed since the beginning of the trade in *B. discolor* fruit in the last decade. This is a problem relevant to most indigenous fruit and also that of some locally produced agricultural products. The seasonal availability of these products makes it impossible to change prices because the markets are usually flooded with the products at a particular time of the year. Transporting fruit from the rural areas to towns requires the payment of a transport fee. This lowers the profit on the fruit at their current price. The most profitable way for the rural people to sell their fruit is directly to retailers who transport it for themselves to the market in Katima Mulilo.

No quality controls are imposed on the product. No investigations as to what kind of product the consumers expect were conducted. This kind of information is necessary before initiation of a fruit improvement program in *B. discolor* and therefore further investigations are recommended.

Exploration of other market possibilities was not well investigated. In Namibia a high number of people who used to live in the northern parts of the country have moved all over the country especially to the capital city, Windhoek. These people represent a potential market for the fruit as most of them were exposed to the fruit in the rural areas and value it as a symbol of tradition. However, unless people are prepared to pay more for the fruit, the fruit growing industry will not be a sustainable endeavour to embark upon. This is because the distance between the central and northern parts of Namibia is too long.

Tree tenurial rights are traditional in both study areas. In order for commercialisation to be successful it is necessary that the fruit trees be privatised, especially in those areas where it is currently common property. The privatisation of the fruit tree will also encourage other rural people without trees on their land to plant trees and it will also expand the market opportunities because the fruit will not be freely accessible to everybody.

The results obtained in the Omusati Region are not a good reflection of attitudes through the whole region due to limited number of interviews carried out. This was due to language barriers and time constraints. Therefore, although the present results give only a partial picture, further research should be done to present a better picture. The results from the Caprivi Region are a more representative of the actual situation because no language barriers were experienced and a wider variety of people and places were included in the study.

The planning stage of this project, which was the designing of the questionnaire, did not include any suggestions from the local people. This was a disadvantage, because if the project has to be initiated, the local people will be both the implementers and beneficiaries. The viewpoints of the local people should have been incorporated since they have practical and technical knowledge with indigenous fruit trees. The most effective research method would probably be the inclusion of local people in the planning process and having them also participating and monitoring the study this is method is known as participatory (David-Case 1989). This realisation motivated the implementation of the PRA techniques, which are reported next.

2.6 Participatory rural appraisal

2.6.1 Material and methods

The tools used during the PRA exercise are detailed in Table 2.1. The PRA targeted women and children since they usually assume the role of fruit gathering in many rural communities. In the village the meeting aimed to include all the women and children, however in some villages men also attended the meetings. Groups of women and children in villages were asked to participate in a discussion series of basic questions were asked:

- What indigenous fruit trees are available in the area? This involves the examination of types of existing indigenous fruit trees in an area, to determine of which fruit tree is in abundance in a certain area and also whether availability of the fruit determines it's importance in an area. Further questions relate to the importance of indigenous fruit both in the social and economic context.

- What are the uses of the indigenous fruit trees? This involves listing the uses of the different fruit trees and comparing them in order of their importance.
- What is the market value of the different indigenous fruit? The aim here was: to rank and compare income gained from different indigenous fruit trees; to compare it to other income generating sources and to list the most important marketing places for the fruit i.e. neighbours, next village, roadside, outside schools, marketplaces etc.
- How is tree ownership of indigenous fruit controlled? This involves the investigation of resource access and control issues.

Table 2.1 Tools used in carrying out the PRA

Questions	**Tools**
Important fruit trees in the area comparison with other indigenous fruit trees. Income gained	Matrix and ranking
Tree tenure Who controls ownership of trees Who has access to the trees Resource distribution	Transect walk, Mapping
Time of fruit harvesting, Patterns of fruiting seasonality if exists	Seasonal calendar
Marketing of fruit Where are the fruit sold Rank the places of sale accordance to their importance Unit price of the fruit	Matrix and ranking

Resource maps

Resource maps assist in estimating the population, the facilities and resources available in the village.

Seasonal calendars

Seasonal calendars were developed for each village showing the different fruit trees consumed in the area and the time of the year the fruit were consumed.

2.6.2 Results of the PRA

The results for each PRA exercise are discussed separately for each village.

2.6.2.1 Bito village

The community had some burning issues, which they wanted to resolve with the Forestry office in Katima Mulilo. On the second day the District Forest Officer (DFO) from Katima Mulilo was included in the research team so that he could discuss issues of concern.

One of their topmost problems was that they lived near a forest area declared as state forest and they were not allowed to utilise the forest resources in that area. They said forestry officials confiscated those resources, which they collected. This was a problem since some of the resources like thatching grass and other fruit trees were not so abundant in the communal forest as they were in the state forest. The other concern they had was that at some point they had erected a market close to the road where they used to sell curios, baskets and some indigenous fruit trees, forestry officials once again raided their market and confiscated everything. The forestry people accepted to this accusation and said that they did not allow the village people to freely roam the state forest as they usually start forest fires, which lead to resource degradation. The villagers wanted to know what their rights were in regards to utilisation of resources from the state forest and what laws are there about marketing of forestry resources.

Resource map

All the villagers drew the resource map on bare ground using dust paint to indicate the roads and sticks to indicate the houses. At the same time, a young man who was among the women was drawing the map on a flip chart. The village was not very big so the villagers could easily come to consensus about the location of the different features on the map.

At the end of the day the flip chart was taken to the office and the map was copied and returned to the villagers on the second day of the PRA exercise. The map was presented to the chairperson of the women's group in the village. Some key informants who were selected and interviewed in their households verified the map features.

The map identified 32 households in the village, location of the school, water point, cropland and forest (Fig. 2.2). The most important places where the fruit trees occur were in the forest and cropland. The map however does not include the forest and cropland resources in detail although a survey of the resources in these areas was done. Indigenous fruit tree species like

Strychnos sp. and *B. discolor* were commonly found on cropland while species like *Ximenia* sp., *Grewia bicolor, Schinziophyton rautanenii* and *Guibourtia coleosperma* all occur in the forest. *Berchemia discolor* was the most abundant fruit tree in the area.

Seasonal calendar

Table 2.2 Seasonal calendar of availability of local indigenous fruit trees drawn by Bito village people

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Berchemia discolor			■	■								
Grewia bicolor			■	■								
Strychnos sp.							■	■	■			
Guibourtia coleosperma							■	■				
Ximenia sp.							■	■	■	■	■	■
Schinziophyton rautanenii							■					
*mumbole**										■	■	
Grewia sp.			■	■								

*= Unidentified

The village listed eight indigenous fruit tree species, which are utilised in their area. Three species *B. discolor, Grewia* sp. and *Grewia bicolor* ripen during the rainy season, while S*chinziophyton rautanenii, Ximenia* sp. *Guibourtia coleosperma* and *Strychnos* sp. during the dry season (Table 2.2). *Mumbole* (which was unidentified) ripens at the beginning of the rainy season.

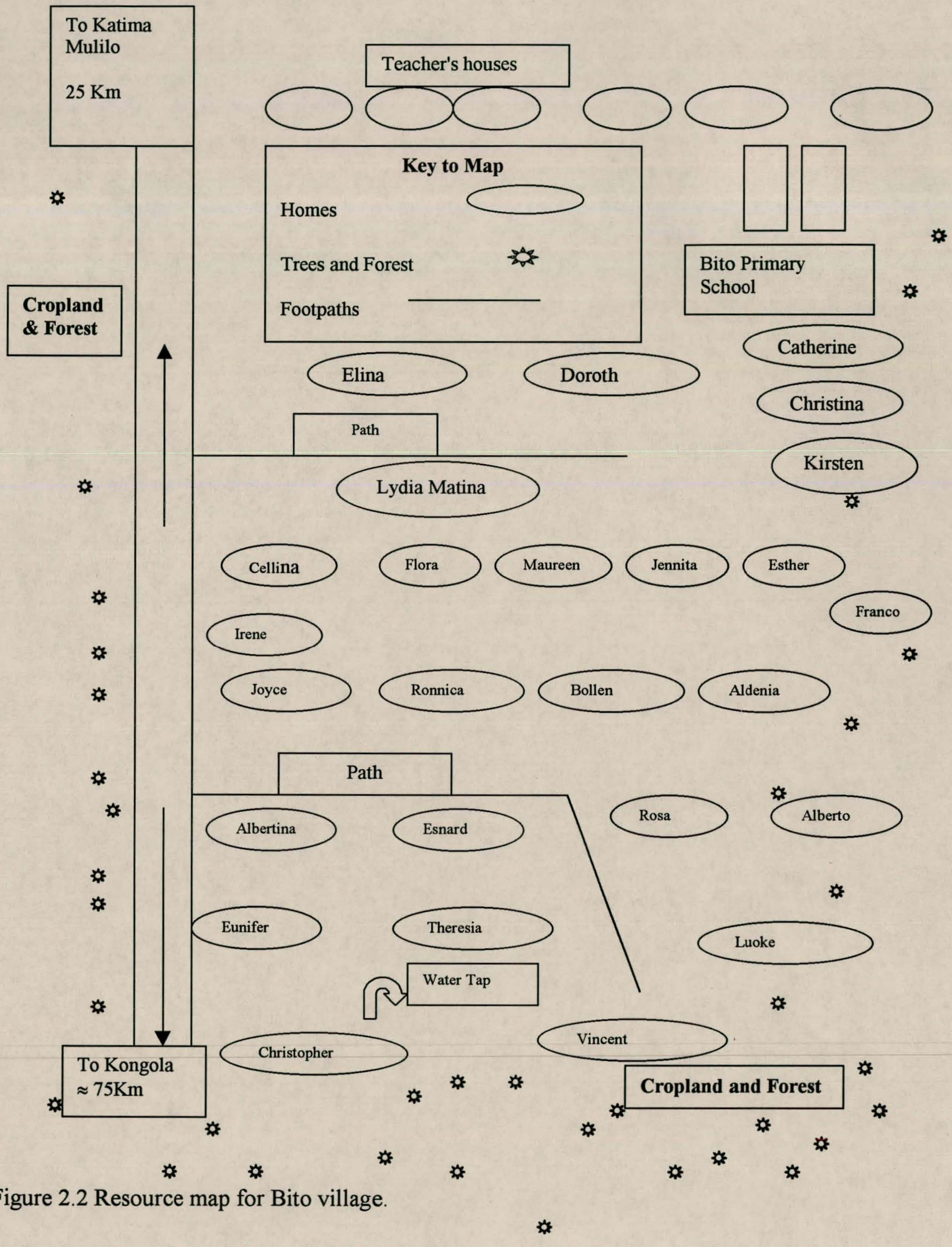


Figure 2.2 Resource map for Bito village.

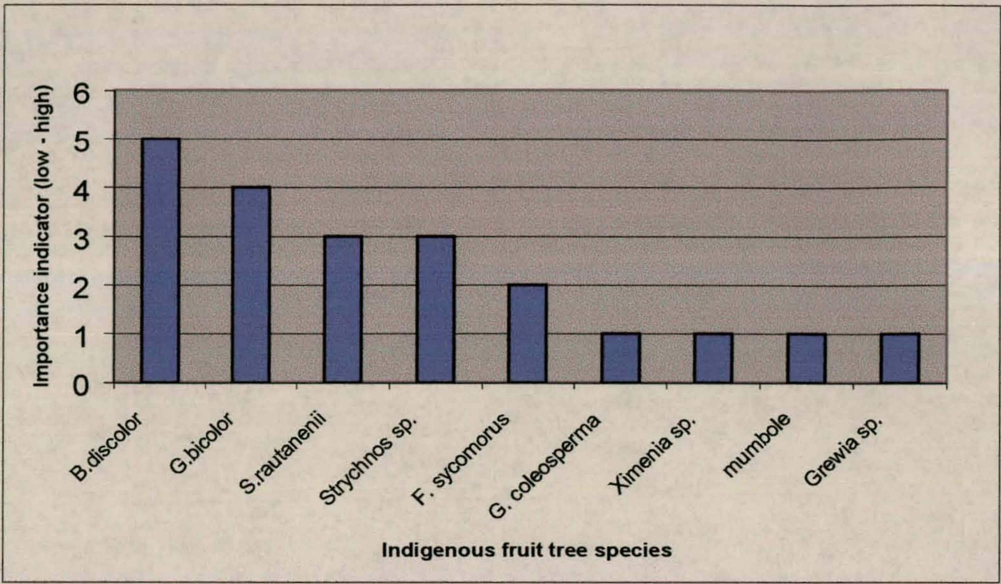


Figure 2.3 Ranking of various indigenous fruit in order of importance in Bito village.

B. discolor was given the highest rank of five points, *Grewia bicolor* (*mumaka*) had four points, while *Strychnos* sp. and *Schinziophyton rautanenii* had three points each, *Ficus sycomorus* had two points and lastly *Ximenia* sp., *mumbole*, *Grewia* sp. (*mupundu*) all had one point each (Fig. 2.3).

Box 1

Case studies

Catherine Mupoti usually trades three items in a year, these are: *B. discolor* fruit, watermelons and sugarcane. In a good year she harvests a 65 kg sack of *B. discolor* fruit, in a bad year she only harvests a 25 kg sack.

Christina Taezo also sells *B. discolor* and *Grewia bicolor* fruit. The other goods which she trades in are mainly agricultural crops such as Bambara beans, beans, groundnut, Fresh and dried maize, sugarcane, pearl millet and sorghum. She usually harvests a 50 kg sack full of *B. discolor* per annum. The indigenous fruit she usually sells between February and May. Fresh maize and sugarcane are sold February to April. The Bambara nuts, groundnuts and beans are sold from August and usually finish by the beginning of the rainy season. Dried maize, pearl millet and sorghum are sold all year round depending on availability.

Strychnos sp. was limited and sold mainly by children. Children always harvest the fruit before it changes colour from green to yellow when it ripens. They then ripen the fruit by burying it in the sand. The adults complained that this practice led to resource wastage as sometimes the fruit are removed from the trees before they are physiologically mature and thus ended up rotting during the ripening process. However no measures have been taken by the adults to rectify the situation it seems to be entirely regarded as a children's resource.

Table 2.3 Marketing of indigenous fruit and agricultural crops in Bito village

Species	Unit of sale	Price	Location of sale
Grewia bicolor	cup≈500 ml	N$1.00	Household
Berchemia discolor	cup≈500 ml	N$1.00	Households + Market
S. rautanenii	cup≈500 ml	N$1.00	Households
Strychnos sp.	Small fruit Big fruit	N$0.50c N$1.00	Households
Beans	cup≈500 ml	N$2.00	Households + Market
Bambara nuts	cup≈500 ml	N$2.00	Households + Market
Groundnuts	cup≈500 ml	N$2.00	Households + Market
Watermelons	Small Big	N$5.00 N$8.00	Households + Market
Sugarcane	Small Big	N$0.50c N$1.00	Households + Market
Dried maize	500 gallons 25 gallons	N$240.00 N$25.00	Households
Pearl millet	25 gallons	N$25.00	Households
Sorghum	25 gallons	N$25.00	Households

The following can be deduced from Table 2.3: The two most commonly traded fruit in the village, *G. bicolor* and *B. discolor*, are sold at the same price. Women in the village mostly trade these two species and they are sold both in the village and at the market in Katima Mulilo. *Strychnos* sp. is sold as whole fruit, which are classified into smaller fruit and bigger fruit, and is mainly sold by children in the village. Watermelons and sugarcane are also classified into big and small units. Agricultural crops such as beans, Bambara nuts and groundnuts cost almost double what the indigenous fruit (*B. discolor* and *G. bicolor*) costs for the same unit. Dried maize, pearl millet and sorghum are the highest income generating crops for villagers.

Table 2.4 Patterns of tree tenure in Bito village

	Control	Access	Use
Cropland	Owner	All	All
Communal forest	Headman	All	All

Although the tree tenure is controlled by the person who is farming on cropland where the fruit trees are growing, everyone else in the village has access to the resource and user rights over it (Table 2.4). Similarly on communal land the headman is in control but access and utilisation is open to every person in the village (Table 2.4). However the villagers did not seem satisfied with the current state of affairs on tree tenure. The free access and utilisation rights given to everyone else in the village to trees growing on cropland was seen as a disadvantage by some people. This they said was unfair since people with fruit trees on cropland spent their energy cleaning and tending the trees for fruit production and they end up sharing the resource with other people. They also raised the concern that people who come to harvest indigenous fruit on other people's cropland always ended picking crops like watermelons and maize in the process.

On the one hand some people felt that fruit trees even those found on cropland should not be restricted to use by the landowners only. This was because these people did not plant the trees in the first place and if they were to move they would still leave the trees on the land as they had found them. One of the women told of a story, which had happened in the village. A man had planted a *Strychnos* sp. tree on his house. Unfortunately he moved his house and built it somewhere else before the tree started producing fruit. A different person thereafter erected his home where the planted *Strychnos* sp. tree was growing. The tree reached reproductive maturity and in the first year the current resident harvested all the fruit. During the second year of harvest the man who had initially planted the tree came and harvested the fruit. The current resident was very angry when he found out, to the extent that he took an axe and chopped the tree down. This illustrates how sensitive the issue of tree tenure is in the village.

Discussion

Although *G. bicolor* and *B. discolor* are sold at the same price per unit (Table 2.3), the village people still regard *B. discolor* as the most important indigenous fruit (Fig. 2.3). This could be attributed to a number of reasons, firstly *G. bicolor* fruit can only be sold when fresh which limits the time when they are available to generate income, while *B. discolor* can be stored dried and sold for up six months after harvesting. Secondly there is a higher abundance of the *B. discolor* tree in the area compared to *G. bicolor*.

Schinziophyton rautanenii is traded to a limited extent although it is a fairly important species (Fig. 2.3). The village explained this as due to the inaccessibility of the resource as it occurs in the state forest. It is therefore necessary for the Forestry Department to guarantee user rights of the resources in the state forest to the neighbouring communities.

Species such as *F. sycomorus* are given a low rank (Fig. 2.3) as it was regarded mainly as food for children and also because it is not traded. The availability of *G. coleosperma* was said to have decreased over the years to such an extent that the fruit is now just ignored and only the birds are exploiting it. *Ximenia* sp. and other species of the *Grewia* genus are of less significance due to the lack of trade and low abundance.

Agricultural crops such as beans; Bambara nuts and groundnuts were found to cost twice as much as some indigenous fruit like *B. discolor* and *G. bicolor* for the same unit. This could be attributed to a number of factors such as the labour which goes into cultivating agricultural crops as compared to just picking indigenous fruit and also the nature, in which the two are used in the diets. Indigenous fruit is mainly eaten as a snack while these agriculture crops form a staple diet.

Watermelons and sugarcanes are very short-term crops on the market because they are usually sold fresh. Dried maize, pearl millet and sorghum are highest income generating crops, this is because they are the staple crop and food source of the local people and they play an important role in their livelihoods.

The trade in indigenous fruit could at a later stage influence tree tenure as shown by the reluctance of people with trees on cropland to share this resource with other village people. If changes were to be made to the current status of tree tenure, it could however be a good thing, as it will bring security in ownership to the people who have trees on their land. It could also be a disadvantage to people without trees on their land because they will have limited access to the fruit, except by purchasing.

