SEED PRODUCTION, VIABILITY AND GERMINATION POTENTIAL OF *CITRULLUS LANATUS* IN THE KING NEHALE CONSERVANCY

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

OF

THE UNIVERSITY OF NAMIBIA

AND

THE HUMBOLDT-UNIVERSITÄT ZU BERLIN

BY

UAZAMO KAURA

JANUARY 2007

SUPERVISOR: DR. MUTJINDE KATJIUA

CO-SUPERVISOR: MR. MICHEL MALLET

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By

Uazamo Kaura

Supervisor: Dr. Mutjinde Katjiua (University of Namibia)

Co-supervisor: Mr. Michel Mallet (Center for Research-Information-Action for development in Africa - Southern Africa Development and Consulting (CRIAA SA-DC))

January 2007

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DECLARATION

I, Uazamo Kaura, declare hereby that this study is a true reflection of my own research except where it is specifically indicated contrary in the text. This work or part thereof has not been submitted for a degree in any other institution of higher education.

…………………………………….

Uazamo Kaura

January, 2007

ACKNOWLEDGEMENTS

Foremost, I wish to thank the Lord Almighty for carrying me thus far in my life, my source of wisdom, knowledge and strength.

I would also like to thank my supervisors Mr. Michel Mallet and Dr. Mutjinde Katjiua for their guidance, constructive criticism and immerse patience through out the course of the research

My gratitude is extended to the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) for the funds provided for the field trips. My appreciation is extended to the villagers in north central Namibia especially the King Nehale Conservancy and its Chairman Tate Immanuel Shali Johannes. My sincerest gratitude is extended to my assistant and field guide, Mr. Immanuel Sharukeni and to Mr. Ibo Zimmerman from the Polytechnic of Namibia who supplied the ‘Essential Microbes’ for the seed treatment.

I am grateful to my family, friends and colleagues for always been there to render their moral support and their positive comments, especially toward the end of the thesis. May the Almighty God abundantly bestow all your favors.

DEDICATION

This work is dedicated to my parents who prepared me for the life I lead today, my late father Thomas T. Kaura and my late grandmother Fransika K. Kaura-Tjerije.

ABSTRACT

The melon under investigation, *Citrullus lanatus* (Thunb.) Matsumura and Nakai is a wild and often cultivated species originating in southern Africa. Melon seeds are utilised as oil crops for household consumption and are widely used in the cosmetic and pharmaceutical industry.

There is a lack of a suitable harvesting system for C. *lanatus,* exposing it to over-exploitation. Low recruitment is experienced in the field and active germination trials by villagers in north-central Namibia have been ineffective. It is for this reason that investigations leading to the domestication, cultivation and management of wild-harvested plants were required.

Ethnobotanical studies revealed that villagers were keen to intercrop *C. lanatus* with local traditional crops to increase the seed yield required for commercial trade. Local people were prepared to provide an effective management system for the protection of the melon as provided to other wild foods such as Marula.

The study demonstrated that there was no significant germination difference ($p< 0.05$) between seeds obtained from fully matured fruits, and in young, immature fruits. In field and laboratory experiments, there were various germination successes with the pre-chilling of seeds, and the exposure of the seeds to H_2SO_4 and Essential Microorganisms. These treatments obtained more than 50 % arbitrary values needed for reliable and successful germination. Germinability was negatively effected in

abrased seeds and seeds obtained from herbivore manure, with less that 50 % germination arbitrary values and high germination rates.

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CHAPTER 1

INTRODUCTION

An introduction to Namibia

Namibia is a semi-arid country situated in southwestern Africa, between 17° and 29° S and 11° and 26° E (MET, 2002). The physical-geographic context of Namibia is determined by its position at the border of the continental shelf of the southern African subcontinent in the climatic sphere of influence of the Tropic of Capricorn and the cold Benguela Current (MET, 2002). With a long coastline on the south Atlantic Ocean and the cold Benguela Current, Namibia is one of the driest countries in sub-Saharan Africa and constantly experiences water scarcity and unpredictable rainfall.

The country-wide average rainfall of less than 250 mm per year is coupled with annual mean evaporation of up to 3700 mm (MET, 2002). It is estimated that about 83% of rainfall evaporates, and a further 14% is transpired by plants. This leaves 2% to enter drainage, where some is retained in dams, and only 1% recharges the land's severely stressed ground water tables (MET, 2002). In Namibia, most rain occurs in the summer months from November to April (Figure 1.1). The inter-annual coefficient of variation of rainfall is very high, ranging from 25% in the northeast to more than 80% in the southwest (MET, 2002).

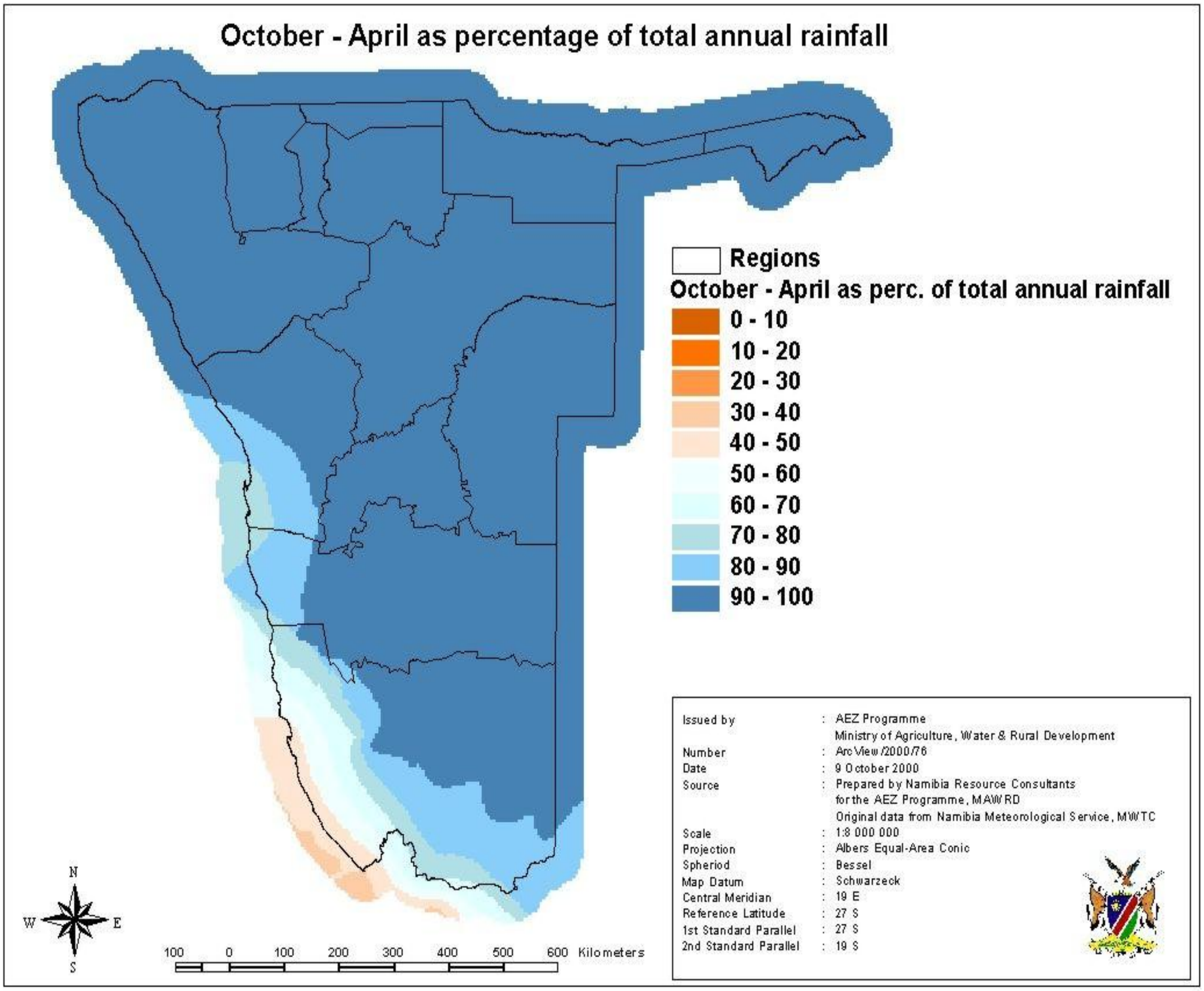

Figure 1.1 The percent of the total annual rainfall occurring in the summer months (October to April)

Namibia has a complex geology and lies between two deserts, the Namib on west and the Kalahari on the east. Namibia's steep northeast-to-west climatic gradient, plus its varied soil types and landforms, largely determine the distribution characteristic vegetation zones in Namibia, deserts, savannas and woodlands (MET, 2002). Savanna covers 37% of Namibia, dry woodlands and forests 17%, while desert vegetation is distributed over 46% (MET, 2002). In Namibia, almost 64% of the country is covered by savanna range types, most of them into a discontinuous, open to moderately dense stand of nitrogen-fixing Acacia trees and bushes and a continuous herbaceous layer dominated by grasses, with 14 vegetation types recognized in Namibia (de Klerk, 2004). In Namibia, 4 138 plant species have been recorded, of which 687 (17%) are endemic and occur in the escarpment and southwest winter rainfall area (MET, 2002).A diverse resource base with a range of different trees and plants increases the options for maintaining food security and improving the livelihood of rural populations.

Close to 70% of Namibia's population practice subsistence crop farming and agro-pastoralism on communal land (MET, 2002). Namibia's arid climate and infertile soils does not allow to a large extent, for intensive agricultural production, and makes it inapt for livestock or crop production. Dryland crop production is common in the north and north-eastern parts of the country, while livestock production is more common in the east of the country. Pearl millet is the staple crop in the various communal areas while wheat and maize is mainly grown in the commercial areas (MET, 2002).

Purpose of the Study

Biodiversity policies and legislations

Existing biodiversity is the result of dynamic evolutionary process since life first appeared on Earth almost three thousand million years ago. Since time immemorial, man has constantly depended on biodiversity; early man evolved with plants and animals and soon began to use them for food, shelter, clothing and fire.

The concept of biodiversity emerged in scientific circles and has a broad range of meanings. An internationally-agreed definition was coined in 1992 when the Convention on Biological Diversity Biodiversity defined biodiversity as the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (de Klemm and Shine, 1998). This definition makes no distinction between wild and domesticated animals, wild and cultivated plants, and land and sea areas under or beyond national sovereignty or jurisdiction. Biological diversity therefore functions as an all-embracing concept providing a common frame of reference for the development of appropriate forms of management by all countries.

In the past 20-25 years, there has been an increased scientific practice of biological prospecting and the commercial utilization in systematic research, collection and utilization of biological resources which attracts immerse monetary value. Biodiversity research is conducted in primarily academic research in a wide range of fields including botany, microbiology, chemistry, agricultural breeding and cultural anthropology (Laird, 2002). Biodiversity research and management is important in that it addresses the objectives of conservation and development projects, compiles community biodiversity registries of knowledge and identifies new or improves existing commercial products (Laird, 2002).

Prior to 1993 before the CBD came into force, there was a non-existing international legal regime and in many countries, national legislations to regulate access to genetic resources and to promote the sharing of benefits arising from their commercial and scientific use. The principal objectives of the CBD are to actively promote the conservation of biological diversity, ensure the sustainable use of its components and ensure the equitable sharing of benefits from the utilization of biological and genetic resources (de Klemm and Shine, 1998).

Due the various technological changes, biological resources have been given potential economic value as raw materials for the development of pharmaceuticals and other products. It has thus become essential to establish national regulation to administer the use of biological resources despite the practical challenges face as national policies are established.

Article 95(1) of the Namibia's Constitution is in line with the provision of the CBD objectives, as it obliges the Government of Namibia "to adopt policies aimed at the maintenance of ecosystems, essential ecological process and biodiversity, and the utilization of living natural resources on a sustainable basis for the benefit of all Namibians, both at present and in the future" (Barnard, 1998). Namibia has various overarching legislations governing the access and use of biological resources. Namibia inherited the Roman Dutch common law with outdated environmental laws, these laws have been reviewed to revise Namibia's environmental legislation. The country is currently in the process of finalizing its Access to Genetic Resources and the Associated Traditional Knowledge Bill of 2006 (ABS Bill), which proposes access to benefit sharing objectives. Various overarching policies and laws pertaining to the access and use of biological resources include sectoral natural resources management legislation in forestry, fisheries, wildlife, agriculture and those pertaining to land tenure and use.

Scope and Rationale of study

Namibia has unique bio-diversity, particularly in the plant kingdom, with a variety of seasonal wild plants which vary on the patterns of fruiting, leaf production and population cycles of the species.

