

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

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

OF

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THE HUMBOLDT-UNIVERSITÄT ZU BERLIN

BY

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DECLARATION

I, Uazamo Kaura, hereby declare 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 at any other institution of higher education.

.....
Uazamo Kaura
February 2009

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I am grateful to my family, friends and colleagues for always being there to render their moral support and their insightful comments and suggestions.

May the Almighty God abundantly bestow His favour on all of you.

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

Citrullus lanatus (Thumb.) Matsumura & Nakai seeds are valued for their oil for both household consumption and in the cosmetic and pharmaceutical industry. The immense monetary value offered for its seeds has resulted in over-exploitation of *C. lanatus*. This study investigated the ethnobotany, seed production, germination and viability of *C. lanatus* under controlled greenhouse and natural field conditions. An ethnobotanical study was carried out where resource users and key informants were interviewed on the plant resource utilization. Seed collection and germination trials of *C. lanatus* seeds took place at the University of Namibia main campus and the King Nehale Conservancy (KNC). Harvested fruits were collected, weighted and measured. Tetrafolium was used to test seed viability. Seed production was estimated by quantifying the number of seeds in randomly selected fruits from the wild. Seeds were then exposed to various treatments methods including scarification, treatment with essential microbes (EM) and water imbibition, and some kept as controls. Germination rates were expressed as the percentage of seeds germinated within 21 days after sowing the seeds. The data were subjected to statistical treatment using ANOVA, Kruskal-Wallis and T-tests.

Ethnographic studies revealed that villagers are keen to intercrop *C. lanatus* with local traditional crops to increase the seed yield required for commercial trade. Lack of awareness with regard to the decrease of melon seeds or fruits being harvested is a major threat to the survival of this species in the wild. There was no significant difference in the germination rate ($p < 0.05$) among seeds obtained from fruits of different sizes. Smaller fruits do not necessarily contain immature seeds. In addition, seed weight did not influence the germination success of the seeds. Pre-chilling of seeds and the exposure of the seeds to H_2SO_4 and Essential Microorganisms improved the germination success of the seeds. Mechanical scarification did not improve the germination of the seeds of *C. lanatus*. Seeds obtained from herbivore manure attained less than 50% germination.

It is recommended that long-term monitoring is needed to assess the harvesting regimes and the recruitment of *C. lanatus* in the wild. Future investigations should be carried out on the seed yields and the oil yield of the melon. To gain better scientific knowledge, treatments should be extended to a greater variety of germination stimulators and inhibitors such as Gibberellic and Abscisic Acid.

Key Words: *Citrullus*, ethnobotany, Kalahari melon, seed germination, seed viability

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CHAPTER 1

INTRODUCTION

Indigenous fruits play an important role in the socio-economical fabric of Namibia's rural life. Rural communities in Namibia harvest and make use of a diversified range of wild plants such as wild vegetables, berries, nuts and fruits. These indigenous plants are used traditionally for an array of purposes; food, medicine, decoration, clothes, amongst other uses. Wild foods often make up a significant portion of the diet in rural communities as daily supplement to protein and vitamin sources. In the past few years, efforts to use some of this resource have led to a number of projects supporting the commercial exploitation of indigenous plants (du Plessis *et al.*, 2005).

Citrullus lanatus (Thunb.) Matsumura and Nakai is a wild and often cultivated species, originating in southern Africa. Maheshwari (1978) describes the existence of a secondary diversification centre of *C. lanatus* in India. This species is a potentially important intercropping species in Namibia due to its high economic value for household utilization and pharmaceutical use.

Namibia is the leading supplier in the Southern Africa Development Community (SADC) of community-traded Kalahari melon seed-oil, with the trade-mark 'Kalahari Melon Seed Oil' being recognized and used. At present the organization which works directly with the Eudafano Women's Cooperative (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 seeds to be supplied to a leading British cosmetic giant, The Body Shop. Preliminary studies by CRIAA SA-DC in 2004 and 2006 showed that the wild populations of *C. lanatus* have reduced considerably over the period 2004 – 2006 in which the study attributed to over-harvesting and the fact that local communities do not extensively sow *C. lanatus* to replace the wild populations.