2.6.2.2 Ibbu village

In this village there was a previous PRA exercise, which was conducted by a project from both Ministry of Agriculture, Water and Rural Development (MAWRD) and Ministry of Environment and Tourism (MET). A German development worker Mr. Peter Riess, who was attached to MET, Directorate of Forestry did an extensive study on the people's history, farming systems and resource availability in Ibbu village. Unfortunately most of the data is unpublished. His work provided very good resource maps, which were used in the discussions as reference material.

There exists a number of projects, one of which is a conservancy in association with World Wide Fund for Nature (WWF) and MET, a NOLIDEP project in association with MAWRD dealing with provision of small livestock. The MET, through the Directorate of Forestry, also helped the community in establishing a woodlot.

The community woodlot was established to act as a windbreak to the strong winds experienced during the dry season and also to bring closer to home resources such as fuelwood, construction material and fruit trees (Reiss, unpublished). The main species included in the woodlot were *Eucalyptus camaldulensis, Trichilia emetica, Faidherbia albida, Colophospermum mopane, Ficus sycomorus, B. discolor* and *Hyphaene petersiana* (Reiss, unpublished).

The people in the village were not so enthusiastic about the PRA. This was probably due to the fact that it was a repetition, as each project, which was established in the area, had carried out a PRA exercise. However they provided us with most of the written information from the previous PRA.

Resource map

The map illustrated most of the resources in the area including forest resources (Fig. 2.4). The village is big and subdivided in various family subvillages. The village is situated near a floodplain and the forest is a long distance from the village. The cropland of the village people is also situated in the floodplain.

Seasonal calendar

The village people listed nine indigenous fruit tree species. Of the nine species five of them (*B. discolor*, *Grewia* sp., *Ximenia* sp., *Vangueria infausta, Phoenix reclinata*) ripen during the rainy season, which in this area lasts from November to April. In the dry season, from May to October, the following species will ripen *F. sycomorus, Adansonia digitata, Garcinia livingstonei and Hyphaene petersiana* (Table 2.5).

Table 2.5 Seasonal calendar of harvesting local indigenous fruit trees, drawn by Ibbu village people

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Berchemia discolor	■	■	■	■	■							
Hyphaene petersiana								■	■	■	■	■
Garcinia livingstonei									■	■	■	
Phoenix reclinata	■	■	■									■
***Ximenia* sp.**	■											■
Adansonia digitata					■	■	■					
Vangueria infausta			■	■	■							
Ficus sycomorus								■	■			
***Grewia* sp.**			■									

There is a wide range of products that the village people are involved in trading and they could be classified as follows:

Major agricultural crops

- Maize
- Sorghum

Minor agricultural crops

- Various types of pumpkins
- Sugarcane
- Watermelons
- Vegetables (cabbages, spinach)

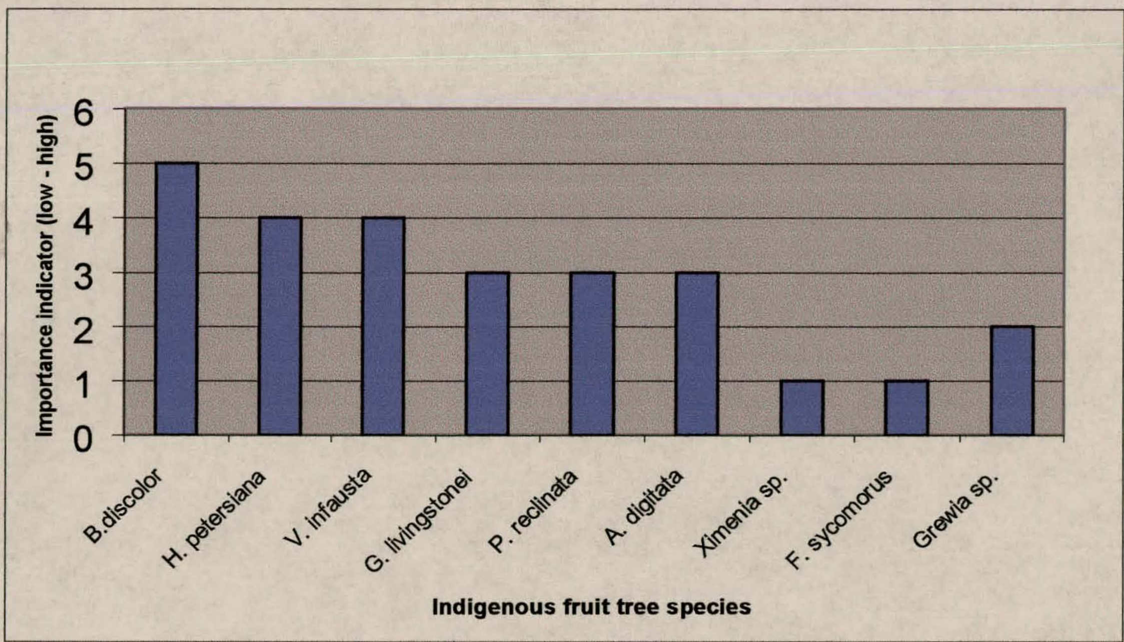


Figure 2.4 Ranking of the various indigenous fruit in order of importance in Ibbu village.

- Wild vegetables (*tepe, ndelele, sishingwa*)

Riverine resources

- Waterlilies (*lisoto, mashela*)
- Reeds

Forest resources (woody and non-wood products)

- *B. discolor* (fruit)
- *H. petersiana* (fruit)
- *A. digitata* (fruit)

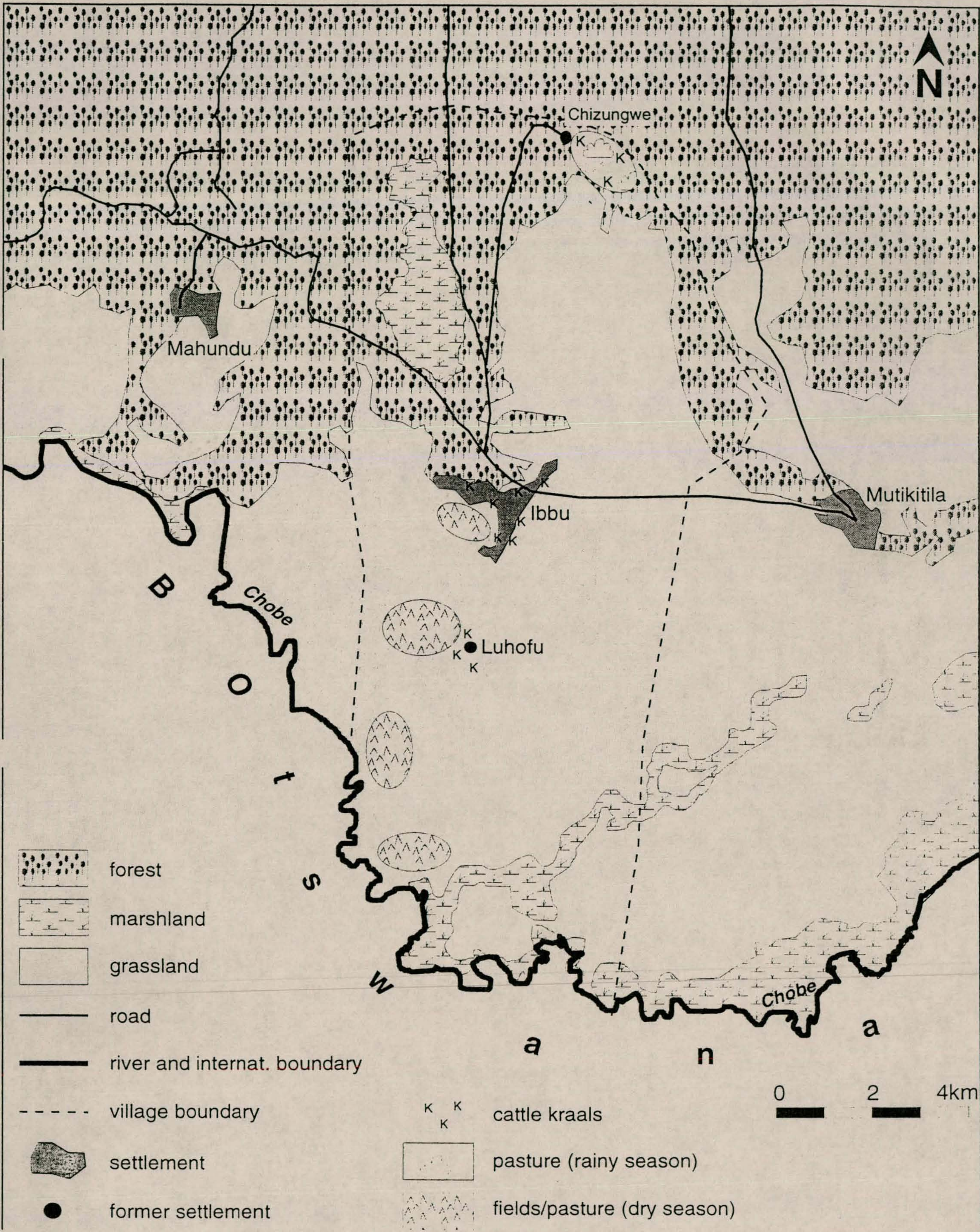


Figure 2.5 Resource map for Ibbu Village (Reiss, unpublished).

- Firewood
- Cattle yoke
- Sledge
- Mortar and pestle
- Baskets, hats and handbags (from palm leaves)
- Thatching grass

Although the above list of traded items includes the three indigenous fruit trees (*B. discolor, H. petersiana* and *A. digitata*) the village denied any involvement in the trade of indigenous fruit. The key informants who were interviewed also confirmed this lack of trade.

The fruit were mentioned in the list of traded items because the neighbouring villages that are much closer to the forest, trade the fruit especially *B. discolor*. In his work Reiss (unpublished) interviewed a lady from the village near Ibbu who sells *B. discolor* fruit. The lady collects up to 50 kg of fruit every year from which she makes earnings of up to N$500.00.

As mentioned earlier on the resource map, cropland for Ibbu village people is located in the floodplain where no trees are growing. This therefore excludes the question of tenure for trees occurring on cropland. The trees occurring in the forest are controlled by the headman and are accessible and utilised by everyone else in the village.

Discussion

Although trade in indigenous fruit is not practised in Ibbu village, fruit are still highly valued mainly for household consumption. The village people attributed the lack of trade in indigenous fruit to the distance they have to travel to collect fruit especially for species like *B. discolor* and *V. infausta* whose ripening coincides with the ripening of crops on cropland. The spatial separation between forest and cropland limits the exploitation of indigenous fruit tree resources by the village people.

Interestingly the three indigenous fruit trees (*H. petersiana, A. digitata* and *B. discolor*) were mentioned in the list of goods, which were traded, although the village people themselves do not engage in their trade. This only puts emphases on how important indigenous fruit is to the village people. The efforts by the Forestry Department in the region to assist the communities by bringing forest resources closer to the community if successful could lead to increased utilisation of fruit or even initiatives in the trade of indigenous fruit in the village.

2.6.2.3 Lizauli village

The village women and children mainly attended the meeting. The women gave instructions to the children who took up the responsibility for drawing the resource map. Everybody actively participated in drawing the map. The PRA exercise was done in two days and the map was again reviewed on the second day to verify the information.

The discussion on forest resources sparked some concerns from the village people. Their village is situated near a river and unfortunately the other side of the river is another country, Botswana. They expressed concerns that not so long ago they could easily cross the river and harvest mostly thatching grass without any problems. Trade in thatching grass is a high money generating activity for the village people. However recently the border control has been intensified as the Tswanas are worried about the Namibians poaching game on their side. This has resulted in the loss of an important resource, which is limited on the Namibian side. They also complained of loss access to a stretch of the Mashi River, which has been given to a concessionaire for an ecotourism business.

Resource map

The map shows the outline of the village, the roads, households, water point, the location of the old cropland, the current cropland, direction to the river and the local tourist lodge (Fig. 2.6). The village people indicated the number of houses in each household.

Seasonal calendar

There were five species mentioned, three species (*B. discolor, F. sycomorus* and *Grewia* sp.) ripen during the rainy season (Table 2.6). *Ficus sycomorus* is also shown to ripen all year round. ~~*Adansonia digitata* ripens during the dry season and *G. livingstonei* starts ripening in~~ last month of the dry season (October) and lasts until the end of the first month of the rainy season (Table 2.6).

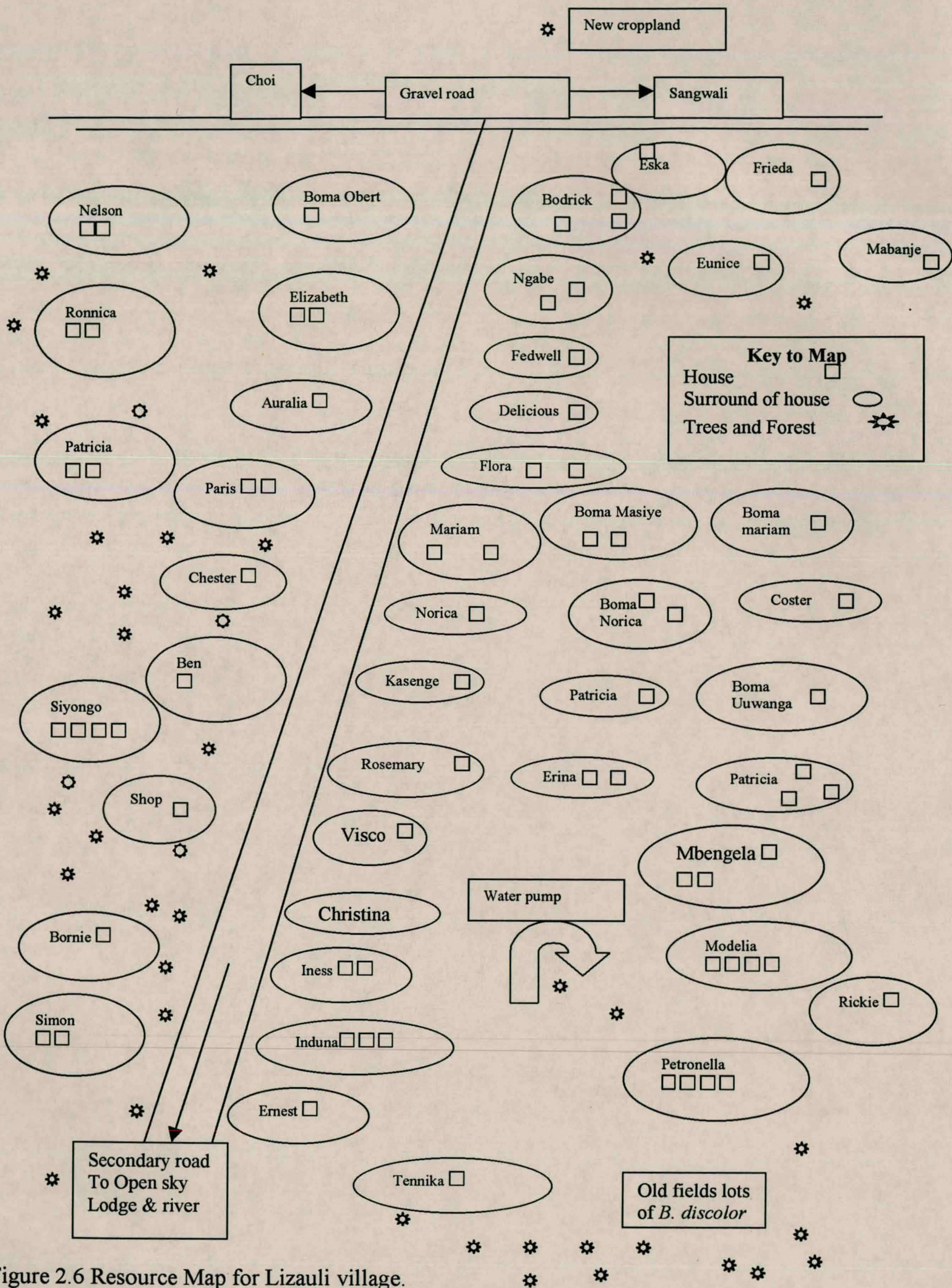


Figure 2.6 Resource Map for Lizauli village.

Table 2.6 Seasonal calendar of local indigenous fruit trees drawn by Lizauli village people.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Berchemia discolor			■	■	■							
***Grewia* sp.**			■	■	■							
Garcinia livingstonei										■	■	
Adansonia digitata				■	■	■	■	■	■			
Ficus sycomorus	■	■	■	■	■	■	■	■	■	■	■	■

According to the respondents *B. discolor* was the most important fruit tree species, followed by *Adansonia digitata* and *Ficus sycomorus*, which have the same rank of four points. *Garcinia livingstonei*, *Diospyros mespiliformis* and *Grewia* sp. were seen as less important (Fig. 2.7).

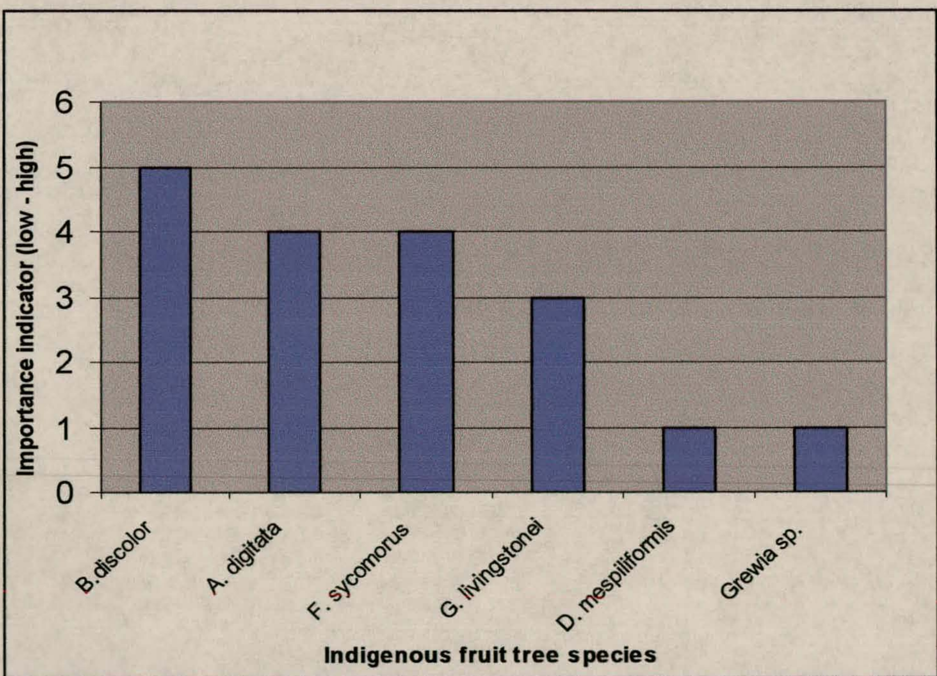


Figure 2.7 Ranking of various indigenous fruit in order of importance in Lizauli village.

Although five types of indigenous fruit are consumed in the area (Fig. 2.7), only two of them (*B. discolor* and *A. digitata*) are traded, mostly in the village and nearby schools (Table 2.7). The village people are also involved in trading agricultural crops, thatching grass and reeds. Thatching grass and reeds were ranked the highest in terms of money generating goods. This is because they are being sold to the commercial sector. Beans were also mentioned as a good source of income and then lastly *B. discolor*.