Indigenous fruits play an important role in the social fabric on Namibia's rural economy. Rural communities in Namibia harvest a diversified range of wild plants such as wild vegetables, berries, nuts and fruits. Some of this diversity is utilized through traditional use of plants for an array of purposes including food, but also for medicine, decoration and clothes, amongst other uses. Wild foods often make up a portion of the diet in rural communities as daily supplements to relishes in addition to as protein and vitamin sources. In the past few years, efforts to use some of this bio-diversity have led to a number of projects supporting the commercial exploitation of indigenous plants (du Plessis *et al.,* 2005).

In Namibia, the Kalahari Melon, *Citrullus lanatus,* a relative of the cultivated watermelon is responsible for maintaining life in the desert, for both man and animals, during the long drought years. Animals eat it raw and use it as a source of water; one can either use it raw or cooked. The seed of the melon produces Kalahari melon seed-oil, which is a sought after commodity in the cosmetic industry. Namibia has a unique genetic diversity of *C. lanatus,* with the Kalahari desert a probable centre of origin of the species, and one of the major centres of domestication of the watermelon (Maggs, 2000).

In Namibia, *C. lanatus* seeds are crushed using a wooden pestle and the small black seeds are extracted by hand. Sometimes the crushed pulp is put in a water bucket to ease the separation of the flesh from the seeds. The seeds are then dried in the sun for at least one week, and then winnowed, separating the chaff from the seed before being processed into oil. Namibia is the leading supplier in the Southern Africa Development Community (SADC) of Community-Traded Kalahari melon seed-oil, with the appellation 'Kalahari Melon Seed Oil' being recognized and used.

The Body Shop, a leading British cosmetic house, sources the Kalahari melon seed-oil from the Eudafano Women's Co-operative (Ltd) (EWC), based in northern Namibia, in Ondangwa (du Plessis *et al*., 2005). The Co-operative was initiated in 1994 by the Department of Women's Affairs and consist of 17 member associations representing some 5 000 women (du Plessis *et al.,* 2005). The business is owned and run by women, who are involved in the complete processing of melon seeds. The long term aim of the co-operative is to market both the oil and seeds; help the economy of the country; help women to earn a fair wage and protect and develop the natural environment (du Plessis, 2002).. At the beginning of the 2004 season, The Body Shop projected a demand for 8 tons of Kalahari melon seed-oil for the year, equalling about

60 tons of seeds, to be supplied by EWC and Community Trade suppliers (du Plessis *et al*., 2005).

At present the organization which works directly with EWC, the Center for Research-Information-Action for development in Africa - Southern Africa Development and Consulting (CRIAA SA-DC), struggles to obtain enough Kalahari melon seeds to meet the demand for the seeds to be supplied the The Body Shop. This demand for the seed may possibly have let to the low recruitment rates of the *C. lanatus* in the wild, reducing the germination rate. This is possibly because buying the seed has disrupted the traditional recruitment system, where melons are allowed to ripen in the fields along with other crops, and villagers subsequently harvest some melons for the seeds and let livestock eat the rest of the seeds along with the Pearl millet (Mahangu) stover. This primes seeds for germination, through partial digestion in the rumen and also distributes the seed in the manure. Creating a market has led to people harvesting the majority of the melons, hence fewer seeds being grazed by herbivores, which result in lower natural recruitment. Efforts by farmers to compensate by actively planting more seeds have experienced problems with germination.

Consequently there was a need to study the harvesting systems of the Kalahari melon in the north-central Regions of Namibia within the Regions of Oshana, Ohangwena, Omusati and Oshikoto). To meet the demand of the growing international market for the Kalahari melon seed, more attempts to domesticate and cultivate the wild-harvested plants are required. This necessitated an understanding of the productivity, germination and the seed viability of the melon hence that farmers can apply these methods in their traditional cropping systems. If melons are included within the traditional methods of crop diversification, this will decrease the demand currently exerted within the wild population, one of the key components of biodiversity conservation and protection of genetic origins of the plant.

General objective

The overall objective of the study was to determine the seed production, viability and germination potential of *C. lanatus* for its economical value and potential for cultivation in traditional cropping systems. There was also a pressing need to investigate the management systems of *C. lanatus.*

Aims and objectives of the study

The specific aims and objectives of the research are to:

1. Investigate why the supplies of *C. lanatus* seeds have reduced considerably over the past year by conducting an ethnobotanical study.
2. To review the literature on the germination of *C. lanatus*, investigate the management and harvesting systems of *C. lanatus* in the King Nehale Conservancy and the north-central regions of Namibia..
3. Study the germination characteristics of *C. lanatus* treated with various methods. To test for the effectiveness of these treatments in the germination of *C. lanatus*.

4. Devise a germination protocol for *C. lanatus* with possibilities of commercial cultivation and feeding it into the traditional cropping regimes, as part of crop diversification.

Key Questions

The study was aimed examining these questions:

1. How does the current management practice of harvesting *C. lanatus* affect its germination and recruitment within the wild population?
2. How does seed mass and seed viability relate to fruit mass?
3. How does seed germination relate to fruit mass?
4. Does the scarification of the seed coat affect the germination potential of *C. lanatus*?
5. What is the germination potential of *C. lanatus* treated with various enhancements?
6. What is the germination potential of seeds obtained from herbivore manure?

Research Hypotheses

The hypotheses were formulated as follows:

1. The current management practices of *C. lanatus* reduce its germination and its subsequent recruitment within the wild population. There is currently no management system in for *C. lanatus* which makes it effortless for communities to exploit the resource. This leads to fewer fruits in the field, therefore affecting is regeneration.

2. There is a significant difference between the seed mass and the seed viability of larger fruits compared to smaller fruits. One would assume that the seed mass is directly proportional to the fruit size. Thus it is assumed that smaller fruits have smaller seeds which are immature and thus unenviable, and thus not suitable for germination.

3. Seeds from larger fruits have a higher germination percentage than those from smaller fruits. Since it is assumed that larger fruits have the most mature fruits, thus yielding mature seeds, they will have a higher germination percentage.

4. The scarification of the seed coat results in a high germination percentage of seedlings than from seeds left intact. Germination will be induced in scarified seeds as water will be permeated by the seed coat, thus impeding dormancy found in many seeds.
5. Treated seeds are more likely to successfully germinate than untreated seeds. The germination percentage will increase substantially due to the seed improvement with enhancements.

6. Seeds obtained from herbivore manure will have significantly higher germination percentages than those of obtained directly from the fruits. The interaction of

many seeds with herbivores is very vital for the reason that seeds are primed for germination through partial digestion in the herbivore.

CHAPTER 2

LITERATURE REVIEW

The Potential of Indigenous Fruits

The study of human use of plants has been a multidisciplinary activity in southern Africa, with significant contributions made by various disciplines. Southern Africa is exceptionally rich in plant diversity with some 30 000 species of flowering plants, accounting for almost 10% of the world's higher plants (van Wyk & Gericke, 2000). According to van Wyk & Gericke (2000), the region has great cultural diversity with many people using a variety of plants in their daily lives for food, water, shelter, fuel, medicines and other necessities of life. The late arrival of agriculture in southern Africa about 2 000 years ago resulted in the interaction of the hunter-gatherer interaction with vegetation (Cowling *et al.,* 1997). Bush foods are of great importance to the rural poor living in the vast region of southern Africa. Differences in climate, soil and vegetation types are reflected as significant in the availability and use of edible plants across southern Africa (Cowling *et al*. 1997).

The diversity of wildfruits provides an important source of vitamins, minerals, amino acids and trace elements for many indigenous communities. According to van Wyk & Gericke (2000), a single species of fruit such as tsamma (*Citrullus lanatus*) in the Kalahari, !Nara (*Acanthosicyos horridus*) in the Namib Desert and the mongongo (*Schinziophyton rautanenii*) in northern Botswana is of vital importance for the survival of the local communities. There is also a significant trade in wildfruits and their seeds in southern Africa contributing greatly as an important source of income for rural households. These important trade fruits include the sourplum (*Ximenia caffra*), corky money apple (*Strychnos cucculoides*) amongst many other fruits. Historically wild foods have been an important component of local coping strategies at times of severe food shortage by sustaining livelihoods.

In Namibia, wild plants such as Marula (*Sclerocarya birrea*) and Wild Medlar (*Vangueria infausta*) contribute greatly to the amount of income for primary producers especially in the North Central Regions of Namibia (du Plessis, 2002). Since 2000, activities in the field of indigenous plants have been coordinated by the Namibian Indigenous Plants Task Team (IPTT), whose purpose is to ensure sustainable utilization and to promotion collaborative approaches in the sector.

Species description

<u>The genus *Citrullus*</u>

The genus *Citrullus* is a dicot belonging of the class Magnoliopsida and the order Cucurbitales of the family Cucurbitaceae (Maggs-Kölling, 2003). Many members of the Cucurbitaceae are indigenous to Africa (Dyer, 1975 in Small & Botha, 1986), several of which occur in arid and semi arid regions. According to Small & Botha (1986), some species like *Acanthosicyos horridus* are endemic to the Namib Desert.

The genus *Citrullus* Schrad. of the family Cucurbitaceae consists of four species native to the Old world, three of which are indigenous to Namibia (Maggs-Kölling *et* *al*., 2000). This genetic group also includes the major commercial crop, watermelon, within the species *C. lanatus* (Thub.) Matsum. & Nakai. According to Maggs-Kölling *et al*., (2000), the origin centre of *C. lanatus* is the Kalahari Desert, a geographical area that currently represents an unexploited reservoir of genetic variation for the cultivated watermelon. Watermelon has a long history of cultivation in Africa and the Middle East and has been planted in the Nile Valley since the second millennium BC. By the 10^{th} century AD, the crop was grown in China and southern Russia (Maggs-Kölling *et al*., 2000). Watermelon was introduced to the New World by the Spaniards in the 16^{th} century and rapidly became popular with Native Americans (Maggs-Kölling *et al*., 2000). According to Maggs-Kölling *et al*., (2000) a number of distinct landraces, are cultivated in the Kalahari region and its periphery, including northern Namibia and may present the early forms of domestication.

Maheshwari (1978) describes the genus *Citrullus* as consisting of three diploid species (2n=22):

- *C. lanatus* (Thunberg) Matsumura and Nakai, including the cultivated watermelon widely grown in several parts of the world;
- *C. lanatus* var. *citroides*, a wild form found mainly found in southern Africa cultivated in other parts of the world; and
- *C. colocynthis* (L) Schrad, found in the north and southwest areas of Africa and Asia, which can be divided into two different races, one found on the Mediterranean coast and in Israel, the other found in the deserts of Negev and Sinai, and *C. ecirrosus*, which is endemic to the Namibian desert.

Maheshwari (1978) recognized several watermelon varieties cultivated in different parts of the world, e.g. India, Pakistan, Malaysia, Polynesia, Japan, China, Iraq, Europe, Africa, and South and Central America. Among other characters, such varieties differ in size, shape and colour of fruit skin, colour of flesh (red, pink, white and yellow), and the colour and size of seeds. The author is aware of 13 varieties of *C. lanatus*: var. *lanatus* a wild watermelon native to southern Africa; var. *viridis* a 'giant' watermelon from Iraq and cultivar 'Black Tom Watson'; var. *albidus* in the *nigro-seminius* and *albidus* forms bred in the central areas of Iran; var. *variegatus*; var. *rotundus;* var. *pulcherrimus*; var. *shami;* var. *oblongus* whose common name is 'Fairfax'; var. *virgatus;* var. *pumilus* which is called 'New Hampshire'; var. caffe a sweet cultivated watermelon and var. *citroides,* whose common names are, respectively, 'citron melon' and 'preserving melon'.

The species ***Citrullus lanatus***

Citrullus lanatus (Thunb.) Matsumura and Nakai is a wild and often cultivated species, originating in southern Africa; Maheshwari (1978) also describes the existence of a secondary diversification centre in India.

Description

The species is characterized by large green leaves with three to five deep lobes on the edges, or more rarely none, medium-sized monoic flowers with short pedicels, medium to large fruit with smooth skin and flesh with a high water content, and oval to oblong seeds of a white or brown colour (Maheshwari, 1978). According to Maheshwari (1978), it is an annual herb with long (up to 10 m) stems lying or creeping on the ground, with curly tendrils. Leaves are 5-20 by 3-19 cm, and hairy, usually deeply palmate with 3-5 lobes, on 2-19 cm long petioles. Fruits of wild plants can be 1.5-20 cm in diameter, subglobose, greenish, mottled with darker green (Maheshwari, 1978). Fruits vary considerably in morphology, whereas the fruits of the wild Kalahari form are small and round, the cultivated forms are large oblong fruits. In addition, they vary from pale yellow or light green (wild form) to dark green (cultivars), and with or without stripes; the pulp varies from yellow or green (wild forms) to dark red (cultivars) (Maheshwari, 1978).