Efforts by farmers to compensate by actively sowing more seeds have been hindered by germination problems. Consequently there was a need to study the germination potential and the traditional harvesting systems of the Kalahari melon.

To meet the demand of the growing international market for Kalahari melon seed, more attempts to domesticate and cultivate the wild-harvested plants are required. This requires an understanding of the productivity, germination and seed viability of the melon. This knowledge could be passed on to farmers who would then apply these methods in their traditional cropping systems. If melons are to be included within the traditional methods of crop diversification, this will decrease the demand currently exerted within the wild population. It was also anticipated that a multidisciplinary study on the Kalahari melon will fill the research gap of currently experienced on this species in Namibia.

Aim and objectives

The overall aim of this study was three-fold, that is to:

- xiv. investigate the traditional management and harvest systems of *C. lanatus*;
- xv. determine seed production, viability and germination potential of *C. lanatus*;
and
- xvi. determine the potential of *C. lanatus* for cultivation in traditional cropping systems.

The specific objectives of the research are to:

1. Investigate if the traditional management and harvesting structures of *C. lanatus* in the King Nehale Conservancy and the north-central regions of Namibia are sufficient to control the over-exploitation of the species by conducting an ethnobotanical study.
2. Relate seed viability and germination of *C. lanatus* to fruit size and weight.

3. Study the germination potential of *C. lanatus* treated with various seed treatment methods. To test for the effectiveness of these treatments in the germination of *C. lanatus*.
4. To devise a germination protocol for *C. lanatus* to be used by the local communities.

Research Hypothesis

1. there is an inadequate traditional management and harvesting system in place to control the over-exploitation of *C. lanatus* over the long-term period.
2. seed viability and germination is directly related to the fruit size and weight.
3. seed treatment methods greatly enhance the germination potential of *C. lanatus*.

Description of the study area

The King Nehale Conservancy

This study was carried out in the north-central Regions of Namibia within the Regions of Oshana, Ohangwena, Omusati and Oshikoto, the major supply areas of the Kalahari melon. This study was centered at the King Nehale Conservancy (KNC), a major supplier of Kalahari melon seeds to The Body Shop, a pharmaceutical giant based in the United Kingdom.

The various investigations and seed collections were carried out in the King Nehale Conservancy for the reason that it supplies almost 80% of the *C. lanatus* seeds exported to The Body Shop in the year 2004 in close cooperation with the EWC (du Plessis, 2002). The King Nehale Conservancy is thus a major supplier of *C. lanatus* seeds and the area experiencing the major of germination problems.

The King Nehale Conservancy is situated 17° 20' 25" S, 18° 30' 50" E in the Oshikoto Region, north-central part of Namibia (Fig. 1.1). This is a newly established conservancy and was officially registered in September 2005. The conservancy covers a total land area of 508 km² with 20 000 people residing within its boundaries (Johannes *per. comm.*, 2006).

The conservancy was established to meet objectives based on the goals of Community-Based Natural Resource Management (CBNRM), to manage natural resources, to gain financial and other benefits. The mission of the conservancy is to sustainably manage and utilize wildlife and other natural resources to improve the livelihoods of its members (Johannes *per. comm.*, 2006). The vision of the conservancy is to be self-sustainable with the conservancy people, livestock and wild animals existing together (Johannes *per. comm.*, 2006).