Table 2.7 Marketing of indigenous fruit in Lizauli village

Species	Product	Unit for sale	Price	Location
Berchemia discolor	Fruit	Cup ≈500 ml	N$0.50c	School and Village
Adansonia digitata	Fruit	Small fruit	N$0.20c	Village
		Big fruit	N$0.50c	Village

Discussion

The ripening of indigenous fruit is spread throughout the year, thus at least one type of fruit is available at a time. This has a positive influence on the nutritional status of the village people all year round. Fruit like *B. discolor* can also be stored beyond their ripening period and thus guaranteeing availability all year round.

Berchemia discolor was ranked the most important indigenous fruit tree by the village people followed by *A. digitata.* It is obvious that these fruit trees are ranking the highest because of their market potential, as they are the only ones which are traded in the village. *B. discolor* has a higher rank than *A. digitata* as it is more abundant in the village. The current status of thatching grass and reeds as the highest income generating goods could be short-lived as it is mainly influenced by the commercial sector. As soon as the market is saturated, their value could decrease.

From the distribution of the trees, *B. discolor* would appear to be partly spread by humans. The location of the trees on old cropland makes them accessible to everybody else in the village, therefore everybody has a chance to collect the fruit for both consumption and selling purposes.

2.6.2.4 Eengolo village

Resource map

A young lady who had just completed her high school did the facilitation of the resource map drawing. The process went smoothly, as there was nothing controversial in the resource map and all people participated. The map mostly shows households, which in this case also represent cropland. Forest is mostly found between the households. A canal, which transports water from Ruacana River to the central parts of former Owamboland, provides the water requirements of the village people. The village also has a school and a Church (Fig. 2.8).

Six species were listed, two of them ripen in the rainy season (*B. discolor* and *S. birrea),* three during the dry season (*H. petersiana, Diospyros mespiliformis and Grewia* sp.*)* and *F. sycomorus* ripens all year round (Table 2.8).

Seasonal calendar

Table 2.8 Seasonal calendar of local indigenous fruit trees drawn by Eengolo village people

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Berchemia discolor		■	■									
Hyphaene petersiana								■	■	■	■	
Sclerocarya birrea		■	■	■								
Diospyros mespiliformis					■	■	■					
Ficus sycomorus	■	■	■	■	■	■	■	■	■	■	■	■
***Grewia* sp.**					■	■						

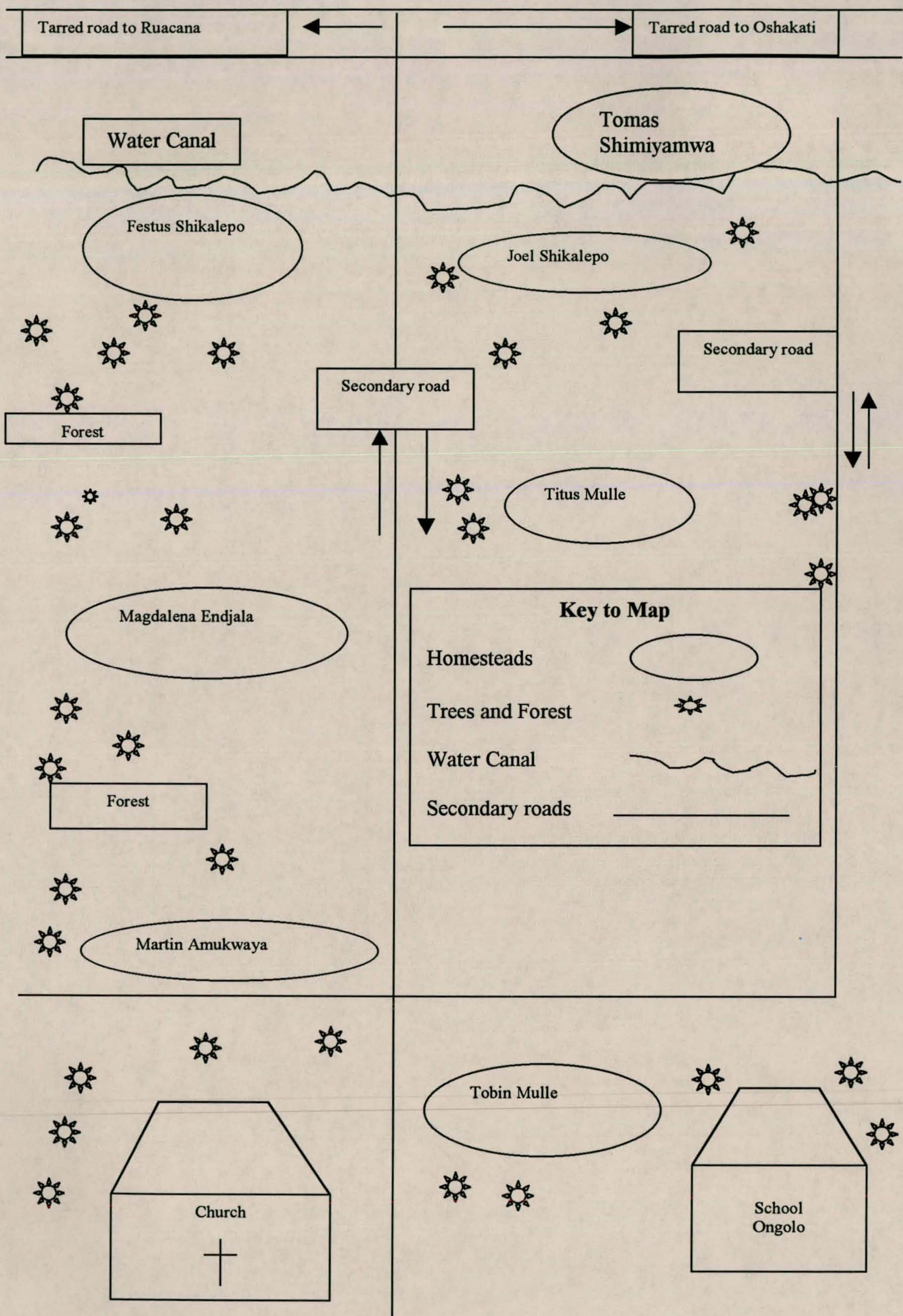


Figure 2.8 Resource map for Eengolo village.

Sclerocarya birrea and *B. discolor* were given the highest rank of five points each, *D. mespiliformis* was given four points, *H. petersiana* three points, *F. sycomorus* two points and *Grewia* sp. one point (Fig. 2.9).

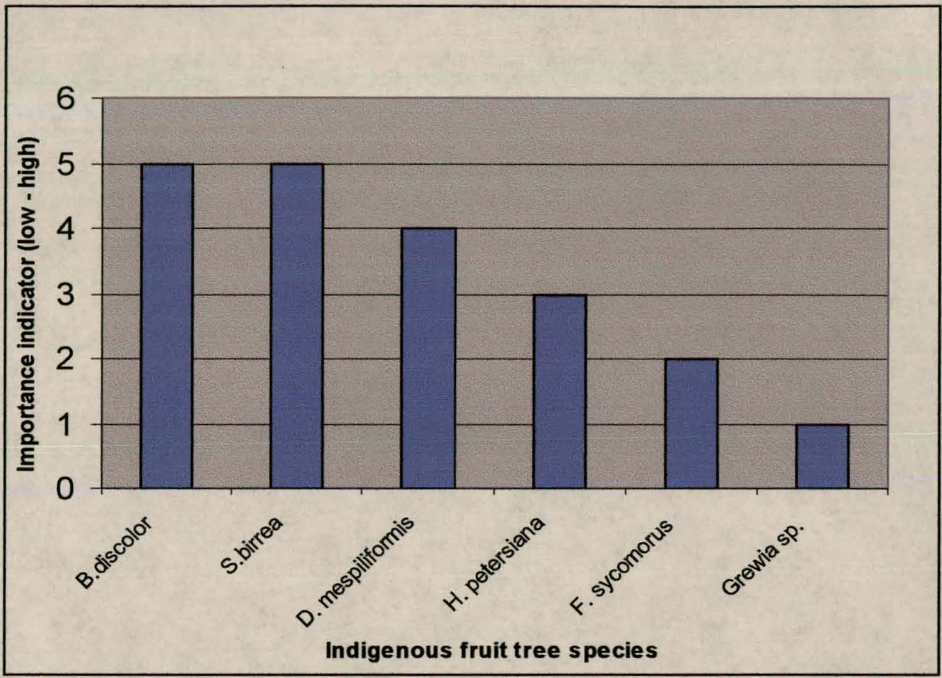


Figure 2.9 Ranking of various indigenous fruit in order of importance in Eengolo.

Two species, *B. discolor* and *D. mespiliformis* are sold at the same price of N$2.00 per unit (Table 2.9). The "dry gin" is sold at the same price for all the different species both in the homesteads and southern Namibia (Table 2.9). Only the extracted nut is traded from *S. birrea* (Table 2.9), although it was mentioned that some people have started selling the wine produced from the fruit at a small scale, no figures were given.

The participants explained that access and utilisation of fruit tree resources on cropland lies in the hands of the land owner, however the resources may be shared with neighbours mostly by seeking permission (Table 2.10). On communal forest, everybody in the village has access to fruit tree resources (Table 2.10) and the headman intervenes in cases of people cutting down fruit trees for other purposes.

Table 2.9 Marketing of indigenous fruit and products at Eengolo village

Species	Product	Unit of sale	Price	Location
B. discolor	Fruit	500 ml engine oil tin	N$2.00	Homesteads and shops
	"Dry gin" Distilled alcohol	200 ml bottle	N$3.00	Homesteads
			N$6.00	South Namibia
S. birrea	Extracted nut	500 ml engine oil tin	N$2.00	Homesteads.
F. sycomorus	"Dry gin" Distilled alcohol	200 ml bottle	N$ 3.00	Homesteads
			N$ 6.00 upwards	Southern Namibia
D. mespiliformis	Fruit	500 ml engine oil tin	N$2.00	Homesteads
	"Dry gin" Distilled alcohol	200 ml bottle	N$ 3.00	Homesteads
			N$ 6.00 upwards	Southern Namibia
H. petersiana	Fruit	Single fruit	N$0.50c	Homesteads
	"Dry gin" Distilled alcohol	200 ml bottle	N$ 3.00	Homesteads
			N$ 6.00 upwards	Southern Namibia
Grewia sp.	"Dry gin" Distilled alcohol	200 ml	N$ 3.00	Homesteads
			N$ 6.00 upwards	Southern Namibia

Table 2.10 Patterns of tree tenure in Eengolo village

	Control	**Access**	**Use**
Homestead & Cropland	Owner	Owner, neighbours by permission	Owner
Communal Forest	Headman	All	All

Discussion

The discussion of results for Eengolo village has been combined together with that of Onuuno village because of the high degree of similarities in results obtained from the two villages.

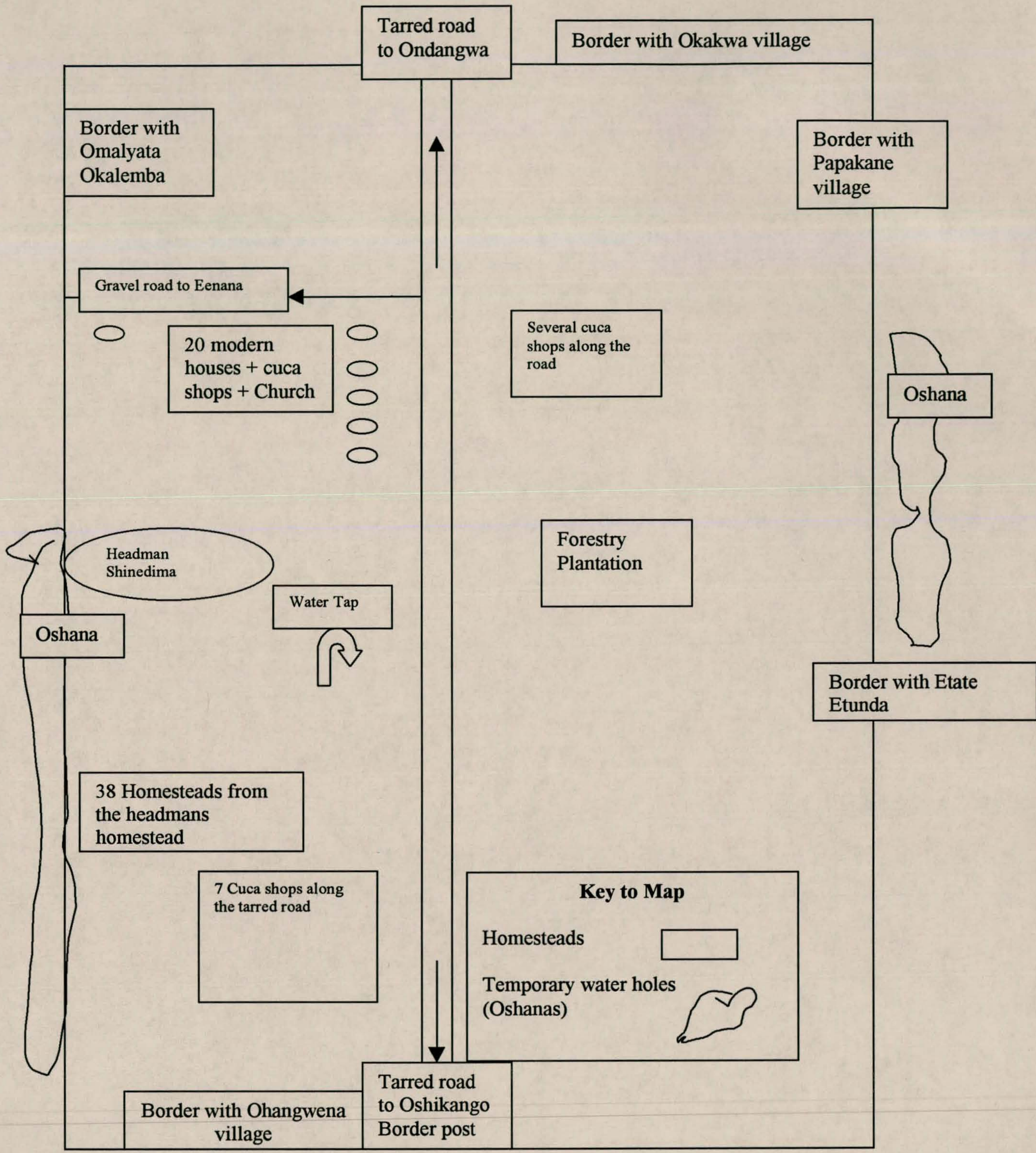


Figure 2.10 Resource map for Onuuno village.

2.6.2.5 Onuuno village

Resource map

This village was the biggest of all the villages included in the study. This made the drawing of the resource map very cumbersome and some parts of the village were just summarised, as the members who were present at the meeting did not represent all parts of the village very well. However the village people provided the number of the households, which are shown (Fig. 2.10), two *Oshana* (seasonal waterholes), water point and shops. The village has a total of 308 homesteads, a kindergarten and an adult school at the church. The nearest hospital and school for children is in Ohangwena and Okatope respectively, which are nearby villages. The only common resource that the village people share is the *Oshana* as most of the land has been fenced off for farming purposes. The map also showed the neighbouring villages on all sides.

Seasonal calendar

Table 2.11 Seasonal calendar of local indigenous fruit trees drawn by Onuuno village people

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Berchemia discolor	■	■	■	■								
Hyphaene petersiana								■	■	■	■	■
Sclerocarya birrea	■	■	■	■	■							
Adansonia digitata						■	■	■	■			
Schinziophyton rautanenii					■	■	■	■				
Ziziphus mucronata							■	■				
Diospyros mespiliformis					■	■	■	■	■	■	■	■
Ficus ycomorus	■	■	■	■	■	■	■	■	■	■	■	■

A total of eight species were listed, two ripen during the rainy season (*B. discolor & Sclerocarya birrea*), five ripen during the rainy season (*H. petersiana, S. rautanenii, A. digitata & Ziziphus mucronata*) and one species ripens all year round, F. sycomorus (Table 2.11)

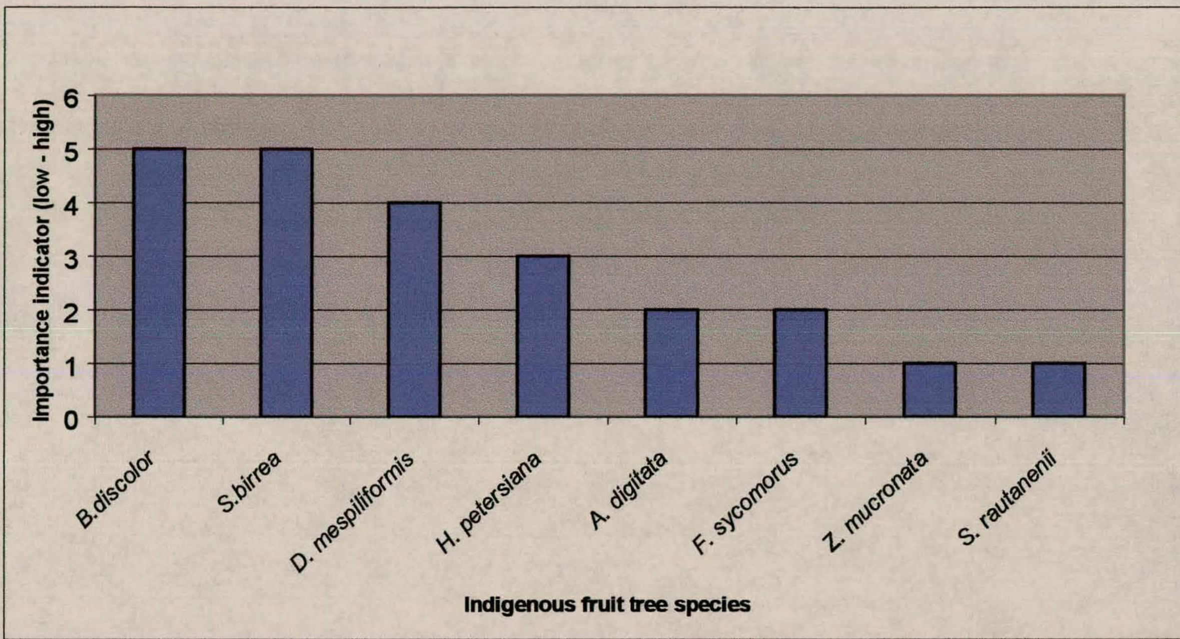


Figure2.11 Ranking of various indigenous fruit in order of importance in Onuuno village.

Sclerocarya birrea and *B. discolor* were given highest rank of five points each, *D. mespiliformis* was given four points followed by *H. petersiana* with three points, *F.sycomorus* and *A. digitata* two points each and *S. rautanenii* and *Z. mucronata* one point each (Fig. 2.11).

Berchemia discolor fruit is traded in four different ways, firstly it is sold in 500 ml containers, secondly it is sold in a 25 litre container, thirdly it is bartered with second hand clothing and lastly alcohol is distilled from the fruit and sold (Table 2.12). Fruit of *D. mespiliformis, H. petersiana* and *Z. mucronata* are mainly sold in bulk (25 litre containers). Trade in "dry gin" is similar for all fruit tree species. The 25 litre containers for *B. discolor* and *Z. mucronata* are the most expensive while *H. petersiana* and *D. mespiliformis* are much cheaper (Table 2.12).