According to Small & Botha (1986), many members of the Cucubitaceae produce long lived fleshy fruits. Although such fruits contain a large quantity of water, germination whilst within the fruit of apparently mature seeds does not occur readily. The mechanisms by which germination is inhibited within cucurbit fruits has been attributed to inhibition of light penetrating the fruits for the negatively photoblastic seeds of *C. lanatus*. In other fleshy fruits germination inhibitors and/or osmotic effects have been responsible for preventing germination (Botha *et al*, 1982a). The germination of *C. lanatus* is very sensitive to osmotic stress, and this contributes to the control of germination within the fruits due to germination inhibitors, and therefore the significance of animals to get rid of the fleshy fruit.

According to Maheshwari (1978), the cultivated species *C. lanatus* includes three subspecies: (i) *lanatus*, (ii) *vulgaris* which has two varieties, var. *vulgaris* and var. *cordophanus*, and (iii) *mucocospermus*. Both morphologic and isozymic variability have been found in *C. lanatus* in several parts of the world where it has undergone introgressive hybridization with the wild species *C. colocynthis* (Maheshwari, 1978). The resulting species has been classified as *C. lanatus* var. *citroides.* The wild species of *C. lanatus* has a bitter taste; this bitter taste is caused by a high concentration of a substance called Cucurbitacine E. glycoside (Maggs, 2000). Cucurbitacins are a group of bitter of compounds found throughout the family Cucurbitaceae but which occur exclusively as glycosides in all species within the genus Citrullus (Rehm *et al*, 1957 in Maggs, 2000). The bitter taste is also present in wild species of other Cucurbitaceae (Maggs, 2000).

Table 2.1 Well known common names of *Citrullus lanatus* in Namibian vernacular.

Language	**Name**
Khoisan	tsamma; t'sama
Afrikaans	karkoer; bitterwaatlemoen
English	Wild watermelon
Tswana	Makataan
Otjiherero	Etanga ra karuru
Oshiwambo	Oontanga

Distribution

The wild watermelon is widely distributed in Africa and Asia, but originates from southern Africa occurring naturally in South Africa, Namibia, Botswana, Zimbabwe, Mozambique, Zambia and Malawi (Maheshwari, 1978). In its natural environment, *C.*

lanatus grows in grassland or bushland, often along watercourses, at altitudes of 50 to 1400m (Loy & Evensen, 1979). *C. lanatus* grows on well drained soil. Root growth is impeded by compacted soil and *C. lanatus* withstands drought better than most melons.

Utilization of the melon

Melon seeds are increasingly utilised as an oil crop for semi-arid regions and also its use in cosmetic and pharmaceutical industry is on the increase, offering prospects for generating foreign currency through exports. There are also prospects for use in the improvement of infant nutrition in view of its high protein and fat content **(**Adegoke & Ndife, 1993).

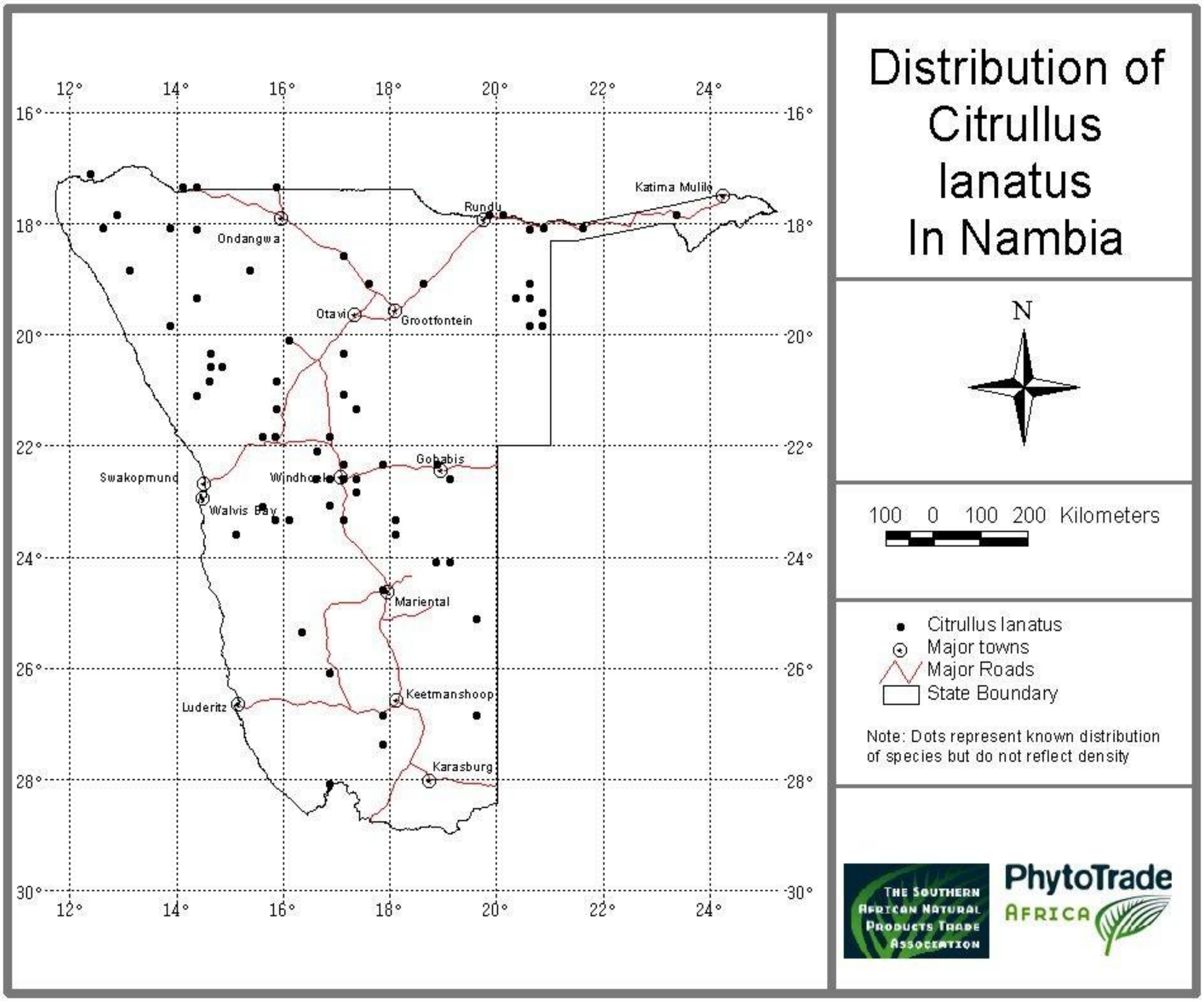

Figure 2.1 The distribution of *C. lanatus* in Namibia. (PhytoTrade Africa, 2006)

Cultivation

It is generally recognized that, within the confines of limited space available to them, traditional farmers cultivate a diversity of crops in order to maximize harvest security (Colson, 1979 in Maggs, 2000). It is also understood that these same subsistence farmers usually practice intraspecific polyculture in addition to interspecific multiple cropping. For thousands of years, farmers have been adapting crops to diversity habitats by experimenting with and developing new varieties. Diversity in cultivated species within the family Cucurbitaceae is reflected by a diversity of regional and local cultivation practices (Maggs, 2000). Although many of these cultivation practices converge towards efficacious commercial production techniques, differences among the crops, even at the cultivar level, require that individual attention be given to the cultivation of specific cucurbits (Robinson and Decker-Walters, 1997 in Maggs 2000). In Namibia, three cereal crops predominate in the northern regions: maize (*Zea mays),* pearl millet (*Pennisetum glaucum*) and sorghum (*Sorgum bicolour*).

A study done by Maggs (2000) in the Caprivi region of Namibia recognized two major categories of *Citrullus* melons – cooking melons and fresh watermelons. Under each of these two generic groups, a host of different melon cultivars were recognized, distinguished by the variation in several phenotypical characters. In the Caprivi region melon is cultivated as a cover crop in the intercropping system, the dominant crops being cereals although this is not a case in many areas in northern Namibia. In traditional cropping systems land preparation is done manually, prepared seedlings are rarely used for planting, three or four seeds are sown at a depth of 3-4 cm and after germination the seedlings are thinned to one or two per hill at 3-4 weeks after sowing when they have 2-4 true leaves (Maggs, 2000). *C. lanatus* germinates best at temperatures of 17°C at night and 32°C at daytime and also at a constant temperature of 22°C, it will not germinate at temperature below 15°C (Nerson *et al.*, 1985).

Melons planting is about 20 – 30 m apart, if planted too close, the vigorous growth of the melons suppresses the other crops (Maggs, 2000). Allelopathy has been reported in the related *Citrullus* species, *C. colosynthis* (L) Schrad. (Shaukat *et al.*, 1985 in Maggs, 2000). Phototoxic principles present in this species were shown to detrimentally affect germination and growth in five crop species. An accumulation of these toxic substances in biologically significant amounts has been indicated to especially affect pearl millet and sorghum in fields where *C. colosynthis* grows abundantly and may act as a potent agent in decreasing yields in these crops (Shaukat *et a*l., 1985 in Maggs, 2000). A similar allelopathic effect might be experienced with *C. lanatus* in Namibia, and especially in the wild form which is regarded as a serious agronomic weed. Local farmers have to adapt their farming system to derive benefits from intervarietal crops without compromising cereal yield.

Diseases

The cultivated watermelon is highly susceptible to *fusarium* wilt, while some resistance can be found in wild species (Neppl, 2001).In *C. lanatus*; some landraces are more susceptible to disease and insect attack than others. A high incidence of insects or the presence other disease such as powdery mildew increases the spread of gummy tem blight, in this crop due to the weakness of the plant and the presence of wounds as a consequence of the insect feeding (Neppl, 2001).

In the case of northern Namibia the cucurbit bug (*Coridius viduatus*) is reported to attack seedling and young leaves of the melon (Maggs, 2000). Although in many cases this pest larvae forms part of the local cuisine and contribute to the local diet. The wild melon may have commercial value due to its genetic characteristic of resistance to various viruses and enhanced drought tolerance (Barnard, 1998).

Potential of Citrullus lanatus

Since the inception of the IPTT, *C. lanatus* has been placed in the top priority list of plant species of the commercialization of the IPTT program, Promotion of Indigenous Plants in Namibia (du Plessis, 2005). Collectively with the Marula kernel-oil, *C. lanatus* seed-oil has been a major Namibian achievement, reaching international niche market access in the lipid oil cosmetic ingredient industry (du Plessis *et al.*, 2005).

Kalahari melon seed-oil is commercially extracted with standard mechanical oilseed expellers, which requires technological innovations for producing quality crude oil within the specifications of international buyers. The current and projected international demand for Kalahari melon seed-oil makes it an opportunity for crop diversification for a large number of communal farmers, beyond the presently restricted demand and supply of other natural oils, such as Marula oil.

Ethnobotanical studies

The prefix *ethno-* is used in disciplines such as botany and pharmacology which implies the way that researchers explore local people's perception of cultural and scientific knowledge (Martin, 1995). The term ethnoecology is used to encompass all studies which describe local people's interaction with the natural environment, including subdisciplines such as ethnobiology, ethnobotany, ethnoentomology and ethnozoology, the study of how people interact with all aspects of the natural environment, including plants, animals, land-forms, forest types and soils, among many things (Martin, 1995). Ethnobotany refers to the study of interactions between people and plants.

According to Posey (1999), there are four major interrelated endeavors in ethnobotany:

1. Basic documentation of traditional botanical knowledge;
2. Quantitative evaluation of the use and management of botanical resources;
3. Experimental assessment of the benefits derived from plants, both for subsistence and for commercial ends; and
4. Applied projects that seek to maximize the value that local people attain from their ecological knowledge and resources.

The bulk of the world's biological diversity is found in developing countries, and within these countries in areas and among people who are frequently and politically and economically marginalized.

Biodiversity researchers have significantly contributed to raising public awareness regarding the alarming loss of biological diversity and cultural diversity. With the strong link between cultural and biological diversity, it means that biodiversity research should be conducted with the close involvement of local communities.

Seed viability

Seeds are uniquely equipped to survive as viable regenerative organisms until the time and place are right for the beginning of a new generation; however they cannot retain their viability indefinitely and eventually deteriorate and die (Copeland & McDonald, 1995). The length of time for which seeds can remain viable is determined genetically.