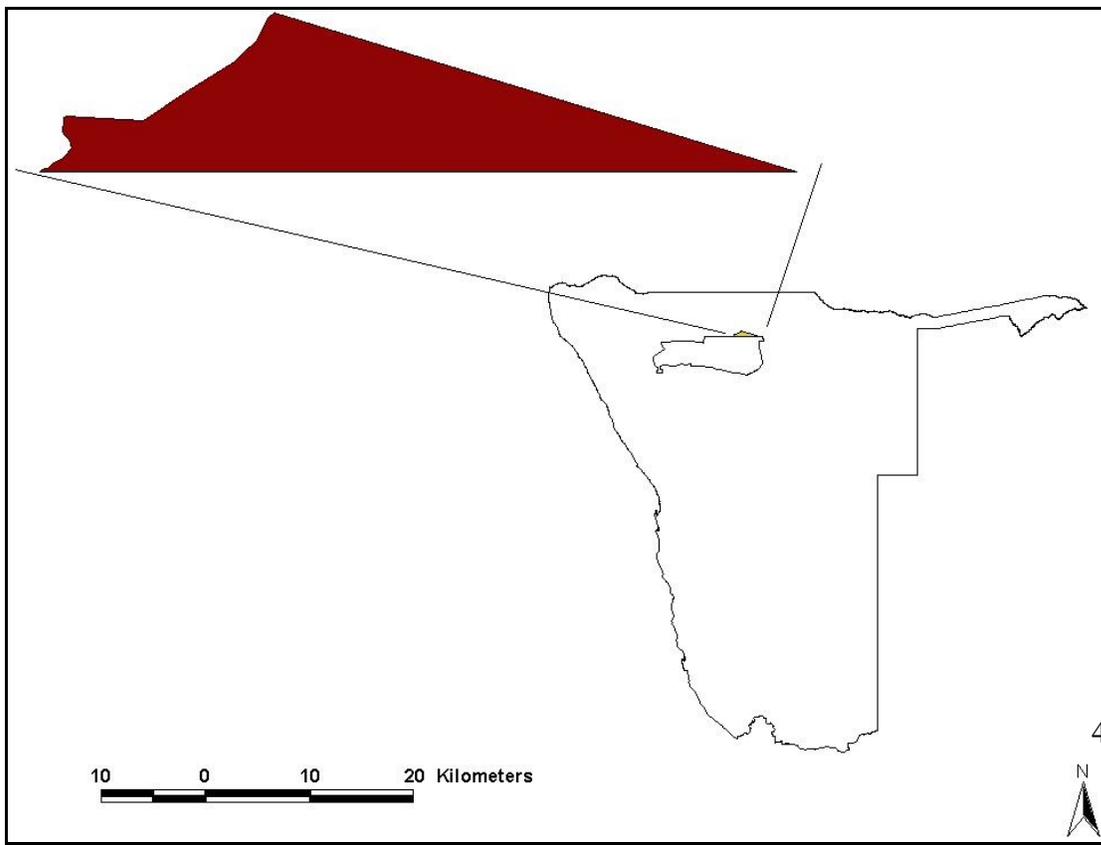


Figure 1.1 The map of the King Nehale Conservancy bordering the Etosha National Park. (Kaura, U (drawn from GIS ARC-VIEW)

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 is undulated with 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 is calculated between 450 to 500 mm (Mendelsohn *et. al.*, 2002). The annual rainfall in this area 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 the north-west of Namibia (de Klerk, 2004).

The conservancy borders the Etosha National Park and receives an influx of game through the game fence especially kudu, springbok, wildebeest, oryx, hartebeest and zebra from the Park. These species are of important economic value as the conservancy tries to launch 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 and other wetland resources in the Cuvelai Basin.

CHAPTER 2

LITERATURE REVIEW

Species description

The genus *Citrullus*

The genus *Citrullus* belongs to the class Magnoliopsida and the family Cucurbitaceae under the order Cucurbitales (Maggs-Kölling & Christiansen, 2003). Many members of the Cucurbitaceae are indigenous to Africa (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 African region, 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 centre of origin of *C. lanatus* is the Kalahari Desert, a geographical area that currently represents an unexploited reservoir of genetic variation for the cultivated watermelon. There is a long history of cultivation of watermelons in Africa and the Middle East and it has been grown in the Nile Valley since the second millennium BC. By the 10th century AD, the crop was grown in China and southern Russia (Maggs-Kölling *et al.*, 2000). The watermelon was introduced to the New World by the Spaniards in the 16th century and rapidly became popular with Native Americans (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) 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. *caffa* a sweet cultivated watermelon and var. *citroides*, whose common names are, 'citron melon' and 'preserving melon' respectively.