Tree tenure in Onuuno village is similar to the one reported for Eengolo village. Control over access and utilisation of fruit tree resources on cropland lies in the hands of the landowner, however the resources may be shared with neighbours by seeking permission or invitations. In the communal forest, everybody in the village has access to fruit tree resources and the headman intervenes in cases of mismanagement of resources. Some practices regarded by the villagers as mismanagement of resources, are the felling of fruit trees, tapping wine from *H. petersiana* by cutting the growing point. The headman may impose fines on those who commit misdemeanours.

Discussion

For both Onuuno and Eengolo villages each method of sale of the *B. discolor* fruit serves a particular purpose. The fruit sold in 500 ml engine oil cans is mainly for consumption as a snack. The fruit sold in 25 litre containers is for people who want to distil alcohol and 50 litre containers are mostly for bartering with second hand clothes. Alcohol is distilled from most of the indigenous fruit. Trade in the fruit of species like *Z. mucronata, H. petersiana* and *F. sycomorus* is mainly influenced by alcohol production.

There was a debate among the participants as to which of *B. discolor* and *S. birrea* was more important. In the end they decided to give the same rank to the two species. From Table 2.8& Table 2.11 it is clear that only one product is traded from *S. birrea*, the extracted nut, while for *B. discolor* both the fruit is sold and the alcohol, which is distilled from the fruit is also sold.

The importance ascribed to *S. birrea* is partly commercial and partly socially and culturally. An explanation given by the participants as to what is the social and cultural importance of *S. birrea* was as follows: A wine known as *Omagongo* is made from the fruit and it is only given to men with status in the community like the headman. Once a man receives this wine as a gift he will slaughter a goat and a party will immediately follow. Women are also known to get together during the *S. birrea* season to produce the wine together. The wine is only reserved for men as the high alcohol content weakens women. A much less potent juice is also made from the fruit, which is fit, for the consumption of women and children.

Table 2.12 Marketing of indigenous fruit and products at Onuuno village

Species	Product	Unit of sale	Price	Location
Berchemia discolor	Fruit	25 litre	N$30.00	Homesteads
	Fruit	500 ml engine oil can	N$2.00 or N$3.00	Homesteads
			N$4.00	Ondangwa
	Fruit	Exchange with second hand clothes	One dress≈ 50 litres container of fruit.	Homesteads
	"Dry gin" Distilled alcohol	200 ml bottle	N$ 3.00	Homesteads
			N$ 6.00 upwards	Southern Namibia
Diospyros mespiliformis	Fruit	25 litre	N$6.00	Homestead
	"Dry gin" Distilled alcohol	200 ml bottle	N$3.00	Homestead
			N$6.00 upwards	Southern Namibia
Ficus sycomorus	"Dry gin" Distilled alcohol	200 ml bottle	N$3.00	Homestead
			N$6.00 upwards	Southern Namibia
Sclerocarya birrea	Extracted nut	500 ml engine oil can	N$ 4.00	Homestead
			N$5.00	Market
Hyphaene petersiana	Fruit	25 litre	N$6.00	Homestead
	"Dry gin" Distilled alcohol	200 ml	N$3.00	Homestead
			N$6.00 upwards	Southern Namibia
Ziziphus mucronata	Fruit	25 litre	N$20.00	Homestead
	"Dry gin" Distilled alcohol	200 ml bottle	N$3.00	Homestead
			N$6.00 upwards	Southern Namibia

The tree tenure in the two villages gives secure rights over trees to the owner of the homestead. This is an advantage because it can encourage further tree planting activities by the village people, as they can be sure that they will benefit directly from the tree products.

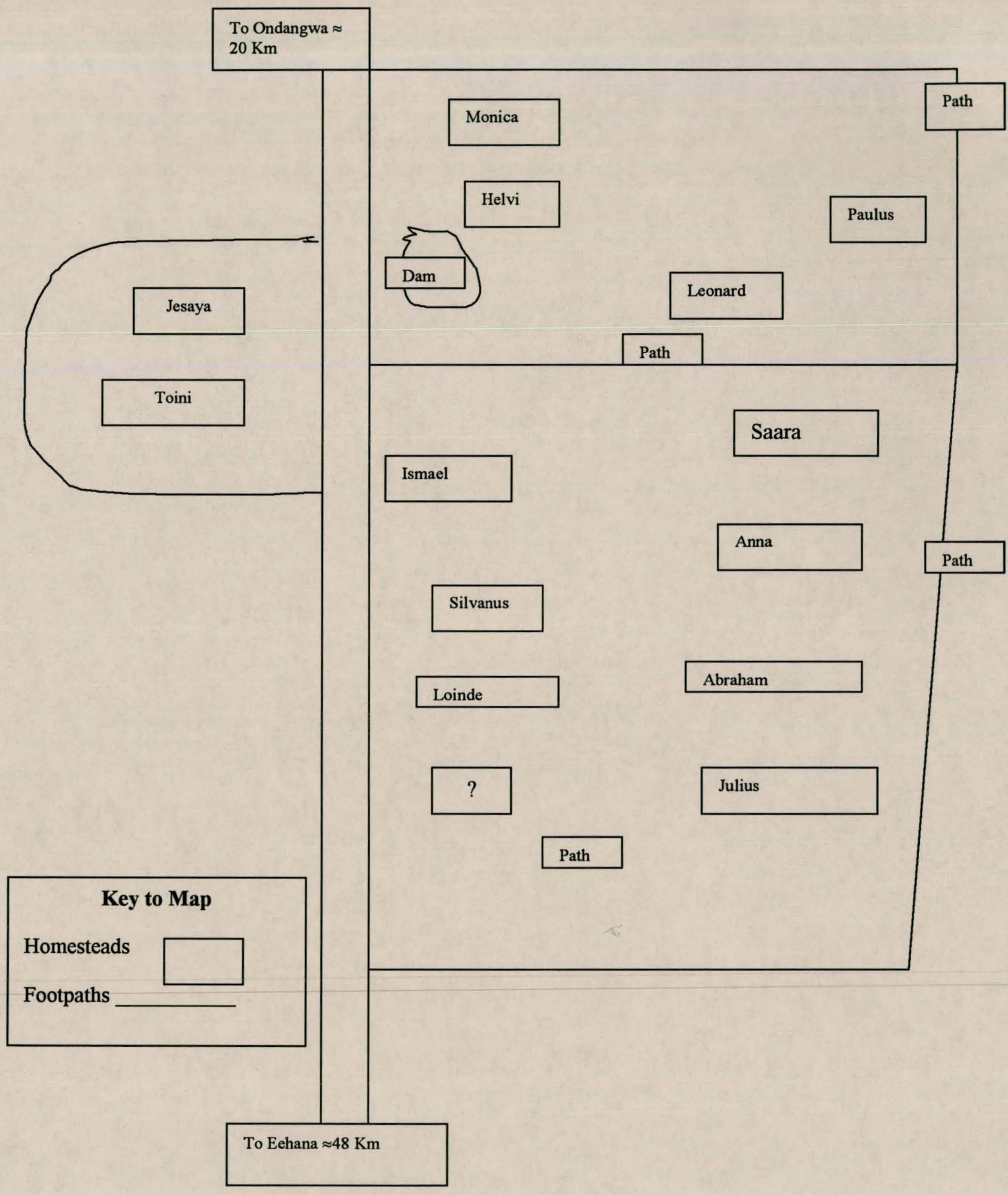


Figure 2.12 Resource map for Omundungilo village.

2.6.2.6 Omundungilo village

The research in this village had to be abandoned, as there were problems with interpretations during the process of carrying out the PRA exercise. The interpreter was not following the instructions from the facilitator. A period of four days passed before another interpreter could be found. It was therefore thought not appropriate to repeat the village once more with the new interpreter.But before it was abandoned the participants (Fig. 2.12) drew a resource map. A good representative of both man and women attended the meeting, however no children attended the meeting. The younger men in the audience assisted in facilitating the drawing of the resource map, the older people mainly directed on the situation of the features on the map

2.6.3 General Results

The information in Table 2.13 was extracted from all the villages that was included in the study in all study areas. The information illustrates the different uses of the different indigenous fruit trees.

The wine made from *S. birrea,* known locally as *Omagongo,* is not sold but exchanged as gifts. The season when the *Omagongo* is available is regarded as partying time because most people will be drunk and happy. Oil is pressed from the extracted nut of *S. birrea*, which is used in cooking and also to add flavour to food. The younger leaves of the male tree can be chewed to cure coughs. Wood from the male trees can be made into milk containers and drinking troughs.

Berchemia discolor fruit are pounded and made into fruitcakes, which are given to schoolchildren as a snack. The fruit are also used to sweeten millet porridge in the place of sugar when it is not available. The bark of the tree is used in dyeing palm leaves for basket making. The seeds are made into necklaces and the leaves of the tree are fed to livestock. The wood from dead trees is utilised for poles and knobkerries (walking stick).

Diospyros mespiliformis is an equally important species in former Owamboland, mostly because it is abundant. The fruit is eaten and alcohol is distilled from fruit. The male trees are used in making chairs, walking sticks, knobkerries and firewood. Both dry and fresh fruit of *F. sycomorus* is consumed and alcohol gin is distilled from the fruit. The wood can be used for firewood, chairs and drinking troughs.

The fruit of *H. petersiana* is eaten, alcohol is also distilled from the fruit and children drink the endospermic fluid of the fruit before it becomes a hard seed. The leaves are used in basket, bag and hat making. The seed can be made into a key holder. The wood and leaves can be used as firewood, mats, cooking sticks, trough, doors, beds, chairs, brooms and to make the fence around the homestead. Cutting the meristem at the top of the tree and tapping the sap, which grows as a result, can produce wine.

The fruit of *Z. mucronata* is not eaten but it is used in the production of alcohol. The leaves are used as medicine for diarrhoea in human beings, while the fruit is also used in treating bloody stools in calves. The wood is used in making animal yokes. The fruit of *S. rautanenii* is eaten. Nuts can be made into soup or pressed for oil. The oil can be used as body lotion and for cooking purposes. As for the baobab (*A. digitata*), *V. infausta*, *G. livingstonei*, *Mumbole*, *Grewia* sp. and *Strychnos* sp. only the fruit is utilised.

Table 2.13 Usage matrix of different indigenous fruit tree species from all study areas

Species	Fruit sold	Fruit eaten	Juice	Medicine	Wine	Oil	Dye	Poles & fuelwood	Soup	Distilled alcohol
Garcinia livingstonei		Yes						Yes		
Ximenia sp.		Yes	Yes							
Ziziphus mucronata				Yes				Yes		
Grewia sp.	Yes	yes	Yes							
Adansonia digitata	Yes	Yes								
Berchemia discolor	Yes	Yes					Yes	Yes		Yes
Schinziophyt-on rautanenii	Yes	Yes				Yes		Yes	Yes	
Diospyros mespiliformis	Yes	Yes						Yes		Yes
Hyphaene petersiana	Yes	Yes			Yes					Yes
Sclerocarya birrea	Yes	Yes	Yes		Yes	Yes		Yes		
Strychnos sp.	Yes	Yes								
Ficus sycomorus		Yes		Yes	Yes			Yes		Yes
Mumbole		Yes						Yes		
Vangueria infausta	Yes	Yes	Yes							

2.7 General discussion and conclusions

In all the four villages included in the study, *B. discolor* was ranked the most important fruit tree species, due mainly to its income generating potential. However comparisons could not be made with exotic fruit tree species, as most of them are not easily accessible to rural people. The study did not address the question of potential commercial markets for trade in *B. discolor* directly. It can however be extrapolated from the information collected that the current market can be expanded to encompass areas outside northern Namibia.

It was also established that a wide range of other products is produced from indigenous fruit trees and is also being traded. However the current study did not go into depth to give the real value of the indigenous fruit to rural people of northern Namibia. Therefore an economic valuation of the indigenous fruit tree resources is recommended for further research. Market research should also include information about the product quality demanded by the consumers and the analysis of the existing demand for the fruit. The market potential also needs to be quantified in monetary terms and other market possibilities should be explored. Discussions should also be held with rural people so that they can realise the potential of *B. discolor* trees as an economic commodity and to encourage them to plant these trees on their land. The price of the fruit should be subjected to policies, which would enable the local people to sell at a reasonable profit. Research should also be initiated towards the domestication of the species, especially the propagation techniques and the fruit improvement to assist the industry. Export opportunities should also be investigated.

The following conclusions were reached about the application of PRA compared to RRA techniques to the present study:

- The PRA helped to gain the confidence of the participants in a very short period, which could not be said about interviews, as an informant may remain alert trying to determine the reason for a particular question.
- The tools, which were used, were designed to answer specific questions, which assisted in the data presentation especially since the type of information collected was qualitative data. It is very difficult to present qualitative data to informants in a meaningful way when it is collected by questionnaire format.

- However, data on income generated from selling indigenous fruit were missed in the PRA exercise, because this type of enquiry requires exposing information on income generated from selling certain products. Interviewing informants or using questionnaire offers more privacy than PRA techniques. Interviewing key informants to obtain this particular information could be a problem as sometimes they might not be involved in the trade or they might not have the information.

Every method has both its strong and weak points, but it can be concluded that when collecting qualitative data as in this case, PRA exercise have a much better application. When collecting quantitative data however a questionnaire could give more meaningful data.

This study should be viewed as a justification for the other studies on reproductive biology, which follows as it has established the importance of *B. discolor* to the rural people of northern Namibia.

Chapter 3

REPRODUCTIVE PHENOLOGY AND FRUIT PRODUCTION

3.1 Introduction

Although general phenological information on tree species indigenous to southern Africa exists (Coates Palgrave 1984), there is still a gap in the information on reproductive phenology. Several studies have concentrated on general phenology of species (Miller 1949; Shukla & Ramakrishnan 1982; Reich & Borchert 1982) except for Zietsman *et al.* (1989) who described both the vegetative and reproductive phenology of *Ziziphus mucronata* subsp *mucronata.* Because of a recent interest in the cultivation and domestication of especially fruit tree species indigenous to southern Africa, there is a need to fill the gap in the knowledge of their reproductive phenology.

Since this is the first investigation of the reproductive phenology of *Berchemia discolor*, an attempt was made to recognise the main phases of the reproductive phenology. At the same time an analysis of the relationship between seasonal climatic changes (rainfall and temperature) and reproductive phenology for the duration of the study was made. In addition to this, the yield for the season of individual trees was determined. The yield per annum will have economic implications in case of cultivation and commercialisation.

3.2 Literature review

Reproductive phenology is the study of the different phenophases during the reproductive stage of a species and their relation to biotic and abiotic factors and the interrelations among phenophases of the same species (Lieth 1974). According to Wood & Burley (1991), seven phenophases can be recognised during the reproductive stage of most trees. These are bud initiation, open flower stage, flower fall, immature small fruit, immature large fruit, mature fruit and fruit fall, a classification that was used as guideline in this study. The abiotic factors such as rainfall, temperature and photoperiod are of great importance as they are pre-eminently responsible for the timing of phenological events. Biotic factors include pollinators and seed dispersal agents, which contribute to the relationship between one phenological event and another.

Alvim & Alvim (1976) mentioned three possibilities of the relationship between climatic factors and flowering in tropical forest trees. Firstly, trees can show no response to the variation in climatic factors, as they would flower every year at the same time regardless of climatic conditions. These trees are probably influenced by photoperiodicity, but moisture or temperature may still play an important role in the quantity and quality of the flowers and fruit produced. Secondly, trees will start flowering only after the first rain of the new rainy season. Thirdly, those that does not show a clear response to climatic factors and some will flower almost every month of the year.

Forest trees usually show periodicity in their fruit production (Harper 1977). In some years a tree would produce a large crop (mast years), while in other years the same tree might not produce fruit at all or produce a very small crop. This phenomenon can be explained as predator-escape strategy in some trees or as seed production versus vegetative growth in others. This type of periodicity can also be influenced by climatic factors (Harper 1977).

3.3 Study areas

The study was carried out in two regions in northern Namibia, namely at Omusati in Owambo and in Caprivi (Fig. 2.1 in Chapter 2). These two areas were chosen due to accessibility and abundance of the species. Initially a third area, Grootfontein was included, but due to manpower constraints the study was narrowed to two areas. An initial survey showed that there are no variations in the ontogeny of the flowers and fruit, so only data on phenology were collected in Katima Mulilo, whereas information on phenology as well as flower and seed ontogeny was gained in the Omusati Region.

At Ombalantu, in the Omusati Region, information on the reproductive phenology was collected from the first week of November 1996 to April 1997 while at Bwara, in the Caprivi Region, data collection started from the second week of October 1996 until the end of March 1997.

Meteorological information for the flowering and fruiting season of 1996 and 1997 of the two study areas was obtained from the Namibian weather bureau in Windhoek. Data requested were the daily minimum temperature, the daily maximum temperature and the daily rainfall.

Although the meteorological data have limited applications as it was collected far away from the study sites. The data were hereby given to set a general trend of the climatic conditions during the study period.

Omusati

In the Omusati Region data were collected from trees in the district of Ombalantu at the village known as Okathimbi Eengolo, which falls under the jurisdiction of Mrs. Magdalena Endjala. The head of the household gave an estimation of the age of the trees included in the study. Trees one, two and three were estimated to be at least 38 years old. Trees four and five were estimated to be only 20 years old. The difference in age was obvious because the older trees had much bigger crowns than the younger ones. The trees were transplanted into the field when the farmer started cultivating the land. Most of the trees growing on the land were felled, but *B. discolor, Hyphaene petersiana, Diospyros mespiliformis* and *Sclerocarya birrea,* were left on the land or transplanted, fenced off and fertilised until they reached a stage when fruit could be harvested (Mrs. M. Endjala, pers. com.). This was because those trees produce valuable fruit.

The meteorological information for Omusati was recorded at Ogongo Agriculture College situated approximately 25 km away and where gaps existed due to the closure of the college during holidays, they were filled in with information from another nearby station, Ondangwa which is approximately 80 km away. These were the closest sites to the study site where the weather bureau collected information

For the six months during which data were collected, there was a limited variation in the daily minimum and maximum temperature, while the rainfall varied from one month to the other. The peak of the rainy season was recorded to have occurred in February (Fig. 3.1).

Caprivi

The Caprivi study site was at the village known as Bwara, about 50 km east of Katima Mulilo (main town). *Berchemia discolor* is one of the dominant species in the village and surrounding areas. The trees were not planted by the inhabitants of the village, but were maintained for their fruit production.