There are many definitions of viability; this study describes viability as adapted from Copeland & McDonald (1995), as: 'viability denotes the degree to which a seed is alive, metabolically active and posse's enzymes capable of catalyzing metabolic reactions needed for germination and seedling growth'. Environmental factors and storage conditions have a decisive effect on the life span of any give seed, of whether the seed will remain viable for the full period determined by its genome or whether it will lose its viability at some earlier stage. In general, viability is retained best under conditions in which the metabolic activity of seeds is greatly reduced i.e. low temperature and high carbon dioxide concentration and in addition to factors determined by seed dormancy (Copeland & McDonald, 1995). According to Copeland & McDonald (1995), the loss of viability is not a sudden abrupt of failure to germinate of all the seeds in certain population, rather the percentage of seeds which will germinate in any given population will decrease. Moreover, even if a seed loses its viability this does not imply that all metabolic processes stop simultaneously or that all enzymes are inactivated, only the sum total of processes which lead to germination no longer operates properly (Copeland & McDonald, 1995).

To test for viability, chemical or histochemical methods are used and these tests are based on the activity of certain oxidizing enzymes. The reagent triphenyltetrazolium chloride is normally used to test for viability, the reagent penetrates the tissue which, if living, will reduce the tetrazolium to a deep red or purple-coloured formaza, the reaction is catalyzed by NADPH dehydrogenases (Hendry and Grime, 1993).

Seed coat-imposed dormancy

Many seeds do not germinate when placed in conditions which are normally regarded as favourable to germination, namely an adequate water supply, a suitable temperature and an atmosphere of normal composition (Bewley and Black, 1994). Nevertheless seeds can be shown to be viable, as they can be induced to germinate by various special artificial treatments, or under specific external conditions (Bewley and Black, 1994). Such seeds are said to be dormant and this can be advantageous for the survival of the species until suitable conditions are established.

Dormancy is referred to as 'primary dormancy' as a result of immaturity of the embryo, impermeability of the seed coat to water or to gases, prevention of the embryo development due to mechanical causes, special requirements or light, or the presence of substances inhibiting germination (Copeland & McDonald, 1995). Other seeds will germinate readily immediately after they shed if conditions are favourable, however, these seed may lose their readiness to germinate, and this phenomenon is called secondary dormancy (Copeland & McDonald, 1995).

Seed coating is one the most economical approaches to improving seed performance as seed germination can be inhibited by mechanical restriction exerted by the seed coat (Nerson *et al.* 1985). According to Nerson *et al.* (1985), permeability limitation of water and gases is typical of hard seed coats, but not uncommon, even in thin-coat seeds. Dormancy is fundamentally the inability of the embryo to germinate because of some inherent inadequacy, but in many cases it is manifest only in the intact seed and the isolated embryo can germinate normally (Mayer and Poljakoff-Mayber, 1989). The seed coat is dormant only because the tissues enclosing the embryo, the seed coat which often includes the endosperm, pericarp, or the extrafloral organs, exert a constraint that the embryo can not overcome (Mayer and Poljakoff-Mayber, 1989). In some seeds, there are cases where the embryo itself is dormant, the removal of the coat does not permit such embryos to germinate normally, and therefore block germination is more profound than in seeds with coat-imposed dormancy (Bewley & Black, 1994). According to Bewley & Black (1994), embryo dormancy is common in woody species especially in the Rosaceace, but sometimes found in herbaceous plants such as some grasses such as wild oats. Both types of dormancy exist simultaneously or successively in some species. Seeds are said to have primary dormancy when they are dispersed from the parent plant in a dormant state, the dormancy is initiated during seed development. Dormancy can also be induced in mature, nondormant seeds known as induced dormancy. This sets in when the seeds are held under conditions unfavorable for germination, e.g. anoxia, unsuitable temperatures or illumination.

According to Bewley & Black (1994), coat-imposed dormancy has a number of possible effects of the tissues enclosing the embryo:

- Mechanical restraint

The coats of many dispersal units are hard, tough tissues which may be expected to offer considerable resistance to the embryo. If embryos cannot generate enough force to penetrate these tissues, they cannot properly germinate. It is known in some cases that the tissues restraining the embryo must be weakened chemically before the radicle can emerge.

- Inference with gas exchange

Several layers of tissue surrounding the embryo limit the capacity of gaseous exchange by the embryo in two ways. First, the entry of oxygen may be impeded; second, the escape of carbon dioxide may be hindered. One important consequence could be the inhibition of respiration. The embryo intact, dormant dispersal unit fails to germinate because of the restrictions by the enclosing tissues, particularly oxygen uptake. Removal, abrasion, or puncturing of these tissues gives the embryo access to oxygen uptake and germination can proceed.

- Prevention of the exit of inhibitors from the embryo

If inhibitors of different chemical classes are retained by the imbibed seed, instead of being lost to the external medium, germination of the embryo may be blocked. The assessment of the whether the seed coat stops the escape of inhibitors is assessed by collecting diffusion products from intact and isolated embryos.

The effect of Essential Microorganisms on seed germination

The uniqueness of microorganisms and their often unpredictable nature and biosynthetic capabilities, given a specific set of environmental and cultural conditions, has made them ideal for solving problems in the life sciences and other fields.

Microbial technologies have been applied to various agricultural and environmental problems with considerable success in recent years. Microorganisms are effective only when they are presented with suitable and optimum conditions for metabolizing their substrates including available water, oxygen (depending on whether the microorganisms are obligate aerobes or facultative anaerobes), pH and temperature of their environment (Higa, 1995).

Soil microbiologists and microbial ecologists have tended to differentiate soil microorganisms as beneficial or harmful according to their functions and how they affect soil quality, plant growth and yield, and plant health.

The concept of effective microorganisms (EM) was developed by Professor Teruo Higa, University of the Ryukyus, Okinawa, Japan (Higa, 1995). EM consists of mixed cultures of beneficial naturally-occurring microorganisms that can be applied as inoculants to increase the microbial diversity of soils and plant.

EM can perform a number of other functions which includes:

- Fixation of atmospheric nitrogen
- Decomposition of organic wastes and residues
- Suppression of soil-borne pathogens
- Recycling and increased availability of plant nutrients
- Degradation of toxicants including pesticides
- Production of antibiotics and other bioactive compounds
- Production of simple organic molecules for plant uptake
- Complexation of heavy metals to limit plant uptake
- Solubilization of insoluble nutrient sources
- Production of polysaccharides to improve soil aggregation

Biotic factors in determination of seed germination

Seeds in their natural environment interact with other plants and with animals. The interaction with other plants may be due to inhibitors, stimulators or modification of the microhabitat Leck *et al.* (1989). Animals may affect germination behavior by seed softening in the digestive tract or due to distribution to other habitats. Many animals can change the balance of different plants in a given area by grazing, by distributing the seeds, by the excretion of seeds in new habitats different from those in which the fruits were eaten and other means (Leck *et al.*, 1989). The retention of seeds in the digestive tract of animals seems to aid seed distribution.

Adegoke & Ndife (1993) describes that *C. lanatus* is distributed widely mainly by animals. These animals include domestic ruminants such as goats and cattle. When the animal eats the fruit, the fleshy part is digested, but the tough seeds usually pass unharmed through the digestive tract (Campbell, 1996). Mammals then deposit the seeds along with the fertilizer supply, kilometers from where the fruit was eaten.

CHAPTER 3

MATERIALS AND METHODS

Study Area

The major part of this study included an ethonobotanical study, seed collection and germination trials of *C. lanatus* seeds from areas in north-central Namibia, especially the King Nehale Conservancy in the Oshikoto Region. Studies and seed collection were carried out in the King Nehale Conservancy for the reason that it supplied almost 80% of the *C. lanatus* seeds exported to The Body Shop in the year 2004 in close cooperation with the EWC (du Plessis, 2004). The King Nehale Conservancy is thus a major supplier of *C. lanatus* seeds and the area experiencing the majority germination problems.

The King Nehale Conservancy is situated 17º 20’ 25”S, 18º 30’ 50” E in the Oshikoto Region, north-central part of Namibia. This is a newly established conservancy and was officially registered in September 2005. The conservancy covers a total land area of 508 km^2 with a total 20 000 people residing within the conservancy ((Johannes *per. comm.*, 2006)). The conservancy was established to meet its objectives based on the goals of Community-Based Natural Resource Management, to jointly to manage the natural resources, to gain financial and other benefits. The mission of the conservancy is to sustainably manage, utilize wildlife and other natural resources to improve the livelihoods of its members (Johannes *per. comm.*, 2006). The vision of the conservancy is to have a self-sustainable conservancy whereby people, livestock and wild animals live together (Johannes *per. comm.*, 2006).

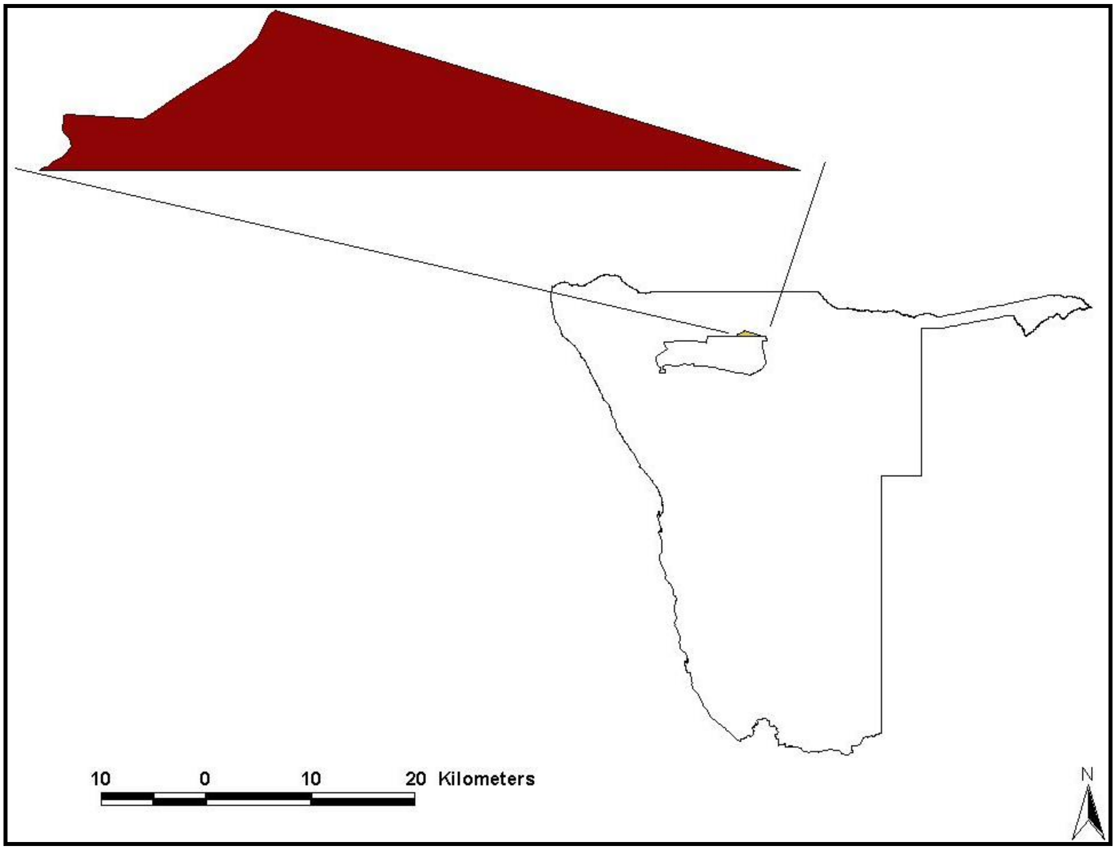

Figure 3.1 The map of the King Nehale Conservancy bordering the Etosha National Park.

Soil types

According to de Klerk (2004), the soils in this area are weakly developed shallow soils of arid regions, bordering halomorphic soils. The areas bordering the Etosha Pan region are part of the Kalahari sandveld with brittle alkaline soils (Barnard, 1998). The sandveld undulated in low, fossilized dunes interspersed with shallow ephemeral river valleys or omiramba (Barnard, 1998). Barnard (1998) points out that most omiramba form lines of pools or pans in the rainy season as the coarse sand is very porous.

Climate

The conservancy is based in the semi-arid areas of Namibia, with the mean annual rainfall calculated between 450 to 500 mm with a high (Mendelsohn *et. al*., 2002). The annual rainfall is concentrated between the months of November and March, evaporation rates higher than the average rainfall with an average water deficit of 1,500 – 1, 700 mm/year (Mendelsohn *et. al*., 2002). The average maximum temperature of the area is 36 °C with an average minimum temperature of 6 °C (Mendelsohn *et. al*., 2002).

Fauna and Flora

The vegetation includes mountain savanna and karstveld, with fringes of the Mopane Savanna which dominates on north-west of Namibia (de Klerk, 2004).

The conservancy borders the Etosha National Park and receives an influx of game especially kudus, springboks, wildebeests, oryx, hartebeest and zebra from the Park. These species are of important economic value as the conservancy tries launching itself as a tourist destination. There are a number of inland ephemeral wetlands from the Etosha Pan/Cuvelai delta inland complex with its Oshana drainage channels (Barnard, 1998). These oshanas are ecologically and economically important receiving irregular seasonal influxes of water and nutrients (Barnard, 1998). The oshanas in the area are a key source of fish, frogs and other wetland resources in the Cuvelai Basin.