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

- *C. lanatus* (Thunberg) Matsumura & 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 the Negev and Sinai, and *C. ecirrosus*, which is endemic to the Namibian desert.

The taxonomic status of *Citrullus lanatus*

According to Maheshwari (1978), the cultivated species plant includes three subspecies: (i) *C. lanatus*, (ii) *C. vulgaris* which has two varieties, var. *vulgaris* and var. *cordophanus*, and (iii) *C. mucospermus*. Both morphological 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 referred to 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 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).

Many members of the Cucurbitaceae produce long lived fleshy fruits (Small & Botha 1986). Although such fruits contain a large quantity of water, germination of mature seeds whilst within the fruit 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).

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). The species 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. 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).

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) (Figure 2.1). 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* tolerates drought better than most melons.

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).

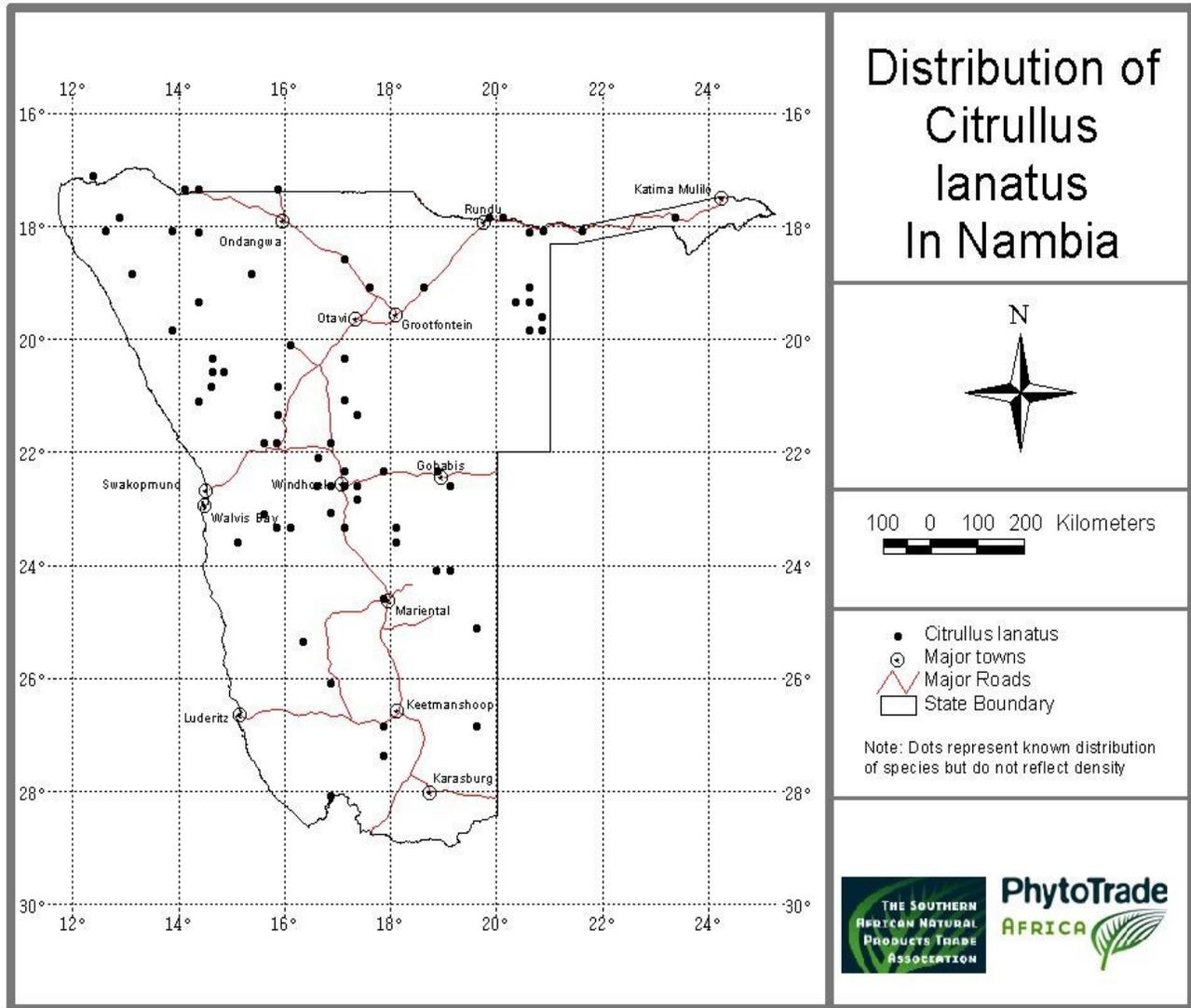


Figure 2.1 The distribution of *C. lanatus* in Namibia. (PhytoTrade Africa, 2006)

Cultivation

Diversity in cultivated species within the family Cucurbitaceae is reflected by a diversity of regional and local cultivation practices (Maggs, 2000). For thousands of years, farmers have been adapting crops to diverse habitats by experimenting with and developing new varieties.

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 (Maggs, 2000).

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 (Maggs, 2000). It is also understood that these same subsistence farmers usually practice intraspecific polyculture in addition to interspecific multiple cropping. In 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 phenotypic 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 the case in many areas in northern Namibia.

In traditional cropping systems, land preparation is done manually and prepared seedlings are rarely used for planting. However, 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). *Citrullus 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).

When inter-cropped, melon plants should have a space of about 20 – 30 m between them. Otherwise 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. (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 (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 of other diseases such as powdery mildew increases the spread of gummy blight, in this crop due to the weakness of the plant and the presence of wounds as a consequence of 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). In many cases larvae of this pest 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).