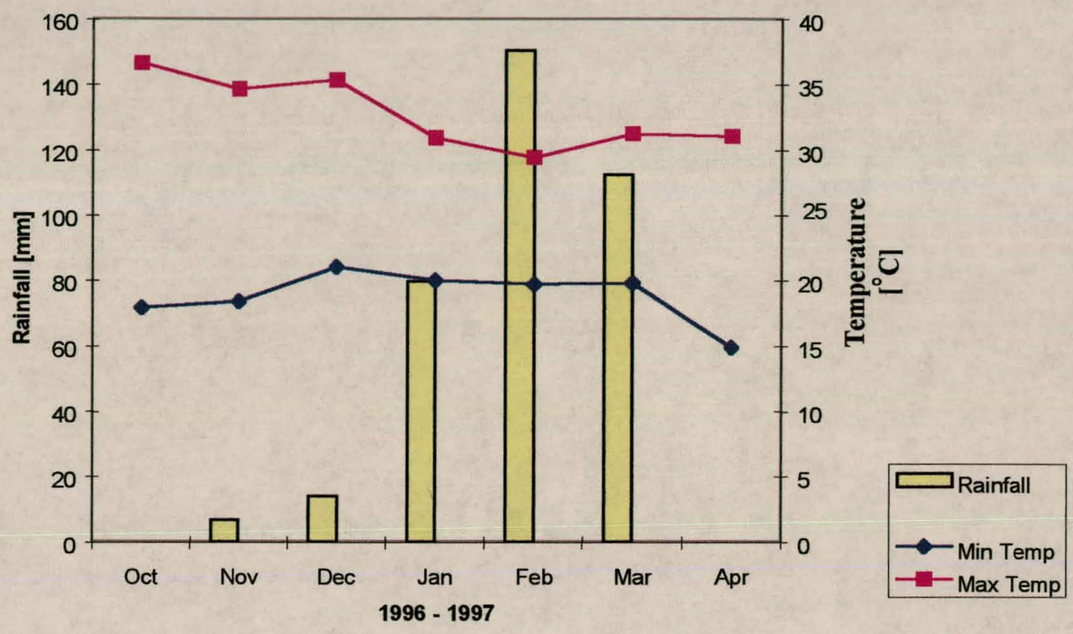


Figure 3.1 Minimum temperature, maximum temperature and rainfall figures for Omusati for the period October 1996 to April 1997.

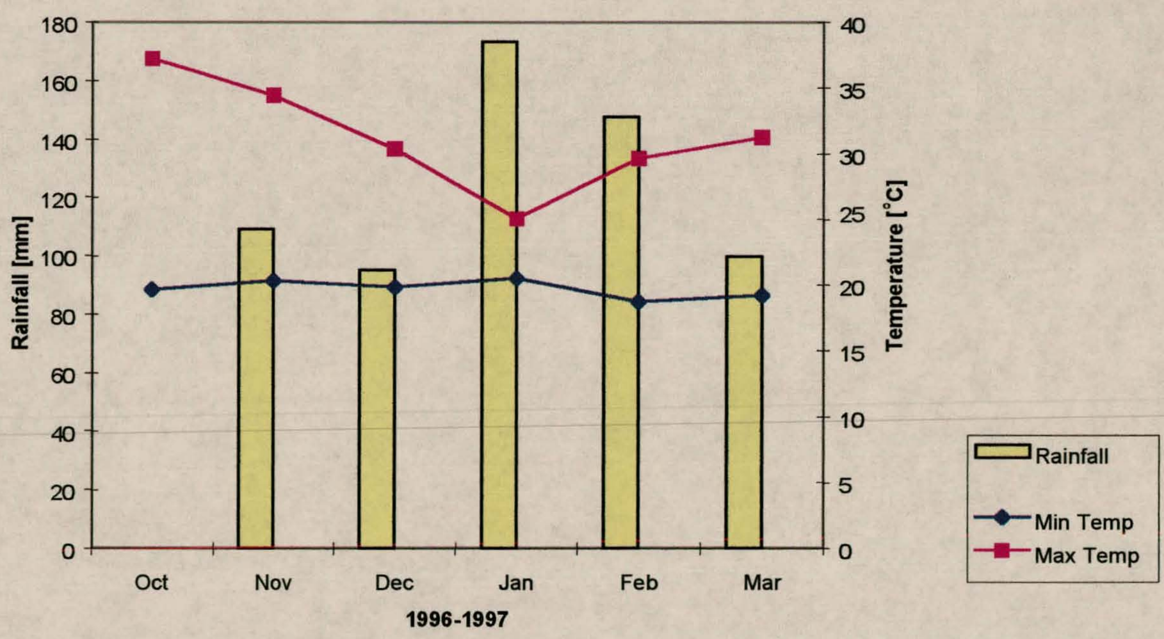


Figure 3.2 Minimum temperature, maximum temperature and rainfall figures for Caprivi for the period October 1996 to March 1997.

In Caprivi the station where the information was collected is situated at Katima Mulilo town, 50 km away from the study site. Similarly to Omusati, there was a limited variation in the daily minimum and maximum temperature, while there was a variation in rainfall figures from one month to the other. The peak of the rainy season in Caprivi was during January. Caprivi received more rain during the 1996-97 season than Omusati (Figs. 3.1 and 3.2).

3.4 Material and Methods

Reproductive phenology

There were 12 trees occurring on the farmer's land, of which five trees were chosen for data collection. These were selected by allowing a minimum distance of 100 m between the sample trees. The five trees were numbered from one to five for identification purposes (Table 3.1). A form for data recording in the field was designed (Appendix 3.1), featuring the seven phenophases described by Wood & Burley (1991). In both the study areas information was collected weekly over a period of six months. The phenophases were recorded on a two-scale matrix i.e. low and high. A phenophase was considered to be of low abundance if less than half of the branches of the tree exhibited the phenophase and it was considered high when more than half of the branches of a tree exhibited the phenophase. When one of the five marked trees displayed a certain phenophase, it was recorded as the beginning of that phenophase for the study area. In this study the term bud formation is used instead of bud initiation because the buds were recorded once they could be observed on the trees with the naked eye.

Table 3.1 The description of the trees studied at Omusati

Tree no.	DBH(cm)	Crown width(m)
1	54	18
2	38.6	10.9
3	47	16.4
4	40	11.5
5	32.5	6.9

Fruit production

Omusati was the most suitable site for data collection on fruit production. In this area the trees are semi domesticated and the owner of the farm practices fruit harvesting. Fruit production was estimated by weighing the ripened fruit per tree per week. At the end of the fruiting period the different fruit weights per week were aggregated to find the fruit production of a particular tree for the season. The DBH (diameter at breast height) crown size and flavour of fruit for the five trees were also recorded.

3.5 Results

Reproductive phenology

In both study areas the commencement of the reproductive phase of *B. discolor* was marked by bud formation during the rainy season. During 1996-97, the rainy season in Omusati started in November, which was immediately followed by bud formation (Fig. 3.1 & Table 3.2). During the same season Caprivi also received its first rains in November, but bud formation was observed already in October before the onset of rains (Fig. 3.2 and Table 3.3). An overlap among the seven phenophases was recognised throughout the reproductive phase. In each study area the period from bud formation to fruit ripening and eventually fruit all lasted for six months.

Although bud formation at Omusati (Table 3.2) started during the second week of November, new buds appeared until the end of January, which gave a budding period of ten weeks. The largest number of buds appeared during the first three weeks of December. The open flower phase lasted for seven weeks, in which a peak was reached during the last week of December going on to the first week in January. Flower fall started during the second week of December and lasted until the first week of February. Fruit development commenced during the last week of December and immature small fruit could still be found on the trees at the beginning of February. Immature large fruit were already observed by the second week of January and this phase lasted until the second week of April. Fruit ripening commenced by the first week of February and continued until the end of April. Fruit fall commenced with fruit ripening and lasted as long as the fruit ripening period occurred.

During the flowering period of 1996-97 at Omusati, an unusual loss of flowers occurred. Nearly all the trees on the land were affected. Trees which had just started flowering lost most of their flowers whereas trees in which the flowering phase started earlier must have had fertilised flowers which survived. The cause for this phenomenon is not known but is probably responsible for the very poor fruit yield of tree no. 4 (Fig. 3.4).

Table 3.2 Reproductive phenology of *B. discolor* at Omusati

PHENOPHASES	Nov	Dec	Jan	Feb	Mar	Apr
Bud formation	- - -	- - -	- - -			
Open flower		- - -	- - -			
Bud & flower fall		- - -	- - -			
Immature small fruits			- - -	-		
Immature large fruits			- - -	- - -	- - -	
Mature fruit				- - -	- - -	- - -
Fruit fall				- - -	- - -	- - -

Table 3.3 Reproductive phenology of *B. discolor* at Caprivi

Phenophases	Oct	Nov	Dec	Jan	Feb	Mar
Bud initiation	- - -	- - -				
Flower opening		- - -	- - -			
Flower fall		- - -	- - -			
Immature small fruits		- - -	- - -	-		
Immature large fruits			- - -	- - -		
Mature fruit				- - -	- - -	- - -
Fruit fall				- - -	- - -	- - -

At Bwara in Caprivi (Table 3.3) bud formation started earlier than that of Ombalantu and commenced already by the second week of October and continued for nine weeks until the second week of December. The peak of the budding phase was during the first three weeks of November. The open flower stage commenced during the second week of November and lasted for eight weeks until the beginning of January. Flower fall continued from the second week of November to the end of January. Fruit development commenced by the third week of November and immature small fruit were still being formed by the third week of January. Immature large fruit could be observed from the last week of December to the third week of February. Fruit ripening started by the second week of January and continued until the end of March. Fruit fall lasted for the same period as fruit ripening.

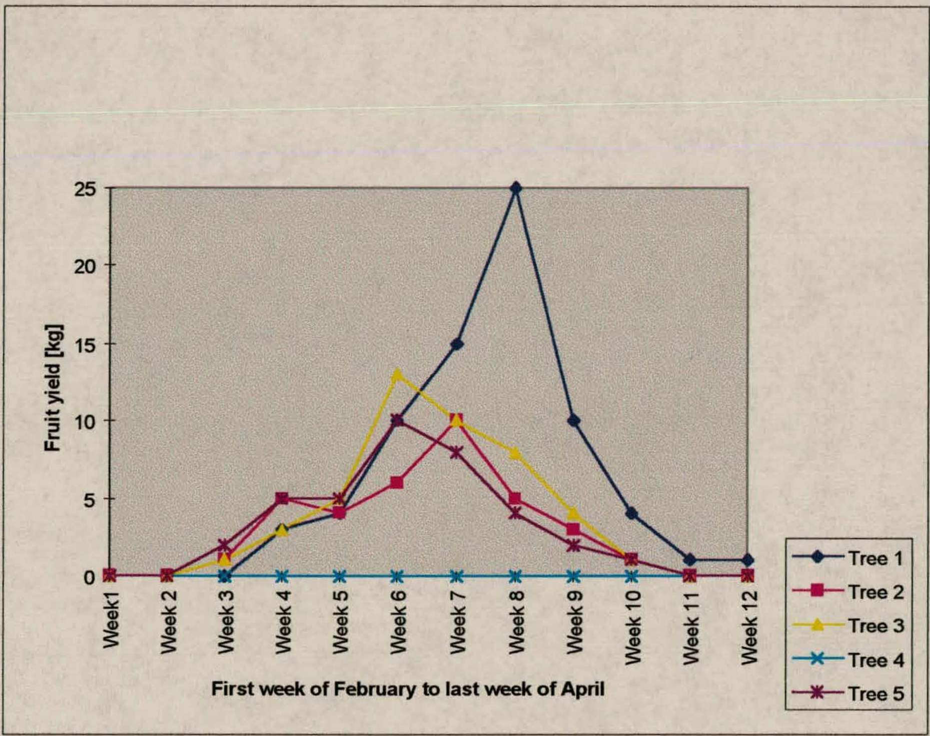


Figure 3.4 The weekly fruit yields of the studied trees at Omusati during the 1996-97 season.

Fruit production

Fruit fall in Omusati started in February and lasted until April with the peak of the fruiting period being reached in March. According to the local people the 1996/7 crop was bad especially for the trees included in the study. There appears to be a correlation between the age of the tree and its yield with mature trees yielding more fruit as compared to younger ones. Although exceptions do occur because tree no. 5 which is only 20 years old had given more or less the same yield as the 38-year-old tree no. 2. When comparing the crown width, it is obvious that the trees are almost similar in size and therefore one can conclude that the bigger the crowns size the higher the fruit yield (Table 3.1 & Fig. 3.4). Tree no. 1 had the highest fruit yield of about 73 kg and Tree no. 4 had the lowest fruit yield of about 1 kg, the other three trees were intermediate.

Since tree no.1 is one of the older trees and has a large DBH, crown width and the highest yield, one is inclined to draw a correlation between size, age and yield, unfortunately conclusions cannot be drawn on the results of one season with only five trees concerned. Another limiting factor is the event during 1996-97 season, in which flowers died and immature fruit were weaned.

3.6 Discussion

It is not clear what triggers bud initiation, but rainfall could be one of the factors involved. Rainfall is the most unpredictable factor in woodlands and it has been observed that any delay in the rains will virtually result in delayed flowering and vice versa (Reich & Borchert 1982). Since the results for the timing of bud formation differed for the two study areas, generalisation on the timing of bud formation is difficult to make. In Omusati bud formation was observed after the first rains, while in Caprivi it was observed two weeks before the onset of rains. Bud formation was observed at it's macroscopic stage therefore the results might be misleading in terms of the exact timing of bud initiation at the microscopic level. Both locations are at similar latitudes; consequently day length is discounted as a factor.

The relationship between temperature, humidity and photoperiod and the flowering phase could not be investigated due to the limited period of the study. Variations for these factors are usually less during the same season and even between seasons of different years the variation could be small (Reich & Borchert 1982). These factors could however, be playing an important role in triggering anthesis and fruit ripening (Van Rooyen *et al.* 1986b). Further studies should be carried out to determine their influence on flowering and fruiting especially if *B. discolor* is to be considered for cultivation.

Reich & Borchert (1982) gave the probable reason for some trees being able to start vegetative growth and flowering before the onset of the first rains. During the dry winter season when the trees are exposed to a low water potential, they shed their leaves to reduce water loss through transpiration. The trees however continue to absorb a minimal amount of water from the soil. At the end of the dry winter and beginning of spring the water potential of the tree continues to rise because of the small amount of water that is being absorbed during winter. When the water potential of the tree reaches a certain threshold, leaf flush and bud initiation is able to start before the onset of rains.

At Omusati where vegetative growth and flowering commenced after the onset of the first rains, there is a possibility that it was triggered by rainfall. The variation in the two areas can be explained by the climatic differences (Vasek & Sauer 1971; Primack 1980). The main factor that probably could explain the differences in the flowering and vegetative growth as observed in the two study areas, can be rainfall. The annual rainfall for Caprivi area is much higher (wet site) than that of the Omusati area (dry site), not only for the 1996-97 season but in general (see Chapter 2 on study areas: Owambo and Caprivi as well as in Chapter 3).

Reich & Borchert (1982), from the University of Kansas, USA, in their study of the tropical tree *Tabebuia neochrysatha* A. Gentry., found that trees growing on dry sites required provision of water before leaf growth and flowering could occur. In case of those trees growing on wet sites, they regained their growth prior to the onset of rains. The same could apply for the Omusati site, since the water potential experienced by the trees during the dry season could be very low so that rain was needed for the trees to rehydrate before growth can start. This might not have been necessary for the much wetter site in Caprivi.

On the other hand Shukla & Ramakrishnan (1982) explained that the pre-rain flowering and leaf production occur as a response to increasing temperature and day length. Both explanations could apply in the case of *B. discolor*. However the explanation by Reich & Borchert (1982) fits better than that of Shukla & Ramakrishnan (1982). This is because the increase in temperature and day length in the habitat of *B. discolor* occurs from the onset of spring, which is August and flowering only started in October or November. It should not also be overlooked that this project only observed bud formation at the macroscopic level, there is a possibility that bud initiation could have started much earlier on than what was reported here. It should also be kept in mind that climatic factors do not act independently when inducing phenophases, but they interact, and might all be of sequential importance.

There was a variation in the commencement of flowering among the different trees in the same area. This lengthens the reproductive period of the population to a large extent and it can be seen in the range of each phenophase, which in some cases last up to 10 weeks. According to Primack (1980), this variation could be under genetic control but also influenced by environmental factors such as microsite differences, which are the nutrient status of individual plants and moisture availability. This is seen as an advantage to the fruit market because the period in which fresh fruit will be available due to the variation in the flowering period is lengthened. This variation in flowering exhibited by natural populations of *B. discolor* could result in the development of early or late flowering cultivars through genetic improvement.

Although the sample of trees included in this study for fruit yield was very small, it gives an idea of what could be the expected fruit yield in *B. discolor* trees. Fruit yield studies on *B. discolor* trees are difficult to conduct because most trees occur in the wild and those that occur on communal land are communally owned and are therefore accessible to everybody. This made conducting controlled experiments almost impossible. At the study site in Omusati the trees are owned by one individual. The owner of the land practices fruit harvesting, which simplified the study.

Conclusions could not be drawn about the relationship between the size of the tree, crown width and fruit yield as the sample is not a representation of young and old trees or big and small trees. Personal communication with the owner of the land confirmed that the 1996-97 fruit crop was one of the worst she has experienced. The low fruit production in Omusati for the 1996-97 season could be attributed to the incidence observed during the flowering phase where the flowers dried on the trees. It is not clear whether this phenomenon was a strategy of the tree to reduce reproductive potential due to moisture stress or that the flowers dried because of the high ambient temperatures, which were reported during this season.

3.7 Conclusions

Vegetative growth and bud formation in Omusati occurred just after the onset of the first rain whereas in Caprivi it occurred two weeks prior to the onset of the rain. These differences in the timing of bud formation in the two study areas are probably attributed to the annual rainfall of the study areas. The length of the reproductive phase in 1996-97 season extended from mid October to end of March in Caprivi and from beginning of November to early April in Omusati. Further analysis of the relationship between reproductive phenology and climatic factors was limited by the duration of the study. According to the local people, the fruit yield for the trees included in the study at Omusati was very low during the 1996-97 season. There was variation in the fruit yield of the individual trees observed, at this point it can only be speculated that the factors causing this variation are tree size, genetic variation and climatic conditions.

Chapter 4

FLORAL AND POLLINATION BIOLOGY

4.1 Introduction

For successful reproduction angiosperms must undergo a transition from the vegetative phase to a reproductive phase. The beginning of the reproductive phase is marked by the formation of floral primordia as a reaction on some or other stimulus. Floral initiation is followed by growth and development in the floral unit until it reaches maturity, fruit formation is preceded by pollination, compatibility, pollen stigma interactions, fertilisation and embryo development (Malik 1979).

However, the reproductive phase is not always a smooth process with the result that flower and fruit production vary in most species from tree to tree and from year to year. Several factors are responsible for these variations. Stephenson (1980) regarded pollination failure as the most important factor for failure of fruit set. He attributed it to the lack of pollinators in zoophilous species and to prevailing rainy or windy conditions in wind pollinated species. The second factor, which Stephenson (1980) regarded as a cause of poor fruit set, is the failure of fertilisation. Pollen sterility or viability, stigma receptivity, pollen tube growth in the styles, pollen competition and incompatible mechanisms can affect this. Thirdly embryo abortion can occur due to homozygosity or lethal or defective genes or by external factors like drought, frost and defoliation by herbivores. A proper knowledge of these factors is necessary to design management to intervene or manipulate in order to increase reproductive success.

This study looks at the various aspects of the floral and pollination biology of *Berchemia discolor* such as the morphology of the flower in association with its functions, pollen viability, pollen sterility, stigma receptivity, odour production, pollen tube growth in the styles, flower visitors and floral behaviour. It also attempts to establish the type of breeding system operating in the species through the analysis of the available information.

4.2 Literature review

Pollination is the transfer of pollen grains from the paternal (anthers) to the maternal (pistil) part of the flower (Faegri & Van der Pijl 1979). Pollination and plant pollinators are inseparable since insects and flowers mutually assure reproductive success (Kevan & Baker 1983). Insects specialised for feeding on flowers are mainly from the orders Hymenoptera (bees and wasps), Lepidoptera (butterflies and moths), Coleoptera (beetles) and Diptera (flies) (Free 1970; Proctor & Yeo 1973; Kevan & Baker 1983). Insect pollination is unique to the angiosperms and the reproductive success of angiosperms is largely attributed to that (Simpson & Neff 1981).