Germination procedures

Limitations of research

In all experiments, unless otherwise indicated standard germination procedures were followed. Experiments were carried out in Ondangwa in northern Namibia, a town that has similar geographical and climatic variables as the King Nehale Conservancy in northern Namibia, and the University of Namibia main campus in Windhoek. Experiments had to be carried out in Ondangwa due the lack equipments such as cold storage and water scarcity experienced at various villages in the Conservancy.

The field research did not make use of some methodologies carried out under normal laboratory and greenhouse conditions, due to a lack of equipment; this included the keeping seeds at a constant temperature in an oven. Methods indicated below were carried out at Ondangwa and in the greenhouse at UNAM unless otherwise indicated. Due to the equipment limitation faced in Ondangwa, some standard procedures were unobserved to facilitate the experimental procedures.

Growth medium

Seeding was done directly into plastic pots (60 cm x 40 cm) filled with planting soil that was brought from Ferreira Gardens in Windhoek.

Seed germination

A seed was considered to have germinated when the radicle reached 2 mm in length after it has protruded from the seed. The radicle was measured using a measuring calibre. The seedling numbers were recorded daily for 21 days thereafter which the samples were discarded.

At UNAM, greenhouse temperatures averaged 23 to 43°C (8 a.m. to 5 p.m.) for the season when the experiments where performed. These average temperatures were found to be optimal in tests done by Nerson (2000). Nerson (2000) established that breaking the dormancy in the propagation and planting of *C. lanatus*, was mainly found under high temperatures regimes. Consequently, there was a need to carry out the germination trials during the warmer months of the year and this was completed during August and September in the latter in Windhoek and the former in Ondangwa.

It was important to carry out comparative laboratory and field trials to pinpoint the distinctive characteristics and management needs of *C. lanatus* under a wide range of environmental conditions.

Sampling design

Ten rows by five columns were prepared in planting trays i.e. 50 seeds per pot. Four trays had a sample lot treated seeds, while another four had untreated seeds as the control. Replication was important in this experiment to provide an estimate of experimental error and reduce the standard deviation of the treatment mean (50 x 4 replicate), hence 200 seeds per treatment. The data represented a mean of 4 replicates with standard error. The trays were randomly placed using the randomized complete block design for both seeding (field and greenhouse).

Ethnobotanical studies and seed collection

The *C. lanatus* seeds were obtained from the King Nehale Conservancy in northern Namibia through the help of different villagers around the Conservancy. Seeds collected included melon seeds obtained from herbivore manure, which has been associated with the germination of the melon. An ethonobotanical study was carried out in various villages in northern Namibia attached as Appendix 1.

The researcher recorded some of the ethnobotanical information associated with *C. lanatus*. The research method included interviews with KNC members and other farmers within the northern-central Region based on an open-ended questioning technique, supplemented by ground-survey observation. This method is not rigid and allows a wider range of freedom for the respondent to embellish as he or she wishes. A checklist of the questions was compiled prior to the mission. While in the field an initial analyses of the data was made to assess if the unit of measurement are appropriate for the study. The questionnaire included the management and the harvesting system of *C. lanatus* and possibilities of cultivation with traditional crops. The study also observed and recorded some of the harvesting methods used by the fruit collectors. Villagers were requested to rank important activities based on different livelihoods; namely crop production, livestock production and the utilization of natural resources. The villagers were also asked to rank the utilization of Kalahari melon seed and the different harvesting systems.

The study was done during a period when the harvesting of the melons usually occurs, namely June. By way of this information, the analyzed data was referred to literature on whether harvesting methods are sustainable for plant propagation and seed recruitment and dispersal.

Measurement of seeds per fruits, measurements of fruits and seed viability test

Harvested fruits were collected, weighted and measured. Each fruit was then cut open to get an average number of seeds per fruit. This helped with the determination of how many fruits are harvested to get a sustainable income per kilogram of seeds harvested. A hundred seeds from 15 fruits were weight to get the average mass of seeds for each size class as illustrated in Table 3.1. The total number of seeds for each fruit classes were summed up and averaged by the number of fruits.

Table 3.1 Size classes used for the purpose of this study

Size Class	**Mass**
Small	< 150 g
Medium	150 – 300 g
Large	> 300 g

The test for viability was done on seeds from all size classes. Viability tests were important to determine if seeds have deteriorated to an extend that, they are no longer viable and revealing a high percentage of ungerminated seeds. A sample of seeds was brought to the University of Namibia Windhoek campus to test for viability. The tetrazolium test was used as a means of estimating seed viability. The tetrazolium test distinguishes between viable and dead tissues of the embryo on the basis of the relative respiration rate in the hydrated state (Copeland & McDonald, 1995). Single samples of 50 seeds per seed lot were imbibed in distilled water for 24 hours to allow for complete hydration of all tissues. After hydration, the seeds were placed in a Petri-dish within a 0.05 % solution of 2, 3, 5 triphenyl- tetrazolium-chloride after cutting them in half. Seed viability was interpreted as according to the topological staining pattern on the embryo and the intensity of the coloration with the purple coloration considered as viability and the white coloration not viable.

Coat-imposed dormancy: seed coat permeability of *Citrullus lanatus*

Citrullus lanatus seeds were treated with various methods to test for seed-enhanced dormancy.

Water submergence

Seeds were soaked in distilled water for 24 hours. Soaking of seeds in water prior to planting has been suggested to enhance germination, seedling growth and by controlling the imbibitions conditions and reducing the vagaries of adverse weather and soil conditions (Copeland & McDonald, 1995). Seeds were fully submerged in 100 ml of distilled water in a glass beaker at varying temperatures: room temperature and pressure at 20 °C, in cold water at a constant temperature of 4°C in a refrigerator and warm water at a constant temperature of 30 °C in an oven. After soaking the seeds were air-dried for 6 days and then planted in pots.

Scarification

It has been reported by Porter and Lawlor (1991) that many seeds can germinate only after the seeds have been exposed to heavy rain in the company of abrasive sand and small stones, which scarify the testa. It was thus one of the objectives of this research to apply diverse methods of seed scarification to investigate germination of *C. lanatus*.

Acid Scarification

Sulphuric acid (H_2SO_4) was used as scarification agent. In most studies where seeds were treated with sulphuric acid, concentrated sulphuric acid (95% pure) is normally used (Wang and Pitel, 1991 in: Shikongo, 2003). According to Shikongo (2003), sulphuric acid requires acid resistant containers and present a risk to both nursery people at the village level and to the seeds. Diluted sulphuric acid was used in this experiment in order to minimise the risk to nursery people in that they will not have to work with pure concentrated sulphuric acid. Seeds were rapidly exposed to 18% sulphuric acid in a glass beaker for 1 and 5 seconds, this period is suitable to the thickness of the Kalahari melon seed coat. The seeds were then rinsed in running to remove all traces of the acid. Dried seeds were then sown.

Mechanical Scarification

In another treatment, a mortar and pestle was used to abrase seeds mixed with soil, this was to ensure the scarification of the seed coat to allow water permeability. The seeds were then sampled to examine the possible effects of the seed coat in regulating germination. The nicked seeds were then sown.

The effect of Effective Microorganisms on the germination of seeds

Effective Microorganisms culture is sold as an innoculant that can be activated or extended for reasons of economics. The process of activation can result in up to a 20 times the increase from the original culture. Activation usually involves adding the original Effective Microorganisms culture to a mixture of water and blackstrap molasses, its main food source (Higa, 1995).

The EM innoculant was obtained from the Polytechnic of Namibia. Seeds were fully submerged in 1:1, 1:50, 1:100 and 1:150 ratios of EM and distilled water. Care should be taken as not to use tap water as it is chlorinated and will kill the microbes. Rain water is recommended and if tap water has to be used, it should be put in an open container in the sun to get rid of the Chorine. The seeds were soaked for 24 hours before they were sown.

Data analysis

Ethnobotanical studies

The ethnobotanical studies made frequent use of descriptive statistics to portray trends in the data. The analytical tools based on open-ended questions posed in anthropological research, cause low ease in the statistical analysis of data; however they do cover broad breath of subjects. A direct matrix ranking was use as part of the preference ranking to order various activities on 'value' or 'desirability' by considering various attributes based on livelihoods. The result of the various responses was created to make matrix representative of the north-central villagers.

Germination percentage

The test of germination was expressed in percentage and the rate of germination of all seeds sown. The measurements of the time and rate of the germination process are important aspects that must be considered. These aspects can predict the degree of success of a species based on the capacity of their harvest seed to spread the germination through time, permitting the recruitment in the environment of some part of the seedling formed (Ranal and de Santana, 2006).

The rate of germination was calculated by using formulae adapted from Bewley and Black (1994) as the time taken for the germination process to be completed by the population.

Hence, the mean time to complete germination (t) is equal to:

$\Sigma (t*n)/\Sigma n$

Where,

t = Time in days, starting from day 0, the day of the sowing

n = Number of seeds completing germination on day t;

The mean germination rate R, therefore equals to:

$\Sigma n/\Sigma(t*n)$; and

The coefficient of the rate of germination CRG equals to:

R*100

Data manipulation

Data collected was primarily computed statistically by using SPSS and Genstat for Windows.

A Kolmogorov-Smirnov test was used to test whether the distribution of the data was significantly different from a normal distribution with a significant value of less than 5% (<0.05). Data not normally distributed i.e. more than 5% (>5), a Kruskal-Wallis test, a non-parametric test was used. ANOVA was used to test whether group means differ for normal data and at a 5% significant probability level. A confidence level of 95% was considered for all tests.

Germination was rated as illustrated in Table 3.1 as adapted from Shikongo (2003).

Table. 3.1 Ratings used for germination periods and germination percentages

Germination period		**Germination percentages**	
< 7 days	Uniform	80 – 100 %	very good
		60 – 79 %	good
7 – 14 days	Moderately uniform	30 – 59 %	fair
		1 – 29 %	Poor
14 – 21 days	Sporadic	0 %	nil

CHAPTER 4

RESULTS

Ethnobotanical studies

There is high reliance of amongst household on arable production, 100% of all villagers interviewed indicated that they dependent heavily on arable production. A number of villagers were busy with crop harvesting season, and most of the respondents had crop fields. As illustrated in Figure 4.1, 18% of households ranked millet production as an important actively, followed closely by maize (16%) and sorghum (15%). The overall ranking of the production and sowing of traditional melons and cultivated watermelons was only 6th.

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Figure 4.1 The combined rating of the economically important crops and domestic farming for the different households.

The entire households visited owned a number of livestock, poultry, goats and donkeys. Many respondents (25 %) ranked the ownership of cattle as important (Figure 4.2). Through the various interviews carried out, villagers indicated that *C. lanatus* contributed to livestock feed and nutrition, as it was rich in oils and proteins.

The villagers utilized the melon in various ways, thereafter; the waste obtained from the fruits is fed to livestock such goats, pigs and poultry.

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Figure 4.2 The combined rating of the economically important livestock for the different households

A number of natural resource products were important economic contributors to most household. Activities indicated as important include the harvest of wildfruits such as Marula for a local brew, utilization of insects such as Mopane caterpillars (*Imbrasia belina*) both for household consumption and for trade and, the utilization of timber products to build dwellings and as a cash resource (Figure 4.3 & 4.4). Wild melons were harvested either for household consumption, or trade. Harvesters did not discriminate between the melon sizes i.e. mature (large) or immature (small). The collection of the melons was not controlled; therefore proper management structures were not in place. The villagers did not hunt for game, however they considered game as an important revenue bringer. Large mammals were found mostly in the vicinity of the Etosha National Park.

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Figure 4.3 The combined rating of the utilization of economically important wildlife for the different households

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Figure 4.4 The combined rating of the utilization of economically important vegetation for the different households

A high proportion of households (66.7%) indicated that they sowed *C. lanatus* and with a few households indicating that they experienced problems with the seedling growth. The seeds were planted in December to January, when the rain has picked-up, intercropping with Mahangu and Sorghum seeds. Most sown seeds were obtained from those of the previous season, the dry seeds stimulating the growth of the melons. The melon cultivation was not intensive, with melon seed sowed with an intention of household use. Villagers indicated that the fruits and the leaves of *C. lanatus* attracted insect pests, rats, mongoose and livestock such as cows and donkeys. The ripe fruits are harvested, and the seeds are dried on corrugated iron for two weeks so that they can be fried and eaten at a later stage. All respondents indicated that they left some fruits in the field for herbivores to graze and browse on; however many felt that the fruits left in the field are gathered by other people. The researcher noticed thorough a rapid appraisal of the fields that there was diminutive a number of fruits left in the wild. The entire households interviewed indicated that they consumed *C. lanatus* within the household. The fruit flesh was cooked with traditional Mahangu porridge and the seeds were fried on a pan over an open-flame to extract-oil. 76.7% of households indicated that they sold excess *C. lanatus* seed-oil to the King Nehale Conservancy.