The plant-pollinator interactions revolve around the plant providing floral rewards to the pollinators and in the process of visiting, the insects pollinate the flower (Simpson & Neff 1981). The main rewards that pollinators get from the flowers are pollen and nectar. Simpson & Neff (1981) mentioned that some plants offer floral rewards other than nectar and pollen, which include nest construction material, brooding places, sleeping places, floral tissues and oil. They explained that the force behind the evolution of these floral rewards was to explore other available pollinators. Insects are guided by both visual and olfactory stimuli in their visitation of flowers (Pellmyr & Thien 1986). According to Pellmyr & Thien (1986) olfactory stimuli alone can direct insects to flowers while vision alone cannot do this.

The most common techniques used in the study of pollination ecology are the observation of flower visitors in the field to determine the plant-pollinator interactions. However, semi-natural and laboratory studies can also be carried out (Opp & Prokopy 1986). Since it is nearly impossible to distinguish between accidental flower visitors and functional pollinator merely by observation in the field, insects are usually collected and checked for the presence of pollen on the bodies or in their guts (Faegri & Van der Pijl 1979).

Pollen viability and the time it lasts are important in plant breeding, because in artificial pollination it is necessary to know whether the pollen used will be able to fertilise the ovules. Pollen may be viable from 1 to 2 hours or even longer than a week (Dumas *et al.* 1985; Dafni 1992) and different methods could be used, of which the germination of pollen grains is one. Different sugar concentrations should be used to find the optimal concentration for pollen germination for the species concerned since different species differ in this regard. This method proves to be excellent for bicellular pollen grains but tricellular pollen grains need more sophisticated methods (Dumas *et al.* 1985; Owens *et al.* 1991; Dafni 1992). Another method, but a time consuming one for testing pollen viability is by fertilising flowers and monitoring fruit set (Dumas *et al.* 1985).

Stigma receptivity is another important aspect of breeding programs or artificial pollination since pollination can only be successful if accurate information on the timing of the stigma receptivity is known. This is because, depending on the species, stigma receptivity lasts from a few hours to up to ten days (Dafni 1992). Different methods can be applied to assess stigma receptivity, depending whether it is a wet stigma or dry stigma (Heslop-Harrison & Shivanna 1977). According to Dafni (1992) stigma receptivity can be determined by observing morphological changes, especially in wet stigmas where receptivity is characterised by the presence of an exudate. Staining for the presence of enzymatic activity can also test wet stigmas. For both dry and wet stigmas Dafni (1992) recommended pollen germination or tube growth or seed set after pollination at different times relative to flower opening for the determination of stigma receptivity.

There is limited knowledge and understanding available about the growth of pollen tubes in the styles. Pollen tube growth studies could provide information on the interactions between pollen and pistil. This would lead to an understanding of the various breeding systems and reveal to what extent sexual mechanisms such as self-incompatibility exist (Heslop-Harrison & Shivanna 1977). Pollen tubes in the styles could be studied after staining of the styles with a stain combination of Safranin O and Aniline blue. The pollen grains supposedly stain blue while the pollen tubes stain red (Dafni, 1992). Another method involves the use of the fluorescent microscope, with which the presence of the pollen grains and pollen tubes in the styles can be easily distinguished (Martin 1959).

The study of pollination and breeding systems of plant species in their natural environment contributes in gaining knowledge on gene flow within and between populations (Dafni 1992). A higher percentage of angiosperms are hermaphrodites as compared to unisexual species (Bawa & Beach 1981; Dumas *et al.* 1985; Richard 1986), which could put autogamy as the most obvious type of fertilisation to xenogamy. However, since autogamy results in low quality offspring whereas xenogamy results in good quality offspring (Free 1970), selection acts towards the promotion of outcrossing mechanisms. Since annual variations do exist in the availability of pollinators, plants may resort to self-pollination as a temporal measure to assure reproduction of future generations (Lewis 1979). Consequently, breeding systems of angiosperm range from obligatory self-fertilisation in self-compatible species to obligatory cross-pollination in self-incompatible species (Bawa & Beach 1981). Breeding systems are further modified by means of temporal and spatial mechanisms, which resulted in dichogamy and herkogamy respectively (Lloyd & Yates 1982; Richard 1986). Lloyd & Yates (1982) argue that the force behind the evolution of dichogamy and herkogamy was to avoid interference between maternal and paternal functions in hermaphrodite flowers. This is because both mechanisms are sometimes found in close conjunction with other mechanisms such as self-incompatibility, which effectively prevents self-fertilisation (Lloyd & Webb 1986). However, in the absence of self-incompatibility mechanisms, dichogamy and herkogamy function as mechanisms to avoid interference in the presentation of the stigma and pollen. At the same time this maximises cross-fertilisation (Webb 1985). The interference in maternal functions could be established by self-pollen, which may clog the stigma and at the same time displace compatible pollen grains. The anthers can also remove cross pollen from the pollinators; or the presence of incompatible pollen tubes in the style, may limit the growth of the compatible pollen tubes (Lloyd & Yates 1982; Lloyd & Webb 1986). Interference in the paternal functions could be brought about by the stigmas interfering with the collection of pollen and causing self-pollen to be deposited on self-stigma instead of being transported to conspecific stigmas (Lloyd & Yates 1982; Lloyd & Webb 1986).

The way in which dichogamy is exhibited will determine the success of cross-fertilisation and the success with that maternal and paternal functions are separated. A dichogamous protandrous flower, in which pollen presentation precedes stigma receptivity, is usually considered successful (Webb 1985). This is because intraspecific competition for mates requires pollen to be dispersed to conspecific stigmas before they have received pollen from other genotypes and the receptivity of the stigmas should occur after pollen has been removed from the various genotypes (Bawa & Beach 1981; Webb 1981). However the success of protandry depends on the degree of overlapping between the male phase and the female phase. A continuum exists in plant species from no overlap at all to a slight overlap or to a complete overlap (Webb 1985). The condition where there is no overlap of the two phases is more successful in separation of the two phases and thus promotes cross-fertilisation. Lastly the degree of synchrony of protandry within a plant also plays an important role. In asynchronous and hemisynchronous individuals there is still a possibility of geitonogamy whereas synchronous individuals have a complete separation of the female and male phase of all the flowers of a plant (Webb 1985).

Several authors have concluded that protandry is more common in angiosperms than protogyny (Darwin 1876, Gray 1880, Muller 1883 cited in Lloyd & Webb 1986). After examining the existing evidence Lloyd & Webb (1986) ruled out this statement because the evidence presented was insufficient to make any conclusions about the frequency of the two mechanisms in dichogamous plants.

4.3 Material and Methods

Study areas

A description of the study area for this section of the work can be found in Chapter 3. Page 54.

Flower buds, flowers and seed collections

Collection of flowers, buds and fruit was carried out once a week on the same trees from which data on reproductive phenology and fruit production were collected at Ombalantu area. Data collection started during the second week of November and lasted to the second week of January. Six buds, flowers or fruit were collected randomly from each tree every week, two from the upper, two from the middle and two from the lower crown.

Since the size of the flowers is small they were immediately fixed in the field, and put into specimen bottles containing formalin-acetic-acid (FAA) solution. Thicker specimens like immature fruit were sectioned before being fixed in FAA (Owens *et al.* 1991). Afterwards the fixed material was transported to Stellenbosch.

In the laboratory the fixed material was dehydrated and embedded in wax using the tertiary butanol method (Johansen 1940) and sectioned with a rotary microtone. The sections were stained with Alcian Green Safranin (AGS) according to Joel (1983).

Scanning Electron Microscope (SEM) Procedures

The flowers, buds and fruit were removed from the fixative FAA, critically point dried, coated with gold and then examined under the Joel 4100 SEM (Berlyn & Miksche 1976).

Floral behaviour

Observation on floral behaviour were started two weeks before the opening of the first flowers. At least three individual trees were monitored for floral behaviour. Five flowers were chosen on all sides of a tree and tagged, observations were then done every 30 minutes from the time of anthesis. The flowers observed were mostly on the lower branches for better visibility and accessibility. Observations on an individual tree lasted for a day. The number of individuals monitored was limited because all the trees in the population had open flowers almost at the same time. Anthesis and the movement of the sepals, petals, and stamens as well as the development of the pistil were monitored on three different days (Zietsman 1991).

Pollen viability

For germination tests, one day open flowers were collected from the trees and brought to the laboratory. The anthers were removed from the flowers and the pollen was dusted in different petri dishes. Following Dafni (1992), pollen was dusted on cellophane paper, which was previously soaked in a sugar solution. Different sugar concentrations, ranging from 5—20% were used in the different petri dishes. The petri dishes were left for 24 hours at room temperature.

Stigma receptivity

Initially attempts were made to determine stigma receptivity with the aid of peroxidase paper (Dafni 1992) but it was later realised that *B. discolor* has a dry stigma, because the test paper remained dry throughout the trials. Alternatively, stigma receptivity was estimated by observing the morphological changes occurring in the flowers after anthesis.

Pollen tube growth in the styles

Flowers were collected on the second and fourth days after anthesis. The flowers were immediately fixed in an ethanol-acetic acid solution and left for one hour, after which the material was stored in 70% ethanol. Whole flowers were hydrolysed in 45% acetic acid at 60°C, which was done at ten minutes intervals from 10—60 minutes. The styles were separated from other floral parts and stained in a hot dye solution of Safranin T, aniline blue and glacial acetic acid (Dafni 1992). In preparing the dye solution, in the absence of Safranin O, Safranin T was used, as they are known to yield the same results. The stained styles were placed on a microscopic slide together with a drop of dye and were squashed with the coverslip to be examined under the microscope. Pollen grains were supposed to stain blue and the pollen tubes were supposed to stain red (Dafni 1992).

Odour production

For odour production different vials were used for different floral parts. Anthers and petals were put in one vial whereas the intrastaminal disc, sepals and pistils were cut and placed in a different vial for an hour to accumulate odoriferous substances (after Van Wyk & Lowrey 1988).

Flower visitors

Insects visiting the flowers were captured using a net, killed with a household insect killer and preserved in 70% ethanol. A student at the Department of Entomology, Faculty of Agriculture at the University of Stellenbosch identified the insects. This gives an idea of the overall insect visitors to the flowers and therefore the potential pollinators. Pollen grains attached to the body of the insects were not checked because they had been washed away by the preservative used.

4.4 Results

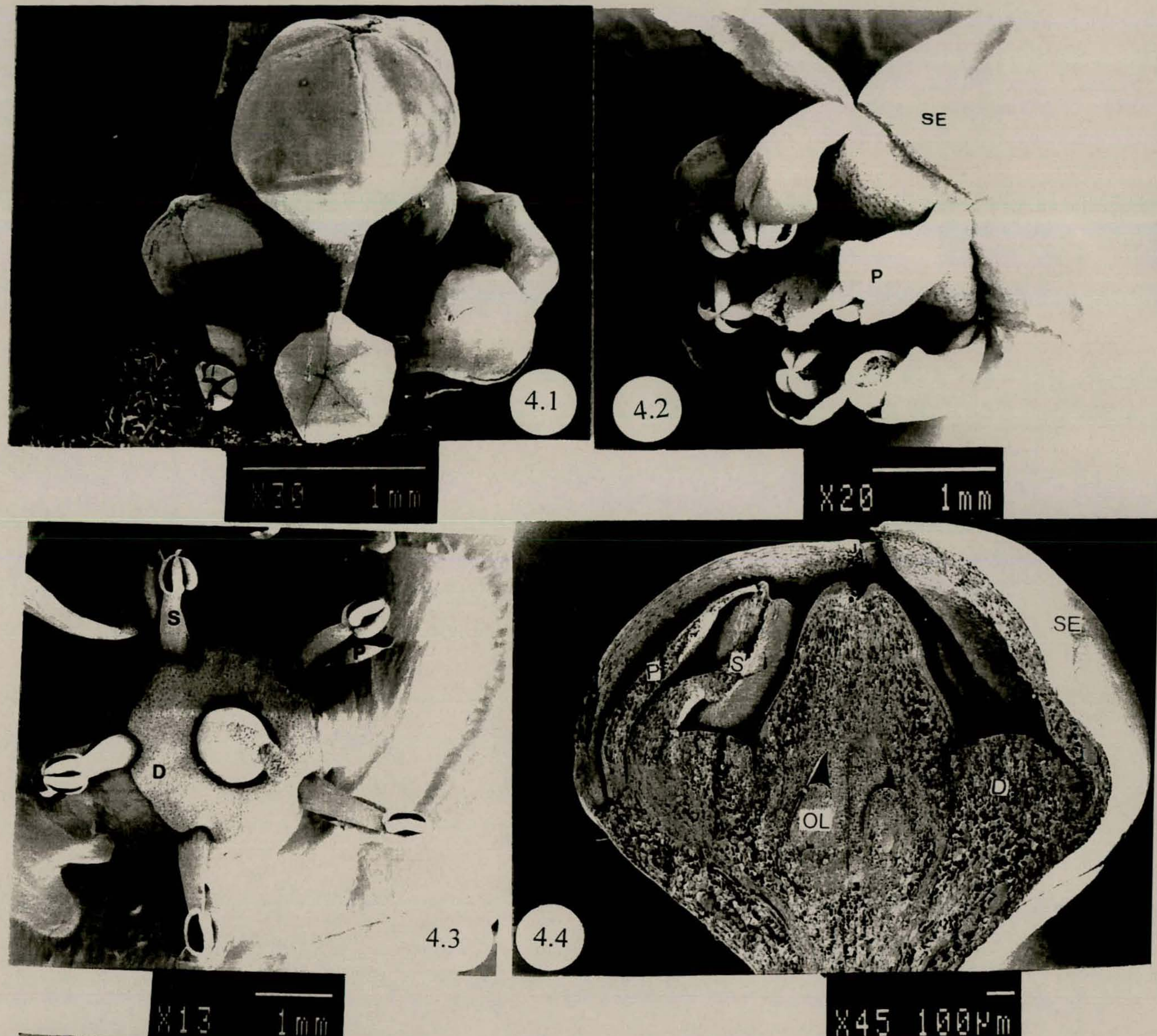
Floral and fruit ontogeny

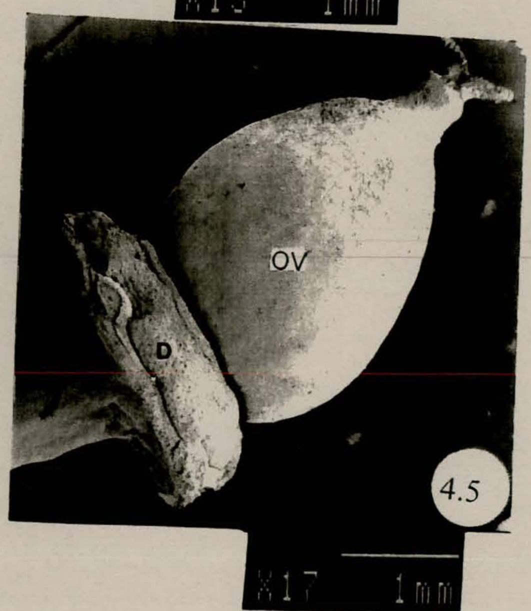
Structural and morphological characteristics

The structure of the flower of *B. discolor* is in accordance to the family description by Lawrence (1951). The small bisexual flowers are borne in axillary cymes consisting of four to eight flowers of different ages (Fig. 4.1). Each flower has five sepals, five concave petals alternating with sepals, and five stamens. The stamens are borne opposite the petals and are enclosed by the concave petals (Fig. 4.2). The stamens and petals arise from outside the intrastaminal disc (Fig. 4.2 & 4.3) and the intrastaminal disc (Fig. 4.3, 4.4 & 4.5) surrounds the superior ovary. The intrastaminal disc consists of typical glandular tissue (Fig. 4.6 & 4.7) and just after anthesis the disc is covered with fluid, which is probably nectar. The pistil consists of a two-celled ovary, a short style and a bilobed stigma (Fig. 4.5). The two-celled ovary (Fig. 4.4) has only one ovule per locule, which is basally attached.

Floral behaviour

Floral behaviour was divided into the following phases:





Figures 4.1—4.5 Scanning electron microphotographs of the buds, flowers and fruit of *B. discolor*. 4.1 Different stages of bud development within one inflorescence. 4.2 Opening flower. 4.3 Open flower. 4.4 Longitudinal section through the bud. 4.5 Young fruit. D=intrastaminal disc; P=petals; S=stamens; SE=sepals; OL=ovule; OV=ovary

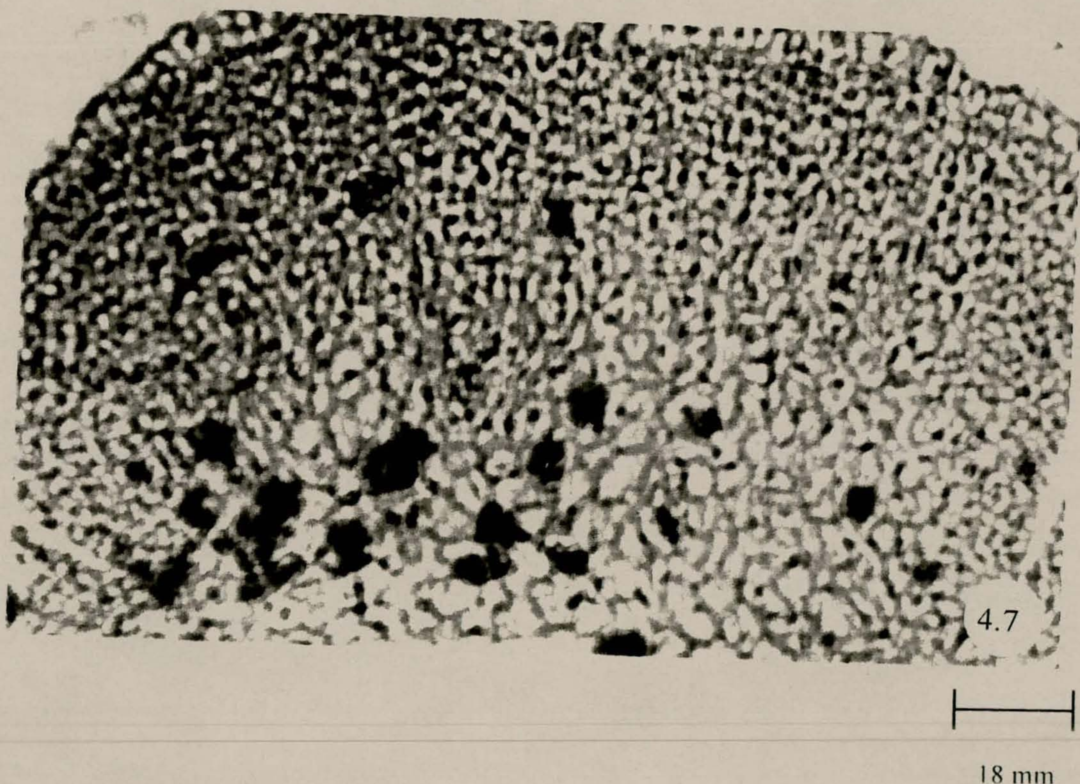


Figure 4.6 & 4.7: Light microscope photographs showing a longitudinal section through the flower of *B. discolor*. 4.6 A longitudinal section showing the intrastaminal disc and the superior ovary. 4.7 The intrastaminal disc to show the glandular cells that characterise it. D=intrastaminal disc; OL=ovule. Scale =100 μm

Bud phase

Rounded buds with partitions indicating the divisions of the sepals are visible from a very young stage (Fig. 4.1). Cross sections of the buds show that most of the floral parts are fully developed by the time they reach macroscopic level. A bud may last up to four weeks on a tree before anthesis.