Villagers interviewed indicated that they normally only grew mahangu, sorghum, maize and beans and did not extensively sow Kalahari melon. The King Nehale Conservancy was in a process of establishing a camp-site for melon seed production and to make the supply of Kalahari melon seeds one of the main activities (Shali

Johannes *pers. comm.*, Chairman of the KNC). According to Johannes *pers. comm*., the community receives a substantive amount of income for their seeds as they got about N$ 2.50 /kilogram for the seeds provided. This price low as compared to similar oils, this is particularly because Kalahari melon seed-oil has to compete on the international market with similar oils such as Marula and *Ximenia* kernels with higher oil content.

There are currently efforts by various communities to establish management committees to control the harvesting of the melon to be on par with other wild food such as *Ximenia* and Marula. Many respondents were unaware of the role played by the Indigenous Plant Task Team (IPTT) and the National Botanical Research Institute (NBRI) based at the Ministry of Agriculture, Water and Forestry (MAWF), that is conducting research, protecting and promoting the sustainable utilization of indigenous plants. Many respondents from the KNC knew of CRIAA SA-DC as an organization providing essential technical knowledge, but this assistance was mostly on the harvesting and the exportation of the melon.

Overall, a significant number of respondents claimed that there was no notable decline in the availability of *C. lanatus*, with no overexploitation of this resource with only the yield of the fruits seen as a setback.

Measurement of seeds per fruits, measurements of fruits and seed viability test

Fruits were divided into size classes under the assumption that larger fruits have the most mature fruits, thus yielding mature seeds, and the smaller fruits were the least mature, producing immature seeds which are not viable, thus not suitable for high germination percentages.

Viability tests indicated that seeds from all class sizes were viable. Recognizing this, no statistical analysis was carried out on these results

The Kolmogorov-Smirnov test indicated that the data for the average mass of the fruits from different size classes and average mass of a 100 seeds in each class group was normally distributed ($P > 0.001$).

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Figure 4.5 The average mass of *C. lanatus* fruits in different size classes. Mean of 4 replicates a 100 hundred seeds (±SE) are presented

There were strong significant differences between the average fruit mass (ANOVA, $F = 74.68$, $P = 0.00$) (Figure 4.5). The mean mass for the small fruit was 128.07 g (± 6.59 SE) when compared to the mean of 421.11 g (±26.02 SE) of large fruits.

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Figure 4.6 The average mass of seeds obtained from the fruits of different weight classes Mean of 15 fruits (±SE) are presented.

As can be seen in Figure 4.6, there was a significant difference between the average seed mass (ANOVA, F = 3.22, P = 0.04). The contrast reveals that on average, the larger fruits had bigger seeds with a mean of 14.28 ±1.35 for a hundred seeds, compared to those of smaller fruits (10.84 ± 0.59).

The Kolmogorov-Smirnov test on the germination percentage for the different size classes indicated that the data was not normally distributed (P < 0.001).

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Figure 4.7 Total germination of *C. lanatus* seeds obtained from fruits of different mass classes planted at the UNAM Greenhouse. Mean of 4 replicates (±SE) are presented.

The Kruskall-Wallis test revealed that there was no significant difference between the germination percentage for treatments carried out at the UNAM Greenhouse (H (1) = 2.89, P = 0.24) (Figure 4.7). The fruit size did not improve the seedling germination, no significant difference was found between the germination percentages of the different class sizes (P > 0.05). .

Error! Not a valid link. Figure 4.8 Total germination of *C. lanatus* seeds obtained from fruits of different mass classes planted in Ondangwa Mean of 4 replicates (±SE) are presented.

The statistical analysis revealed that there is no significant difference between the germination percentage for sowing carried out in at Ondangwa (H (1) = 2.25, P = 0.33) (Figure 4.8).

Table 4.1 The germination percentage and the mean rate of germination for seeds of different fruit size classes of *C. lanatus* at Ondangwa

Treatment	**Germination Percentage**	**Mean rate of germination**		
		time (*t*)	**Rate (R)**	**Coefficient (CRG)**
Small	16	3.36	0.30	29.76
Medium	14	2.94	0.34	34.01
Large	18	3.78	0.26	26.46

For field studies, the seeds from medium fruits obtained lower germination percentage (14 %). The overall germination rate of the all the seeds did not reach the arbitrary 50 % for the maximum germination. The rate of germination was highest in the seeds obtained least-mature fruits (R = 0.30) and lowest in the seeds obtained from the most-mature fruits (R = 26) (Table 4.1).

Coat-imposed dormancy: seed coat permeability of *Citrullus lanatus*

<u>Water submergence</u>

The germination treatments revealed that the data was not normally distributed (P<0.001).

Error! Not a valid link. Figure 4.9 Total germination of *C. lanatus* seeds which were not submerged n any medium planted at the UNAM Greenhouse. Mean of 4 replicates (±SE) are presented.

When the different treatment groups were statistically analysed, it was revealed that the seeds left under cold conditions were strongly significantly different from the other treatments (H (1) = 18.82, P=0.00) (Figure 4.9). The germination percentage of the seeds exposed under cold conditions was rated good, as it resulted in 70 % germination; the control resulted in 11 % germination.

Error! Not a valid link. Figure 5.10 Total germination of *C. lanatus* seeds which were not submerged in any medium at Ondangwa Mean of 4 replicates (±SE) are presented.

Similarly, at Ondangwa, the germination of seeds left under cold conditions were significantly different from the control (H(1) = 4.82, P =0.03). The seeds exposed under cold conditions resulted in 74 % germination; the control resulted in 14 % germination (Figure 4.10).

Error! Not a valid link. Figure 4.11 Total germination of *C. lanatus* seeds submerged in water at varying temperatures at the UNAM Greenhouse. Mean of 4 replicates (±SE) are presented.

The Kruskall-Wallis test revealed that there was no significant differences between the germination percentages for treatments carried out at UNAM Greenhouse (H(3) = 5.70, P = 0.06) Figure 4.11).

However, further statistical analysis revealed that the seeds left under cold conditions (4 °C) were significantly different from the control and the water (at standard room and temperature) ($P < 0.00$) (Figure 4.9). The seeds exposed in cold water (4 °C) conditions resulted in 56 % germination and the control had the highest germination rate (R = 0.40) (Table 4.1).

Table 4.2 The germination percentage and the mean rate of germination for seeds of submerged in water with various temperatures at UNAM Greenhouse.

Treatment	**Germination Percentage**	**Mean rate of germination**		
		Time (*t*)	**Rate (R)**	**Coefficient (CRG)**
Control	12	2.52	0.40	39.68
Warm water	18	3.78	0.26	26.46
Cold water (4°C)	56	11.76	0.09	8.50
Water (rtp)	16	3.36	0.30	29.76
Water (30 °C)	24	5.04	0.20	19.84

Error! Not a valid link. Figure 4.12 Total germination of *C. lanatus* seeds submerged in water at varying temperatures at Ondangwa Mean of 4 replicates (±SE) are presented.

The Kruskall-Wallis test revealed that there was no significant difference between the germination percentages for treatments carried out at Ondangwa ($P > 0.05$) (Figure 4.12).

Statistically analysis, it revealed that there were no significant differences within the groups ($P > 0.05$). Seedling germination resulted in 56 % for seed under cold conditions (°C), thus ranked as having a fair growth, this is past the arbitrary 50 % of the maximum percentage germination required for the establishment of a population.

The effect of seed scarification on germination

This experiment was done under the assumption that scarification of the seed coat results in a high germination percentage of seedlings than from seeds left intact due to the permeability of water in the seeds. Acid scarification and mechanical scarification methods were tested.

The Kolmogorov-Smirnov test for normality on the germination period for all treatments from mechanical and acid scarification the data was not normally distributed ($P < 0.001$).

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Figure 4.13 Total germination of *C. lanatus* seeds obtained from three different scarification methods at the UNAM Greenhouse. Mean of 4 replicates (±SE) are presented.

The Kruskall-Wallis test revealed that there was a significant difference between the germination percentages for scarification treatments carried out at UNAM Greenhouse. ($P < 0.05$) (Figure 4.12). Statistical tests further revealed that there was no significant difference between the germination percentages of seeds treated with H_2SO_4 for 1 second and those treated with H_2SO_4 for 5 seconds ($H(1) = 1.70$, $P = 0.19$).

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Figure 4.14 Total germination of *C. lanatus* seeds obtained from three different scarification methods at Ondangwa. Mean of 4 replicates (±SE) are presented.

For trials carried out in Ondangwa, statistical analysis revealed that the treatment were significantly different ($P < 0.05$). Further analysis revealed that the treatment of seeds exposed to H_2SO_4 for 5 seconds and 1 second were not significantly different ($P > 0.05$) (Figure 4.13) from each other, however different with the other treatments. The seeds abrased with sand resulted in 18 % germination, while seeds treated with H_2SO_4 for 5 seconds had a coefficient rate of germination of 6.80 (Figure 4.14 and Table 4.3).

Table 4.3 The germination percentage and the mean rate of germination for seeds exposed to various scarification methods at Ondangwa.

Treatment	**Germination Percentage**	**Mean rate of germination**		
		time (*t*)	**Rate (R)**	**Coefficient (CRG)**
Control	16	3.36	0.30	29.76
Nicked	18	3.78	9.26	26.46
H_2SO_4 1”	54	11.34	0.09	8.82
H_2SO_4 5”	70	14.70	0.07	6.80

The effect of Essential Microorganisms on the germination of seeds

These experiments were carried out under the assumption that seeds treated with EM will have higher germination percentages, as the seeds have been improved by the microorganisms in the medium.

The Kolmogorov-Smirnov test for normality on the germination period for all EM showed that the data was not normally distributed ($P < 0.001$).

Error! Not a valid link. Figure 4.14 Total germination of *C. lanatus* seeds obtained from four different concentration of Essential Microbes (EM) at the UNAM Greenhouse. Mean of 4 replicates (±SE) are presented.

Analysis of the results carried out at the UNAM Greenhouse (Figure 4. 14) indicate that there was a strong significant difference between the different EM treatment concentrations (H(3) = 12.55, P = 0.00). There were no significant difference between the germination percentages of the treatment of EM 1:1 and EM 1:50 (H(1) = 2.29, P = 0.13). No significant difference was also found between EM 1:100 and EM 1:150 of the treatment (H(1) = 3.35, P = 0.07).

Error! Not a valid link. Figure 4.15 Total germination of *C. lanatus* seeds obtained from four different concentration of Essential Microbes (EM) at Ondangwa. Mean of 4 replicates (±SE) are presented.

Analysis of the results carried out at the Ondangwa (Figure 4. 15) indicate that there were significant differences between the different EM treatment concentrations (H(3) = 12.05, P = 0.01). There were no significant difference between the germination percentages of the treatment of EM 1:1 and EM 1:50 (H(1) = 1.92, P = 0.17). In addition no significant difference was found between the treatment of EM 1:100 and EM 1:150 of the treatment (H(1) = 1.39, P = 0.24).

Table 4.4 The germination percentage and the mean rate of germination for seeds exposed to four different concentration of Essential Microbes (EM) at Ondangwa

Treatment	Germination Percentage	Mean rate of germination		
		time (*t*)	Rate (R)	Coefficient (CRG)
Control	12	2.52	0.40	39.68
EM 1:0	18	3.78	0.26	26.46
EM 1:50	30	6.30	0.16	15.87
EM 1:100	26	5.46	0.18	18.32
EM 1:150	14	2.94	0.34	34.01

Table 4.4 of trials carried out at Ondangwa, illustrates that the mean rate of germination was lowest within the treatment of EM 1:50 (R = 0.16), at the same time the control had the highest coefficient rate of germination (CRG = 39.68). The germination percentage of all treatments were rated as poor as they fell within the range of 1 – 29 %.

The effect of herbivore manure on seed germination

Seeds were obtained from herbivore manure under the assumption that they have a high germination percentage because the seeds are primed for germination through partial digestion in the herbivore.

The Kolmogorov-Smirnov test for normality on the germination period for all treatments from herbivore manure and the control showed that the data was not normally distributed ($P < 0.001$).

The Kruskall-Wallis test revealed that there is no significant difference between the germination percentage for treatments carried out at UNAM Greenhouse ($H(1) = 3.13$, $p > 0.05$) (Figure 4.16).

Error! Not a valid link. Figure 4.16 Total germination of *C. lanatus* seeds obtained from herbivore manure at the UNAM Greenhouse. Mean of 4 replicates (±SE) are presented.

There was a significant difference between the germination percentage for treatments carried out at Ondangwa ($H(1) = 4.83$, $p < 0.05$) (Figure 4.17). Pairwise comparisons were made between seeds obtained from herbivore manure and the control to know how the groups significantly differ from each other. The Mann-Whitney U test revealed that the control and herbivory differ from each other significantly ($U = 135$, $P < 0.001$).

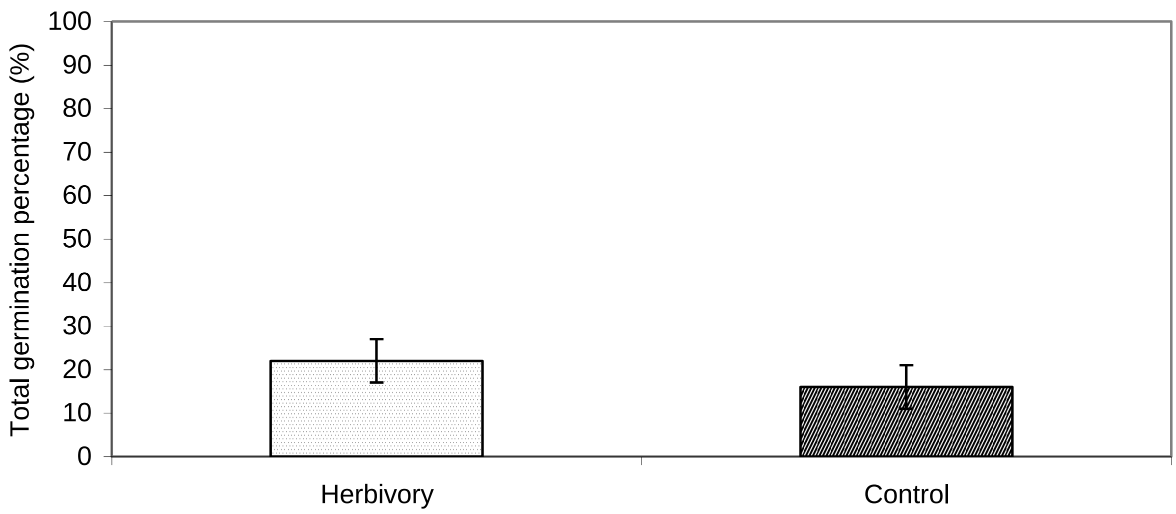

Figure 4.17 Total germination of *C. lanatus* seeds obtained from herbivore manure at Ondangwa. Mean of 4 replicates (±SE) are presented.

It is then concluded that even though there was no significant difference between the germination percentage of seedlings at UNAM Greenhouse ($p>0.05$), there was a significant difference when the germination is tested under field conditions ($p<0.05$) (Figure 4.17).

Table 4.5 The mean rate of germination and the germination percentage of seeds obtained from herbivore manure and the control at UNAM Greenhouse.

Treatment	**Germination Percentage**	**Mean rate of germination**		
		time (*t*)	**Rate (R)**	**Coefficient (CRG)**
Control	10	2.1	0.48	46.62
Herbivore	18	3.78	0.26	26.46

Table 4.5 illustrates that the mean rate of germination was lower (R = 0.26), in seeds obtained from herbivore manure, whilst the control had the highest coefficient rate of germination (CRG = 46.62). The germination percentage of both treatments were rated as poor as they fell within the range of 1 – 29 %.

For field studies, the control had a lower extent of germination (16 %), compared to the 22 % germination percentage acquired from seeds obtained from herbivore manure. The overall germination rate of the control and seeds obtained from herbivore manure seeds did not reach the arbitrary 50 % of the maximum percentage germination. The high coefficient rate of germination within the control (CRG = 29.76) indicates concentrated germination spread over time.

CHAPTER 5

DISCUSSION

Ethnobotanical studies

There are concerns that the economic value placed on *C. lanatus* has decreased its recruitment potential in the field, due a lack of proper harvesting systems and the community management of the resource. Community resources management should be in such a as to way as to maximize the benefits from a natural resource whilst enhancing their status, there should be essentially a dynamic equilibrium between the renewal and utilization of the resource.

The people in the north-central regions of Namibia are generally agro-pastoralist practicing pastoralism and agriculture. Most of the respondents are subsistence farmers depending heavily on agriculture to supplement their income and to provide food for the family. The high dependence on agricultural and livestock production, combined with the population pressure increases the threat and over-exploitation of natural resources. A study by Kiringe, (2005) found that the exploitation of trees and shrubs and the increase in the human population attributed to the decline in medicinal plants in the Kuku Group Ranch in Kenya. The community depended greatly on the utilization of natural resources for purposes of firewood, construction material and the harvest of wild food for household consumption and for monetary trading, contrary to a study by Reyes-Garcia *et al*. (2005). A research carried out in the Bolivian Amazon by Reyes-Garcia *et al*. (2005), suggests that as indigenous people become more integrated into the market economy and adopt plant substitutes; they stopped using plants, creating a gap in ethnobotanical knowledge and their use of wild plants

It is important to incorporate resource management strategies to address the challenge of balancing resource conservation and utilization. Most of the respondents did not rate the current management practices of *C. lanatus* as factors that reduce its germination and its subsequent recruitment within the wild population as important. The finding of this study revealed that since most of these communities depend heavily on agricultural crops, they considered *C. lanatus* to be locally abundant. The melons were therefore not extensively cultivated to reduce the pressure put on the wild populations of the melon. As indicated in the results, there were very few observed melon fruits growing in the wild, however, villagers were actively harvesting the melons in their farmlands. The few observed melons can be attributed to the onset of the harvesting season, and the number of domestic animals such as goats actively feeding on the melon. Since the research was carried out during a dry month, the green melons provided an attractive alternative forage material when compared to the dry grasses and crop fields.

In the study, the respondents indicated that they did not harvest all of the melons in the field. Most of the villages visited are within communal areas, it is therefore an intricate situation to monitor the harvesting of the melon. Communities invested in the management of their own crop fields, rather than manage a resource which is communally owned. With commercial exploitation of the melon, it has become a financial gem for many poor communities, exposing it to over-exploitation.

Although local communities have appropriate indigenous knowledge to manage their resource, this was not actively practiced. It is important to establish community based awareness programmes to create awareness relating to resource and ecological management. When communities are fully educated and are conscious of the current problems relating to the unsustainable harvesting of the melon they will be more likely willing to extensively plant the melons. Currently, the lack of awareness on the decrease of the melon seeds will result in an unsustainable livelihood both for the trader and the consumer of the melons,

Germination tests

Due to the similar germination percentages obtained from both the studies carried out the UNAM Greenhouse and at Ondangwa, it was assumed that there was negligible location effect amongst the treatment variables. The discussions are therefore not treated separately but rather as overall results and trends within the various treatments. In the initial collection of the data, it was observed that distinctions were made on names of the various local types of melons. This distinction was important so that the collection of the fruits could only be those of the Kalahari melon.

Measurement of seeds per fruits, measurements of fruits and seed viability test

The significant differences between seed weight of the different fruit classes is an indication that the weight of a fruit is proportional to the weight of its seeds. This similarity is comparable to preliminary trials carried out by Maggs-Kölling and Christiansen (2003), wild forms of *C. lanatus* had a weight percentage of seeds per fruit (3-4 %) for various Namibian cultivars, while large fruited cooking melons averaged 0.6 %. Research by Maggs-Kölling & Christiansen (2003), determined that the relationship between yield and fruit weight was more pronounced in commercial varieties, whereas the number of fruit was more critical in local watermelon yields. According to Maggs-Kölling & Christiansen (2003), literature indicates that the mean fruit weight had marked effect on fruit yield. This is important for village nurseries to plant fruits which are able to obtain high yields, however studies on obtaining fruit yield was not in the scope of this study.

Although smaller fruits might indicate immature fruits, with immature seeds, the fruit weight and the seed weight did not play a role in determining the germination percentage. The removal of the seeds from fresh fruits at the end of the growing season i.e. May/June, when the fruit abscission are in a state of primary dormancy, can result in the failure of seeds to germinate. The harvesting of immature fruits can result in poor germination over long period as can be observed by the poor germination rate of smaller melons. The poor germination rate can be attributed to the limited inability of embryo of young, non-mature seeds to break through the coat. Nerson (2002) provides another reason for low germination rates in immature seeds; this may be as a result of the penetration of excess water into the young embryo and the seed cavity which impedes the flow of gases in biochemical pathways of the germination process.

The seeds obtained from the different fruit classes obtained poor germination ranking. It is important for seeds to first desiccate before germination is promoted. To improve the germination percentage it is important to dry the seeds for long periods. The drying of the seeds for longer period was not possible for this experiment due to the time limit. This can be attributed to the low germination experienced. According to Bewley & Black (1994), Desiccation of developing seeds, whether prematurely or during the final stages of maturation, not only promotes germination on subsequent imbibition, but also results in cessation of developmentally related synthetic events. It has been proven by previous studies by Nerson (2002) that the germination of the water melon can be improved after several years of storage. Melon seed dormancy is common in the wild species as a means of survival and an evolution director.

Coat-imposed dormancy: seed coat permeability of *Citrullus lanatus*

The seed coat of many species may prevent the entry of water delaying germination for many years. This is due to the fact that insufficient water reaches the embryo, as the water uptake is impeded by the testa.

Water submergence

The overall treatments shows that seeds soaked in water had higher germination percentages when compared to the control. The improved germination of the pre-soaked seeds can be attributed to increased embryo size. According to Small & Botha (1986), the success of various soaking treatments in improving germination suggests that the poor germination with the small size of the watermelon seeds is connected to the small size of the embryo in relation to the seed coat.

The overall germination percentage of seeds exposed to cold conditions was higher when compared to those exposed to other temperatures. Chilling can overcome physiological dormancy, and has been long practiced in horticulture and forestry. The melon dormancy was broken in 24 hours; however exposing seeds for longer periods in low temperatures can also be beneficial in improving the germination percentage. There is no set temperature effective for chilling, with most suitable temperature falling in a range between 1.4 – 15 °C for most seeds. According to Bewley & Black (1994), germination reactions can be favored if chilling arrests the inhibitory reactions that retard the germination mechanism. Chilling can be an effective method to break seed dormancy and improve the germination of seeds for village nurseries, if there is access to cold storage.

The effect of seed scarification on germination

There is a possibility that the seed coat imposes dormancy by affecting gaseous exchange gains. The inhibitory action of the tissues surrounding the embryo can be reduced by scratching, puncturing or removing the seed coat. The elimination or of the cotyledons allows the embryonic axis of the dormant embryo to germinate and grow.

H_2SO_4 supports the growth of more seedlings and produces a better germination rate than the other treatments. The abrased seeds have low germination percentage suggesting that the seed coat must either be removed completely or pin-pricks can be applied near the seed radicle to fully induce dormancy. The waterproofing can be conferred by several parts of the testa with the main barrier for water uptake offered by the osteoclereids, only when these cells are punctured do most seeds begin to imbibe water. This is an easy and affordable method for village nurseries which can improve the germination percentages. The utilization of H_2SO_4 can only be recommend for established nurseries that are able to afford the chemical and are able to apply its basic safety procedures.

The effect of Essential Microorganisms on the germination of seeds

The ratio formulations ratios of EM 1:100 and EM 1:150 attributed to higher germination percentages and good germination rates. These ratios can be considered as above standard compared to the ratios which achieved lower germination rates. Soaking seeds in high concentrations of EM can arrest the germination of the seeds due to high alkalinity in the mixture, and lower ratios do not enhance sufficient germination percentages.

Watering the pots with tap water can have negative effects on the EM population, as many are destroyed by the Chlorine in the water. The inoculation of EM cultures to the soil-plant ecosystem can improve soil quality, soil health, and the growth, yield, and quality of the melons. EM can be recommended to village nurseries, once it is obtained, it can be kept for a long time. The innoculant consisting predominantly of lactic acid bacteria and yeasts populations can be cultivated over long period by allowing it to ferment in water in an anaerobic environment anywhere from several days to weeks or months, depending on the goals of application.

The effect of herbivore manure on seed germination

The seeds obtained from herbivore had lower germination percentages than anticipated. This can emanate from the fact that some of the seeds were damaged by the passage through the digestive tract of the herbivore. The seeds were not planted with the anima dung as it is usually the case in the natural environment. In many seeds, animals consume the seed pods and excrete viable seed in their droppings, helping to spread plant over short distances. If the seeds are not damaged by chewing, digestion actually helps germination, as the expelled seeds are deposited in moist, nutrient-rich dung. There was little literature available to support these studies. It is reported in Mayer & Poljakoff-Mayber (1989), that Cottontail rabbits commonly ate seeds of *Polygonum persicaria*, while some seeds germinated after excretion, other seeds were destroyed in the digestive tract and the passage of the Najas through the digestive tract of the mallard ducks resulted in the destruction of 70% of the seeds. Even though low germination percentages were achieved, it is important to encourage villagers to leave some fruits in the field for herbivore feed. The animals assist with the distribution of seeds, by excreting the seeds in new habitats different from those in which the fruit was eaten and other means.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

Conclusions

Ethnobotanical studies

A great deal of this research was conducted to assess and characterize the importance resource management for *C. lanatus*.