Flower opening

Anthesis occurred mostly in the morning but could also occur any time during the day. It is characterised by the splitting of the sepals and exposure of the stamens, petals and the pistil (Fig. 4.2). At this stage the stamens are partially covered by the concave petals giving them a hooded appearance. The pistil is short and is not fully developed by this time. The flower has a greenish-yellow colour, when open.

Male phase

The anthers split longitudinally to release pollen, after which the stamens and petals diverged along with the sepals. The male phase lasted for about six hours e.g. from 07h00 in the morning to 13h00 in the afternoon. At the end of the male phase pollen had disappeared from the anthers, as the anthers lost their yellow colour and looked wilted.

Female phase

The female phase was characterised by the elongation of the pistil and the development of the stigmatic lobes. It followed the male phase shortly after stamen divergence (Fig. 4.3). The divergence of the stamens completely separated them from the stigma and eliminated chances of contact with the pollinators.

Flower senescence

On the second day after anthesis, the intrastaminal disc and the receptive surface of the stigma changed to a dark colour and the sepals, petals and stamens were wilted.

Fruit development

During the first four days after anthesis, changes were difficult to observe with the naked eye. Thereafter the swelling of the ovary indicated that fruit development had started (Fig. 4.5).

Pollen viability

Although different sugar concentrations were used in the experiment to test for pollen viability, no signs of pollen germination were observed after 24 hours in any of the experiments. The petri dishes were left for another 24 hours but still no germination could be observed.

Stigma receptivity

The morphological changes, which indicate stigma receptivity, were identified to be the growth and elongation of the style during anthesis. This occurred after the presentation of the pollen. Thus *B. discolor* is a protandrous species.

Pollen tube growth in the styles

Pollen grains were observed on stigmas of flowers collected two days and four days after flower opening, but the stain was indiscriminate, because all cells were stained red. Thus it was difficult to distinguish between the pollen tubes and the stylar cells. The pollen grains could be easily distinguished from the rest of the cells because of their structure.

Odour production

There was a strong odour in the vicinity of the tree during anthesis. The results of the experiment for locating the source of odour indicated the intrastaminal disc to be the source. However no further tests were carried out to verify the location of osmophoric tissue.

Flower visitors

The insects were only identified up to family level. Insects visiting *B. discolor* flowers were found to belong to four different orders including seven families (Table 4.1). The largest number of visitors belonged to the order Hymnoptera (bees and wasps), which were represented by four different families. Insects preserved in a liquid preservative could be identified, but pollen attached to the bodies of insects, preserved in liquid preservatives, would have been washed away making the identification of pollen grains impossible.

Table 4.1: Classification of the insects visiting the flowers of *B. discolor*

ORDERS			
Coleoptera	Diptera	Hymnoptera	Heterophera
FAMILIES			
Lycidae Scarabaeidae	Asilidae	Inchneumonidae Formicidae Apidae Vespidae	Reduviidae

4.5 Discussion

The most distinctive part of the flower of *B. discolor* is the intrastaminal disc. The presence of an intrastaminal disc is not confined to *B. discolor*, but is a characteristic of most of the species in the family Rhamnaceae (Lawrence 1951). The intrastaminal disc might be important in nectar and odour production.

The odour production serves as an attractant for pollinators whereas the nectar acts as a reward to potential pollinators. The location for the source of odour and production of nectar are suppositions because the location for osmophores were not confirmed and the composition of the liquid produced by the disc was not tested although the structure of the disc is typical that of glandular tissue. According to Dafni (1992) there are no tests sensitive enough to determine the location of osmophores on floral parts. Singh *et al.* (1996) used a neutral red water solution to locate osmophoric tissue in their study of *Zantedeschia aethiopica* L. Neither did the tissues presumed to be producing the scent, nor the rest of the floral tissue react to this test. Neutral red test was not performed on *B. discolor* flowers since the evidence in literature pointed out that the results would be unsatisfactory.

The poor results obtained on the growth of pollen tubes in the styles confirm the observations made by Heslop-Harrison & Heslop-Harrison (1970) that the stainability of pollen and pollen tubes by ordinary dyes usually yields poor results. A better method could have been the one by Martin (1959), in which pollen tubes are observed by means of a fluorescence microscope. This method could not be applied in this experiment due to lack of facilities.

The use of the sucrose solution in determining pollen germination requires two considerations i.e. the cytology of the pollen grains (bicellular or tricellular type) and the optimal sucrose concentration for optimal pollen germination (Dumas *et al.* 1985). Pollen germination was done at different sucrose concentrations in order to determine the optimal concentration for pollen germination in *B. discolor*. Unfortunately the cytology of the pollen grains of *B. discolor* was not known. According to Dumas *et al.* (1985) tricellular pollen grains are unlikely to germinate in this kind of medium.

A possible reason why pollen tube growth could not be observed could be that the microscope available during fieldwork was not a suitable one. The magnification of the stereo microscope used proved to be too low for one to be able to see the microscopic pollen tubes. It was the only microscope available in the field at the time. A transmission light microscope would have given better results.

According to Lloyd & Webb (1986) one day flowers usually do not permit immediate pollen tube growth. Pollen grain germination could be delayed until stigmas have received pollen from different genotypes. Therefore pollen tube growth in style of the flower of *B. discolor* probably started only later. This could have been on the second day after anthesis since the flowers only lasted for one day. This lead to the decision of collecting flowers on the second and fourth day after anthesis for determining pollen tube growth.

The method used in determining pollen viability was a modification of a technique employed in species with copious amounts of pollen (Owens *et al.* 1991). This probably also limited the application of the method because *B. discolor* is a species with a smaller amount of pollen. Only after fieldwork was done, a technique by Griffin *et al.* (1982) used in determining pollen viability by germinating *Eucalyptus* pollen, was found. This could have been a better experiment since the method is applicable to species with smaller amounts of pollen.

The failure to germinate pollen grains could also be due to the unsuitability of the method to the species. Vaughton & Ramsey (1991) showed that different species respond differently to the different methods used for determining pollen viability. Therefore the choice of a method should solely be determined by its suitability to a particular species. Their attempts to determine pollen viability by both pollen germination and fluorescent diacetate method in *Banksia spinulosa* subsp *neoanglica* failed. The only method, which worked for them, was in vivo determination of the ability of pollen to effect fertilisation and seed set.

The dichogamous, protandrous behaviour of the *B. discolor* flower separates the pollen presentation from stigma receptivity. This reduces the likelihood of self-fertilisation and encourages cross-pollination (Lloyd & Yates 1982). The isolation of stamens from the pistil can explain some of the floral behaviour exhibited by the flower such as the divergence of the stamens towards the petals at the end of the male phase and the elongation of the style during the female phase.

The flowers of *B. discolor* exhibits complete intrafloral dichogamy but the flowers on the tree represent asynchronous dichogamy. According to Lloyd & Webb (1986), intrafloral dichogamy in protandrous flowers is very effective in preventing autogamy, however in the case of *B. discolor,* the asynchronous nature of the dichogamy allows for geitonogamy to occur. One would expect the presence of self-incompatibility in this case because dichogamy might have the sole function of anther and stigma separation while self-incompatibility will prevent autogamy altogether. Further experiments are needed to establish the absence or presence of self-incompatibility.

According to the classification by Heslop-Harrison & Shivanna (1977), a dry unicellular papillate stigma like that of *B. discolor* could be related to a self-incompatible mating system. They furthermore associated dry stigmas with trinucleate pollen. Webb (1985), however argues that the relationship between type of incompatibility, cytology and the receptive surface of the stigma is not clear-cut. Therefore further detailed work is needed to understand the breeding system operating in *B. discolor.*

Since the insect visitors and possible pollinators were only identified to family level, different pollination possibilities should be considered.

Although coleopterans (beetles) can cause pollination they are not very important as pollinators. The family Scarabaiedae reported here belongs to the suborder Adephaga , which feed destructively on flowers (Proctor & Yeo 1973). The inactive nature of beetles may restrict cross-pollination as they would feed on the same inflorescence most of the time. Flowers, in which cantharophily has been observed have adaptations to protect the ovules from the pollinators. Cantharophily is mainly restricted to semi-desert areas (Proctor & Yeo 1973; Kevan & Baker 1983). The flower of *B. discolor* does not exhibit any adaptations to cantharophily since the superior ovary is well above the receptacle and the ovules are not well protected.

Members of the order Diptera (flies) with their suctorial mouthparts are adapted to feed both on nectar and pollen, however some are still predators. The family which was reported here, Asilidae (robberflies), have members that belong to genera with both predatory and vegetarian individuals (Proctor & Yeo 1973; Kevan & Baker 1983).

Hymenoptera (wasps, bees and ants) are the most important order of pollinators. The four families reported here Ichneumonidae, Formicidae, Vespidae and Apidae are all potential pollinators. In the family Ichneumonidae the larva is parasitic but the adults feed extensively on nectar and pollen. The family Vespidae consists of members, which belong to genera with both predatory and vegetarian individuals (Proctor & Yeo 1973; Kevan & Baker 1983).

Although the Formicidae (ants) are frequent flower visitors, their role in pollination is not yet understood. They have been implicated as being successful in the pollination of *Herniaria ciliolata*, a British species, and *Polygonum cascadense*, a North American species (Kevan & Baker 1983). Species pollinated by ants are characterised by a prostate growth form close to the ground. They are usually found in less vegetated areas, but large numbers of individuals will represent the species itself. The plants usually have small dull flowers and ants often live in symbiosis with species. Flowers of such species have extrafloral nectaries where the ants can obtain nectar easily. The plant benefits from the presence of the ants as their aggressive nature drives away nectar thieves and corolla feeders (Proctor & Yeo 1973; Kevan & Baker 1983). The presence of ants on flowers is of little significance to pollination as their role as pollinators is limited by their inability to travel long distances since they cannot fly. It has also been proven that ants secrete a substance, which lowers the viability of pollen on contact (Beattie *et al.* 1985)

The Apidae (bees) are completely dependent on the nectar and pollen diet which flowers supply, both as larva and adults (Proctor & Yeo 1973; Kevan & Baker 1983). Bees are considered the most important of all pollinators because not only do they have sufficient body hairs to carry pollen but they also have the behavioural patterns to ensure pollination. They also forage over long distances not only to satisfy their needs but also those of their young (Free 1970).

There is very little known as to the importance of the visitation of the order Heteroptera (bugs) to the plant or the insect themselves (Kevan & Baker 1983).

Consequently, the orders Hymnoptera, Diptera and Coleoptera could play a role in the pollination of *B. discolor,* however further observation and experimentation is needed to verify these findings. Wyatt (1983), in his analysis of plant-pollinator interactions, came to two conclusions that plants pollinated by bees and flies are generally protandrous while those pollinated by beetles and wasps are protogynous because of the direction of feeding by those insects. This interaction is not clear cut in *B. discolor* as the flower is protandrous and it is visited by a variety of insects. Further studies could clarify this interaction between *B. discolor* and its pollinators.

4.6 Conclusions

The results show that the flowers of *B. discolor* are protandrous and dichogamous. The main floral rewards for pollinators are pollen and nectar. Pollinators are probably attracted to the flowers by olfactory stimuli, however visual stimuli also play a role, as the flowers are greenish-yellowish in colour and borne in small inflorescence. Although the small flowers are inconspicuous, a number of small flowers together is noticeable. Four orders of insect visitors were identified of these four, three may have genera, which are potential pollinators. Attempts to germinate pollen in sucrose solution failed. This calls for investigations with other growth media. Although pollen grains were observed on the stigma, pollen tubes could not be observed in the styles of two-day and four-day flowers. This could probably be due to the indiscriminate nature of the stain used. Stigma receptivity was be indicated by the lengthening and development of the pistil after pollen presentation.

Chapter 5

NUTRITIONAL ANALYSIS OF THE DRIED FRUIT PULP

5.1 Introduction and literature review

Food production for human consumption is one of the greatest challenges of our times. According to Oldfield (1984), developing high yielding crops solved this problem so far. However this method is approaching a peak and irrespective of technological input very little improvement could be expected from this method in future. It is therefore important that future research should focus on domestication of other plants for cultivation like indigenous species and on improving the nutritive value of their fruit and increasing their crop yield.

Some attempts were made in the past to determine the nutritional value of some indigenous fruit. Wehmeyer (1966) found that the nutritional composition of nine indigenous fruit trees of the Transvaal did not differ much from domesticated fruit except for a much higher vitamin C content in the indigenous fruit. Nour *et al.* (1980) investigated the chemical composition of baobab fruit (*Adansonia digitata* L.), and the fruit was found to be rich in Vitamin C, iron, calcium and pectin. The seed of *Tamarindus indica* L. was found to be rich in protein and fat by Ishola *et al.* (1990). The fruit of 16 trees indigenous to Malawi differed in the type of nutrients they contributed to the human diet (Saka & Msonthi 1994). Some had a high protein (*Trichilia emetica* Vahl. and *Annona senegalensis* Pers.), or fat (*Strychnos spinosa* Lam.), and carbohydrate (*Parinari curatelifolia* Planchon ex Benth) content, whereas others had a high mineral content [*Adansonia digitata, Syzygium guineense* (Willd.) DC, *Trichilia emetica* and *Flacourtia indica* (Burm.f.) Merr]. Research into the nutritional value of indigenous plants is necessary to broaden the food base for human consumption.

Humans value fruit because of its pleasant taste, appetising appearances and ability to provide macro and micronutrients (Whiting 1970). There are two aspects to nutrition: firstly, food must be adequate to satisfy hunger needs and secondly, the food consumed must be balanced in supplying all the necessary nutrients required for body maintenance and growth (Duckworth 1966). It is therefore not the quantity that matters but the quality. Fruit mainly satisfies the second aspect of nutrition through providing a range of essential nutrients.

In fruit, carbohydrates include polysaccharides such as cellulose and starch, disaccharides such as sucrose and monosaccharides such as fructose, glucose and galactose (Duckworth 1966). The carbohydrate content of fruit may vary according to the type of carbohydrates and the moisture content of the fruit and can represent up to 23% of the fresh weight of a ripe fruit. The most commonly stored carbohydrate (or sugar) in fruit is sucrose, which consists of glucose and fructose (Fleck 1976). These are present in the form of disaccharides and monosaccharides, which are generally easily digestible.

Not all forms of carbohydrates contribute to human nutrition, e.g. cellulose, which is often associated with lignin. Both these components are non-digestible by the human gastrointestinal tract. Although cellulose and lignin do not have any nutritional value, their value lies in their fibrous nature and are usually referred to as dietary fibre (Osborne & Voogt 1978). Dietary fibre in the diet can reduce the prevalence of colon cancer. The amount of dietary fibre in fruit is limited (Duckworth 1966).

Fat and protein usually occur in relatively small quantities in fruit. According to Duckworth (1966) protein content of fruit seldom exceeds 1.5% and is usually below 1% while fat content is usually about 1%. There are exceptions, however, as in the case of olives and avocados (Duckworth 1966).

The role of mineral elements in body functions cannot be over-emphasised. They are major building blocks in most body tissues and also regulate some important body functions, such as nerve cell functioning and maintenance of body fluids (Fleck 1976). Besides vegetables, fruit is the major supplier of minerals to the human body (Duckworth 1966). The body requires minerals such as calcium (Ca), potassium (K), phosphorus (P) and sodium (Na) in large amounts while some elements such as iron (Fe) are required in smaller quantities (Whiting 1970). Mineral deficiencies could develop into serious diseases such as anaemia due to iron deficiency and goitre due to iodine deficiency.

Although ascorbic acid is found in both fruit and vegetables, fruit is the main source of ascorbic acid because vegetables loose up to 50% of their initial ascorbic acid content during the cooking processes. The ascorbic acid content of dried fruit is lower than that of fresh fruit, since it can be easily oxidised during storage (Duckworth 1966).

In arid countries like Namibia attempts to grow exotic fruit tree species are usually met with difficulties due to harsh climatic conditions, especially species with tropical origin e.g. Mango (Personal observation). Attempts should rather be focused on the domestication of indigenous species, which are adapted to the arid conditions. Further research on these species could also lead to their genetic improvement.

Of all the fruit trees indigenous to Namibia the best known species are *Sclerocarya birrea*, *Berchemia discolor* and *Diospyros mespiliformis* Hochst. Several nutritional studies have been carried out on *S. birrea* (Weinert *et al.* 1990; Taylor & Kwerepe 1995) whereas very little is known about either *B. discolor* or *D. mespiliformis*. *Berchemia discolor* is an important indigenous fruit tree species, both as a food source and as a source of income in Namibia. There are no published data about the nutritional composition of the fruit pulp of *B. discolor*. The present study investigated the chemical and nutritional composition of the fruit pulp to determine the nutritional value of and role it plays in the diet of rural people. The knowledge gained from the chemical and nutritional analysis of the composition of the fruit can provide a basis for utilisation and assist in marketing the fruit in the case of commercialisation.

5.2 Materials and Methods

Collection of samples

Dried fruit of *B. discolor* were bought on a market in Ombalantu, northern Namibia and transported to the University of Stellenbosch in South Africa for further analyses. It could have been better to collect random samples of fruit from different trees for fruit analysis. However, fruit had to be bought from the market as those harvested from the study site had been consumed already.

Sample preparations

The fleshy parts of the fruit were separated from the seeds. The flesh had a low moisture content, therefore additional drying was only necessary when required by a particular method of analysis. Analysis was done in triplicates. Due to variation between triplicates, some of the samples had to be re-analysed.

Proximate analysis

The standard analytical procedures according to James (1995) were used for determination of protein, carbohydrate, ash and fat content. An inductive coupled spectrophotometer was used for the determination of the minerals. The L-ascorbic acid test kit, compiled by Boehringer & Mannheim was used in the determination of ascorbic acid in the dry fruit pulp. Analyses of protein, fat, and D-glucose were carried out at the Department of Food Science, University of Stellenbosch. Determination of total ash and minerals were performed by The Institute of Fruit Technology (INFRUITEC), Stellenbosch. At the time the nutritional analysis of the fruit pulp was done, the laboratories at the Food Science department were under renovations, therefore only some of the nutritional components of the fruit could be analysed due to inaccessibility of facilities.

Determination of minerals

The method for mineral determination was adapted from Perring (1969) and Money (1964). The following procedures were followed: Four one-gram samples were weighed into porcelain crucibles, which were placed in an oven for two hours at 480°C. On removal from the oven, distilled water was added to the ash, followed by three millilitres of 16% hydrochloric acid. The crucibles were placed on a sand bath until the samples were dry, leaving a white residue. Another three millilitres of 16% hydrochloric acid was added to the residues. The residues were washed into 50 ml volumetric flasks and filled to the mark with distilled water. The solutions were filtered through Whatman no. 2 filter paper into plastic sample bottles. The minerals were determined using an inductive coupled emission spectrophotometer.