Many local communities in north-central Namibia are subsistence agro-pastoralists. The maintaining of livestock and the cultivation of crops such as Pearl Millet and maize play an important role within the social fabric of these communities. The sowing and the harvesting of *C. lanatus* are seen as a past-time activities for many communities, with occasional planting of the melon. The KNC and the EWC are currently the major suppliers of Kalahari melon seed-oil for export. The oil trades at about N$ 2.50/kg, which is currently less than the price obtained from other oils such as Marula and *Ximenia*. For communities to extensively plant the melons, communities need to be assured of the incentives involved. The planting of the melon should not be a threat to food security, since the melon is considered as an agronomic weed, suppressing the growth of crops such as Mahangu. However, sufficient research on the cultivation of the melon and its subsequent harvest will greatly reduce the pressures currently exerted on the wild populations.

It is important to develop with the assistance of community based organizations, educational outreach programs to create awareness on the harvesting and the proper methods for intercropping *C. lanatus.* The development of outreach programmes should not be in isolation, rather encompassing plant biodiversity especially indigenous fruits. There are existing structures in conservation programmes and national strategies used for the promotion, conservation and management of indigenous fruits. Organizations such as the IPTT and the NBRI can be further encouraged to promote the scientific understanding and research into the germination and subsequent domestication of *C. lanatus.*

It is only when communities are aware of the magnitude of the unsustainable harvesting of the melon, will they be able to adopt appropriate conservation measures, monitoring and harvesting strategies to enhance the conservation of *C. lanatus*.

<u>Germination studies</u>

The overall germination rating for most treatments was not satisfactory, with germinations below the 50 % arbitrary values need for a population to maintain itself. Seeds exposed to chilling at 4 °C and H_2SO_4 had significantly improved germination. The usage of H_2SO_4 cannot be recommended for village nurseries because of its corrosiveness. However if nurseries do obtain the acid, it should used in low concentrations.

The germination percentage of seeds isolated from fresh fruits was very low. This can be attributed to the onset of primary dormancy in the seeds while in the fruits. It can be suggested that harvested, mature fruits should be left intact to for at least 3 months to complete the dormancy. Seeds should be further exposed to desiccation for at least a month before been sown, to promote germination on subsequent imbibitions.

Allowing seeds to stand in water in pre-chilling treatments can have a negative effect on the germination percentage. High temperature regimes of 30 °C did not improve the germination. EM can be a successful germination method is seeds are watered with chlorine-free water such as rainwater. Scarification of the seed coat can essentially improve germination if the seed has been weakened by other methods such as applying sand-paper to the seed coat to obtain uniform germination.

Recommendations

Future extensive investigations should be carried out on the fruit and the seed yields of the melon. Treatments should be extended to a greater variety of germination stimulators and inhibitors such as Gibberellic and Abscisic Acids.

Seeds should be collected, cleaned and reserved for long-term storage. Seeds which have desiccated over long periods break dormancy faster, therefore increasing the likelihood of a higher germination percentage. It is therefore recommended that villagers' air dry the seeds for up to 3 months before they are sown.

EM can be an important treatment for the germination of seeds. Since most villages receive portable water, and have no irrigation structures, rainwater can used to increase the germination percentages of the seeds. Once the community obtains EM, they will be able to use it over long periods.

One of the most successful attempts for seedling germination is pre-chilling. If communities have access to cold storage (< 15 °C), it is recommended that they first apply this method before seed planting.

The lateral removal of the seed coat has been proven to increase the germination percentage of many seeds. It is recommended that villagers should attempt to split the seed to improve the germination of the seeds.

The achievement high germination percentage is only one of the countless strategies involved in the domestication of a plant. It is important to sustain wild varieties which are genetically superior when it comes to disease and pest resistance. It is important to maintain the ecological balance, as there are various factors that regulate the germination of the seed in its natural environment.

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APPENDICES

Appendix 1. The villages where interviews were conducted and the demographics of the respondents.

Assigned number	**Village**	**GPS reading**	**Gender**	**Main economic activity**
1	Okashana	S 17°47’452”, E 15°32’699”	Male	Employed at MAWF
2	Ondangwa jakamba	S 17°47’432”, E 15°30’760”	Female	Subsistence Farmer
3	Omuthiya	S 17°47’268”, E15°26’880”	Male	Subsistence Farmer
4	Omuthituwa gwalwani	S 17°50’451”, E 15°15’582”	Female	Subsistence Farmer
5	Okahao	S 17°53’986”, E 15°04’628”	Female	Subsistence Farmer
6	Oshikuku	S 17°39’171”, E15°23’765”	Female	Subsistence Farmer
7	Omunda	S 17°50’033”, E 15°58’345”	Female	Subsistence Farmer

8	Oshikango	S 17°33’830”, E 15°54’795”	Female	Subsistence Farmer
9	Oshipanda	S 17°38’008”, E 15°20’705’	Female	Subsistence Farmer
10	Ohangwena	S 17°46’226”, E 15°58’132”	Female	Subsistence Farmer
11	Okashali	S 17°49’907”, E 15°50’905”	Female	Subsistence Farmer
12	Othemayemanya	S 17°47’225”, E15°26’701”	Female	Subsistence Farmer

Appendix 2. The rating of crop production and small house gardens from the different villages.

	Responses from villagers													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total score**	**Ranking**
Maize	8	9	9	9	8	9	9	8	9	9	8	9	**104**	**2**
Sorgum	9	8	8	8	9	8	8	9	8	8	9	8	**100**	**3**
Millet	10	10	10	10	10	10	10	10	10	10	10	10	**120**	**1**
Pumpkin	4	4	4	2	5	5	5	1	4	3	4	5	**46**	**7**
Beans	7	7	6	5	7	4	4	7	6	7	7	6	**73**	**4**
Groundnuts	6	3	5	4	4	2	6	6	7	5	6	5	**59**	**5**
Melon	5	5	2	6	2	6	7	5	1	6	1	7	**53**	**6**
Tomatoes	1	2	3	3	1	3	1	2	2	2	3	3	**26**	**8**
Green Veg.	3	6	7	7	6	7	3	4	5	4	5	2	**59**	**5**
Other	2	1	1	1	3	1	2	3	3	1	2	1	**21**	**9**

Appendix 3. The rating of economically important livestock and their importance ownership

	Responses from villagers													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**	**Ranking**

													score	
Cattle	7	7	7	7	7	7	7	7	7	7	7	7	**84**	**1**
Sheep	5	5	5	6	6	5	5	6	6	6	5	5	**65**	**3**
Goats	6	6	6	5	5	6	6	5	5	5	6	6	**67**	**2**
Poultry	4	4	4	4	3	3	4	3	3	3	4	4	**43**	**4**
Donkeys	3	2	2	3	2	4	2	4	4	4	2	3	**35**	**5**
Horses	1	1	3	1	4	2	1	2	1	1	3	1	**21**	**7**
Pigs	2	3	1	2	3	1	3	1	2	2	1	2	**23**	**6**

Appendix 4. The rating of economically important wildlife

	Responses from villagers

	1	2	3	4	5	6	7	8	9	10	11	12	Total score	Ranking
Large mammals	5	5	2	2	3	4	6	3	3	6	7	7	**53**	**4**
Small mammals	6	4	5	4	7	3	5	7	2	5	1	5	**54**	**3**
Birds	3	3	4	1	3	2	2	1	1	1	3	1	**25**	**6**
Fishing	7	6	7	7	6	6	7	5	6	7	6	6	**76**	**1**
Reptiles	2	2	3	6	5	5	4	6	7	2	4	4	**50**	**5**
Insects	4	7	6	5	4	7	3	4	4	4	5	3	**56**	**2**
Other	1	1	1	3	1	1	1	2	5	3	2	2	**23**	**7**

Appendix 5. The utilization of economically important wild vegetation

	Responses from villagers

	1	2	3	4	5	6	7	8	9	10	11	12	Total score	Ranking
Construction poles	6	5	4	5	7	6	1	6	4	7	5	4	**60**	**3**
Craft making	1	2	3	2	1	2	3	2	2	3	3	2	**26**	**6**
Fuelwood	5	6	6	7	5	5	7	5	7	5	7	5	**70**	**2**
Thatching grass	3	4	5	4	3	3	4	3	1	1	1	1	**33**	**5**
Edible plants	7	7	7	6	6	7	5	7	5	6	6	7	**76**	**1**
Medicinal plants	4	3	2	3	4	4	6	4	6	4	4	6	**50**	**4**
Other	2	1	1	1	2	1	2	1	3	2	2	3	**21**	**7**

Appendix 6. Results from the questionnaire based on the utilization, harvesting and planting of Kalahari melon.

	Responses from villagers												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total score***
Actively plant	Y	Y	N	Y	N	Y	Y	Y	N	Y	N	Y	Y= 8 N= 4
Germination problems	N	N	-	N	-	Y	N	N	-	Y	-	N	Y=1 N=7
Excellent yield	N	N	-	Y	-	N	N	Y	-	N	-	N	Y=1 N=6
Household consumption	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y=12
Animal feed	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y=12
Processing of KMS	Y	Y	N	Y	Y	Y	Y	Y	N	Y	N	Y	Y=9 N=3
Trading of oils	Y	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	Y=9 N=3
Leave for animal grazing	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y=12

* Some villagers did not actively plant or harvest KMS, but apparently used it in the household harvesting from the wild populations in the field.

Appendix 7. Summary values of germination percentages and their standard error for *Citrullus lanatus*.

General treatments	**Location**	**Specific treatments**	**Results (GP ± SE)**
Fruits classes	UNAM Greenhouse	Small	12 ± 0.81
		Medium	16 ± 1.06
		Large	18 ± 1.12
	Ondangwa	Small	16 ± 1.04
		Medium	14 ± 0.94
		Large	18 ± 1.45
Dry seeds: varying temperatures	UNAM Greenhouse	Control	11 ± 1.17
		30 °C Constant	18 ± 1.13
		4 ° C Constant	70 ± 4.43
	Ondangwa	Control	14 ± 1.43
		4 °C Constant	74 ± 7.65
Imbibed seeds: varying temperatures	UNAM Greenhouse	Control	12 ± 1.30
		Water rtp	16 ± 0.96
		Warm water	18 ± 1.11
		30 °C Constant	24 ± 2.33
		4 ° C Constant	56 ± 3.32
	Ondangwa	Control	33 ± 1.46
		Water rtp	16 ± 1.44
		Warm water	18 ± 1.42
		4 °C Constant	56 ± 2.98
Scarification	UNAM Greenhouse	Control	13 ± 0.57
		H_2SO_4 (1 s)	42 ± 2.52
		H_2SO_4 (5 s)	48 ± 2.92
		Abrased	14 ± 0.93

	Ondangwa	Control	16 ± 0.80
		H_2SO_4 (1 s)	54 ± 3.30
		H_2SO_4 (5 s)	70 ± 4.12
		Abrased	18 ± 1.21
Essential Microbes	UNAM Greenhouse	Control	14 ± 1.62
		EM 1:0	10 ± 0.74
		EM 1:50	8 ± 0.98
		EM 1:100	28 ± 1.63
		EM 1:150	18 ± 1.10
	Ondangwa	Control	14 ± 1.46
		EM 1:0	12 ± 0.99
		EM 1:50	18 ± 1.20
		EM 1:100	30 ± 1.72
		EM 1:150	26 ± 1.54
Seeds from Herbivore manure	UNAM Greenhouse	Control	10 ± 1.04
		Herbivore manure	18 ± 1.83
	Ondangwa	Control	16 ± 1.43
		Herbivore manure	22 ± 7.65

Appendix Table 4.1 The mean rate of germination seeds of different fruit size classes of *C. lanatus* at the University of Namibia

Treatment	**Germination Percentage**	**Mean rate of germination**		
		Time (*t*)	**rate (R)**	**Coefficient (CRG)**
Small	12	2.52	0.40	39.68
Medium	16	3.36	0.30	29.76
Large	18	3.78	0.26	26.46

Table 4.1 The mean germination rate of dry seeds C. *lanatus* at Ondangwa

Treatment	**Germination Percentage**	**Mean rate of germination**		
		Time (*t*)	**rate (R)**	**Coefficient (CRG)**
Control	11	2.31	0.43	43.29
Cold (4 °C)	70	14.70	0.07	6.80