Determination of ascorbic acid (Vitamin C)

The L-Ascorbic acid calorimetric test kit method compiled by Boehringer & Mannheim was used in the determination of ascorbic acid. The method was performed according to the instructions provided. The amount of sample used had to be reduced to less than what was on the instructions as there was a lesser amount of sample available for the experiment. The adjustment made during sample preparation were as follows: Twenty five grams of fruit, 0.1ml n-Octanol and 25 ml of metaphosphoric acid were mixed in a mortar with a pestle. The pH of the mixture was adjusted to between 3.5—4.0 using potassium hydroxide (approximately 10—12 ml). The mixture was transferred to a 500 ml volumetric flask, and filled with distilled water. Afterwards the mixture was filtered with the aid of a suction pump, first through a muslin cloth and then through a Whatman no. 2 filter paper. The volume of sample solution per assay was 0.5 ml. Measurements were made using a scanning spectrophotometer model PU8740 UV/V15 at a wavelength of 578 nm and at 37°C. Alterations to the method in sample preparation were effected since less of the sample was required for the analysis.

Determination of D-glucose

D-glucose sugars in the dried fruit pulp were determined using the Lane and Eynon copper reduction method (James 1995).

Determination of fat

The Soxhlet method in which fat is continuously extracted from food with petroleum ether was used to estimate the fat content in the fruit pulp (James 1995).

Determination of protein

The Kjeldahl method (James 1995) was used in determining the protein content of the fruit pulp.

Determination of ash

Four 2 g samples were weighed and placed in a muffle furnace at 500°C for 13 hours and the percentage of ash was calculated (James 1995).

5.3 Calculation of results

Calculations of ascorbic acid, fat, protein and D-glucose content were performed according to the formulae given in Appendix 4.1 (James 1995).

5.4 Results and Discussion

Nutritional information of two other indigenous fruit species occurring in northern Namibia, *S. birrea* (Taylor & Kwerepe 1995) and *Parinari curatelifolia* (Saka, 1995) and that of *Prunus domestica* L. (Nergiz & Yildiz 1997), a domesticated commercial species, are presented together with the results obtained for *B. discolor* (Table 5.1).

The dried fruit pulp of *B. discolor* was found to contain 3.1% ash, which is high when compared to 0.9% for *S. birrea,* 0.55% for *Prunus domestica* and 1.8% for *Parinari curatelifolia*. The ash values represent the mineral content of a sample, therefore a high ash content should reflect a high mineral content. This assumption seems to hold true for *B. discolor* in this case. When the mineral content of the four species are compared, *B. discolor* shows the highest values in several cases. An exception however, was that of phosphorus.

As was expected the protein and fat contents in *B. discolor* fruit were present at very low quantities since these nutrients usually occur generally at relatively low quantities in fruit. *B. discolor* had an exceptionally low (0.1%) protein content in comparison to other species. The three indigenous species contained only a small proportion of fat, with less distinct differences between species (Table 5.1).

Comparing the carbohydrate content of the four species in Table 5.1, big differences between species were observed. *Prunus domestica* and *Parinari curatelifolia* showed the highest carbohydrate content 96.6 g/100g and 88.2 g/100 g fruit respectively, *S. birrea* only contained 12 g/100 g. The total carbohydrate content for *B. discolor* was not determined and the 24.5 g/100 g reported here is only the D-glucose component of the fruit. It must be emphasised that the D-glucose content reported here might be different for fresh fruit, since the percentage carbohydrates in dried fruit compared to that in fresh fruit may vary from 5% in fresh fruit to 60-80% in dried fruit (Fleck 1976). The 24.5 g/100 g of D-glucose found in the fruit pulp of *B. discolor* is reasonably high and can serve as a good source of carbohydrates as part of a human diet.

Berchemia discolor does not appear to be a useful source of ascorbic acid. This is in contrast with Wehmeyer's (1966) findings on the ascorbic acid content of the indigenous fruit he worked on and to that reported by Van Wyk (1972). When the four species are compared *B. discolor* (0.1 mg/100 g), has a much lower ascorbic acid content than that of *Parinari curatelifolia* (70.9 mg /100 g), *Prunus domestica* (157.8 mg /100 g) and *S. birrea* (194 mg /100 g).

Table 4.1 Showing the chemical composition of the fruit pulp of *Berchemia discolor (this study)* , *Parinari curatelifolia* (Saka 1995) *Sclerocarya birrea (Taylor & Kwerepe, 1995) and Prunus domestica (Nergiz & Yildiz 1997)*

Species	Ash %	Protein %	Fat %	Carbohydrates g/100 g	D-glucose g/100 g	Ca mg/100 g	Mg mg/100 g	Fe mg/100 g	Na mg/100 g	K mg/100 g	K %	P mg/100 g	Vit. C mg/100 g
B. discolor	3.1	0.1	0.4	-	24.5	192.3	96.0	2.9	3.4		1.1	82.7	0.1
S. birrea	0.9	0.5	0.4	12	-	20.1	25.3	0.5	2.2	317	-	11.5	194
P. curatelifolia	1.8	3	1.5	88.2	-	129	830	103	252	10.4	-	339	70.9
P. domestica	0.6	7.5	-	96.6	-	25.5	-	4.7	161.6	2228.1	-	-	157.8

Where '-' = data unavalaible

The results reported here for the ascorbic acid content of *B. discolor* could be misleading since problems were encountered with the method employed. Considerable variations occurred in the results although the experiment was repeated four times. This could probably be ascribed to the instability of ascorbic acid, as it oxidises quickly when exposed to light. Saka (1995) mentions that Vitamin C, as is the case with most vitamins, is labile. In order to obtain the true values it is necessary to conduct analyses as soon as possible after collection of samples or the samples must be stored in a frozen state until analyses can be done. The samples used in the analyses had been collected months before the analysis was carried out and stored at room temperature. The ascorbic acid content of fresh fruit would probably be higher.

5.5 Conclusions

The dry pulp of *Berchemia discolor* is rich in carbohydrates, calcium, sodium, iron, magnesium and potassium, but it is not a good source of phosphorus, fat, protein and possibly ascorbic acid. This study gives a partial understanding of the role that *B. discolor* fruit may play in the diet of the rural people who consume it. The real contribution of *B. discolor* fruit to the diet of the rural people can only be evaluated if the whole diet of the rural people is studied in detail. Knowing that few of the rural people who consume *B. discolor* fruit have alternative fruit sources, the contribution of this fruit to their diet could be considerable.

Notwithstanding the above, further studies are still needed to determine the moisture and fibre content, the total components of carbohydrates and the ascorbic acid content of the dried pulp. The nutritional composition of the fresh fruit still requires attention, because no fresh fruit was available at the time the study was conducted.

Chapter 6

GENERAL DISCUSSION AND CONCLUSIONS

According to Maghembe (1995) most of the current domesticated fruit trees were derived from wild varieties, however most of these domesticated and commercial fruit trees originated from elsewhere rather than Africa. Consequently, there is still a wide range of unexplored genetic resources of utilisable indigenous fruit trees in African savanna and forests, especially the Miombo Woodlands. Part of the reason for this lack of exploitation is the continued dependence on introduced domestic fruit tree species and the lack of improvements of indigenous fruit tree species. Furthermore, factors such as the perceived slow growth of indigenous species, lack of knowledge of propagation and no culture of planting indigenous trees have contributed to their under-exploitation.

Rural people manage fruit tree species for food, fodder, cash, fuelwood and building material (Packham 1993). Despite their importance, very little has been done towards understanding the growth, reproductive biology, propagation and conservation of the germplasm of the species. There is a need to understand the above aspects in indigenous fruit tree species, as the information is required in paving the way to their domestication. These studies contributed partially to the understanding of the reproductive biology of *Berchemia discolor*. The most significant contribution from this study is to the understanding of floral morphology and floral behaviour.

Although data collection for reproductive phenological information and fruit production was only limited to one year, it should be perceived as the foundation for further detailed studies. This study into the reproductive phenology of the species yielded more questions than answers as is expected in pioneering work. The scope of the present study on phenology could not establish what triggers bud initiation and the exact timing of bud initiation, whether it happens shortly before buds become visible or earlier on in the season. A question such as why the timing of vegetative growth and bud formation differed between the two study areas was only answered partially as buds were observed only at the macroscopic stage.

The length of the reproductive phase during the 1996-97 season extended from mid October to the end of March in Caprivi and from beginning of November to early April in Omusati.

The timing of vegetative growth and bud formation differed between the two study areas, with vegetative growth in Omusati occurring just after the onset of rain, whereas in Caprivi it occurred two weeks prior to the onset of rain. The difference in the timing of bud formation and vegetative growth between the two study areas is probably due to the local prevailing climatic conditions, where Caprivi is regarded as a wet site and Omusati a dry site.

The protandrous behaviour of the *B. discolor* flowers is probably effective in preventing interference in the paternal and maternal functions although geitonogamy might be possible, and the chances for geitonogamy is high if the flowers are self-compatible because of the lack of synchrony on the individual trees during anthesis. The study focused only on some of the aspects of floral and pollination biology of the species such as floral morphology, pollen viability, pollen tube growth in the styles, floral behaviour and floral visitors. Further studies are still needed to get a more complete overview of the reproductive biology.

Although *B. discolor* has the potential to become a source of income for rural people, the price of the fruit in marketplaces or at other places where the fruit is sold, is very low at present. Despite the low market value, the most significant use of *B. discolor* fruit is the sale of the fruit, and rural people are able to generate a small income, which enables them to acquire other goods and services. The alcohol trade is not widespread but could be encouraged by promotions. There is room to increase the income generated from the fruit trade, particularly with the migration of rural people to urban areas. These people continue to appreciate the fruit especially in their new surroundings. The rural people have established sustainable ways of harvesting and storing fruit and with the tenure system in place encourages tree planting.

Berchemia discolor fruit pulp is rich in carbohydrates, calcium, sodium, iron, magnesium and potassium, but it is not a good source of phosphorus, fat, protein and ascorbic acid. The low ascorbic acid content reported here is not surprising because dried fruit was used in ascertaining the values. The ascorbic acid content of fresh fruit could be probably higher.

It is also useful to note that the study was highly ambitious as it incorporated various studies, which resulted in each study not being done in greater detail as it would have been desired.

Recommendations and future research

Research into reproductive biology and the physiology of the species

- Ecophysiological and transplanting experiments should be carried out on the species to determine why some trees flower before vegetative growth commences and why some will flower after vegetative growth has commenced.
- The phenology of *B. discolor* should be studied for more than one flowering season, to understand the year to year variation in fruit production and the main factors which influence this.
- Further data should be collected and detailed observations made on insect visitors, to identify the pollinator(s) of *B. discolor*.
- Aspects about the breeding system of *B. discolor* should also be the subject of further studies. This will help in understanding the gene flow within and between populations.

Research into nutritional aspects

- Further investigations should be carried out on fibre, total carbohydrates components and ascorbic acid content of the dry pulp and on the nutritional content of fresh fruit.

Recommendations for forestry extension officers

- Forestry officials in northern Namibia could set up an interdisciplinary team to hold discussions with rural people, so that they too can realise the potential of *B. discolor* trees.
- The foresters could supply the rural people with seedlings for increased tree planting and also supply them with knowledge on how to take care of their trees.
- The economists could assist in conducting a market research to collect information about the product quality demanded by the consumers.
- The economists could also analyse the existing demand for the fruit. In addition a market potential could be quantified in monetary terms and other market possibilities could be explored.
- A campaign could also be launched to promote indigenous fruit in general.
- The Department of Forestry should also initiate a research program towards the domestication of *B. discolor*, especially investigating the propagation techniques and fruit improvement.

Chapter 7

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APPENDIX 2.1
Questionnaire used during interviews

1. Personal details of the informant

a. Name:..

b. Address:..

c. Date:..

d. Gender — Male:..................................... Female:...................................

2. Tick which species are consumed in your area

SPECIES	
Sclerocarya birrea	
Berchemia discolor	
Vangueria infausta	
Berchemia discolor	
Strychnos cocculoides	
Adansonia digitata	
Grewia sp.	
Hyphaene petersiana	
Diospyros mespiliformis	

To be completed for all species occurring in the area

3. Uses of the tree and fruit

a. Uses of the tree

b. Uses of the fruit

4. Fruit Quality

Fruit Harvesting and storage

a. How do you know that fruit are ripe and ready for harvesting:

b. Where and how are the fruit stored:

c. Do you still have fruit from last year (1996) Yes:................
No:................

If you do not have fruit from last year do you still remember how long it took before you finished the fruit (Fruit for household consumption only):..

d. Do the fruit deteriorate during storage (do they become inedible): Yes:..............
No:..............

e. If the fruit were not finished through consumption or selling, how long can you store the fruit before deterioration takes place

<12 months:.......
<24 months:.......
>24 months:.......

f. What causes deterioration in fruit

Stage of maturity:....................
Insect infestations:....................
Moisture in storage:...................
Ageing:..................................
Other theories:.........................

g. What precautions are taken during fruit harvesting to prevent fruit deterioration:

h. Do you have ways of preventing fruit deterioration caused by insect damage:

5. Tree tenure

a. Are the trees of *B. discolor* communally owned or are they owned by specific individuals

b. How is ownership acquired? Is it automatically as far as the tree is growing on somebody's land or are the trees allocated to individuals and by whom?

c. What other patterns of ownership exists besides those suggested above?

d. During harvesting of the fruit are the fruit accessible only to the owner:………. or is it also accessible to the neighbours:…………..

6. Flow of the product

a. Do you sell *B. discolor* fruit : (Mark with an X)

Yes:…
No:……

If no go to (5b), if yes go to (5d)

b. If no, are you interested in marketing the fruit:

c. If you are interested, why are you not selling the fruit at the moment?

d. Do you sale the fruit every year or do you sale the fruit only in some years

If you sale in some years answer question (5e), if you sell every year proceed to (5f)

e. Why do you sale the fruit in some years and not in all the years?

f. Can you give an estimation of how much fruit you harvested : [Unit of measurements should be in sacks]

1996:……………………..
1997:……………………..

g. Where are fruit sold from?

Household:……………..
Roadside:………………..
Marketplace :……………
Others specify:…………

j. Who buys the fruit:

Neighbours:…………..
Tourists:………………..
Local retailers :………
Others specify:………..

k. What is the unit for sale?

l. For how long have you sold the fruit at the current unit price?

n. How important is the income gained from the sale of the fruit i.e. is it :

Supporting income:…….
Sole income:…………..

APPENDIX 3.1

The data collection form for reproductive phenology

Country: **Tree no:**

Region **Branch no:**
Forest **Date:**
type:

Month	Bud	Flower	Flower/fall	flower/fall	Immature	Immature	Mature	Fruit
October								
1								
2								
3								
4								
November								
1								
2								
3								
4								
December								
1								
2								
3								
4								
January								
1								
2								
3								
4								
February								
1								
2								
3								
4								
March								
1								
2								
3								
4								

Type of pollination:
Pollination vector:
Disease or insect attack:

Indicate in the appropriate stage
L (less) for less abundance
H (high) for high abundance

APPENDIX 5.1

Calculations of nutritional components

Ascorbic acid

The formula used in the calculation of the concentration was as follows:

$$c = \frac{V * MW}{\varepsilon * d * v * 1000} * \Delta A \text{ [g/l]}$$

where:

V = final volume of the samples in the cuvettes [ml]

v = sample volume [ml]

MW = of the substance to be assayed [g/mol]

d = Light path in [cm]

ε = absorption coefficient for MTT -formazan at 578 nm.

c = concentration of L-ascorbic acid

$\Delta A = \Delta A_{\text{sample blank}} - \Delta A_{\text{sample solution}}$

for L-Ascorbic acid it follows that:

$$c = \frac{3.1 * 176.13}{16.9 * 1 * 0.50 * 1000} * \Delta A$$

The result was then calculated from the amount of fruit weighed as follows:

$$content_{Lascorbicacid} = \frac{c_{Lascorbicacid}[g / l_{samplesolution}]}{c_{sample}[g / l_{samplesolution}]} * 100[g / 100g]$$

Replicate 1

	R_1	R_2	ΔB_1 & ΔS_1
Blank	0.332	0.445	0.113
Sample	0.295	0.414	0.119

$\Delta A_1 = 0.006$

Where: $\Delta A = \Delta A_{\text{sample blank}} - \Delta A_{\text{sample solution}}$

R_1 = first reading

R_2 = Second reading

ΔB= difference in blank reading

ΔS = difference in sample reading

Replicate 2

	R_1	R_2	ΔB_2 & ΔS_2
Blank	0.326	0.415	0.089
Sample	0.290	0.389	0.099

$\Delta A_2 = 0.01$

Replicate 3

	R_1	R_2	ΔB_3 & ΔS_3
Blank	0.325	0.431	0.106
Sample	0.305	0.388	0.083

$\Delta A_3 = -0.023$

The concentration was calculated as follows:

$$c = \frac{3.1 * 176.13}{16.9 * 1 * 0.50 * 1000} * \Delta A$$

This follows that:

c= 0.0646 X ΔA

Therefore

$c_1 = 0.0646 \text{ X } 0.006 = 0.0003876$ g/1

$c_2 = 0.0646 \text{ X } 0.01 = 0.000646$ g/1

$c_3 = 0.646 \text{ X } -0.023 = -0.014858$ g/1

For solid or semi solid samples the following conversion has to be done to mg/100 g:

$$content_{Lascorbicacid} = \frac{c_{Lascorbicacid}[g / l_{samplesolution}]}{c_{sample}[g / l_{samplesolution}]} * 1000[mg / 100g]$$

Where

$c_{\text{L-ascorbic acid}} = c_1, c_2$ or c_3

$c_{\text{sample}} = 50$ g/ 1

Therefore

$c_1 = 0.007$ mg/100 g

$c_2 = 0.012$ mg/100 g

$c_3 = 0.297$ mg/100 g

Average Ascorbic acid content = 0.105 mg/100 g ± 0.166

Fat content

$$\% \text{ Fat} = \frac{w_2 - w_1}{w_3} \times 100$$

where

W_1 = weight of empty flask

W_2 = weight of flask + fat

W_3 = weight of sample used

Results on the three replicates:

$M_1 = 0.019$

$M_2 = 0.174$

$M_3 = 0.973$

Average of three replicates:

Fat percentage in the fruit: = 0.389 ± 0.512

Ash content

$S_1 = 3.04$

$S_2 = 3.10$

$S_3 = 3.08$

% Ash = 3.073 ± 0.031

D-Glucose Sugar

Average final titre reading = 40.73

Sample concentration in titrant solution = 0.972 g

Reducing sugar as D-glucose:

$$= \frac{972F}{C * T}$$

where

C = sample concentration in the titrant solution (g/100 ml)

T = titre in final titration (ml)

F = sucrose correction factor

Reducing Sugar as D-glucose Sugar = 24.533 g/100 g fruit

Protein Content

The protein content in the fruit pulp was then calculated as follows:

Percentage Nitrogen content = 0.28 * B/weight of food in grams

where:

B_1 = 0.2 ml Sulphuric acid

B_2 = 0.2 ml

B_3 = 0.2 ml

Weight of food = 5 g

% Nitrogen = 0.112

Average % Nitrogen = 0.112

To obtain crude protein % Nitrogen was multiplied by 6.25

% Protein = % Nitrogen * 6.25

Therefore

% Protein = 0.069 ± 0

Mineral Elements

Mineral elements	Ca ppm	Fe ppm	K %	Mg ppm	Na ppm	P ppm
Content in fruit pulp	1923	29.44	1.082	960	33.79	827