Utilization of the melon

Melon seeds are increasingly utilised as an oil crop in semi-arid regions. The use of melon seeds 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 oil content (Adegoke & Ndife, 1993).

In Namibia, the Kalahari Melon is a key source of food responsible for maintaining life in the desert, for both man and animals, during the long drought years. Animals eat it and utilize it as a source of water; people can either use it raw or cooked.

The utilization of *C. lanatus* is interlinked with the way of life for the rural communities in Namibia. The melon seeds are crushed using a wooden pestle and 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.

Potential of Citrullus lanatus

Since the inception of the Indigenous Plant Task Team (IPTT), a group which consists of various stakeholders from various governmental and non-governmental organizations, *C. lanatus* has been placed in the top priority list of plant species of the commercialization of the IPTT program (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 processing care to produce quality crude oil within the specifications of international buyers. Most of the extracted oil is traded to The Body Shop. 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.

The Body Shop 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; www.criaasadc.org). 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 managed 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 harvesting 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).

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

This chapter presents the methodology and approaches that were employed in the collection and analysis of the data. It also highlights some of the constraints encountered in the field as well as limitations of the study as a whole. Standard germination procedures were applied to most of the treatments, specific methods peculiar to individual investigations were discussed in those specific chapters.

Citrullus lanatus seeds were obtained from the King Nehale Conservancy (KNC) in northern Namibia through the help of different villagers around the Conservancy. Melon seeds collected included those obtained from herbivore manure. An ethnobotanical survey was carried out in various villages in northern Namibia (Appendix 1, p91).

Material Collection

The major part of this study included an ethnobotanical study, seed collection and germination trials of *C. lanatus* seeds from areas in north-central Namibia, in particular the King Nehale Conservancy (KNC) in the Oshikoto Region (Fig 3.1).

The choice of the King Nehale Conservancy for the study was on reasons mentioned earlier stated in the presentation of the problem statement. Firstly, the KNC is the main supplier of *C. lanatus* seed-oil to The Body Shop, thus an important partner in the maintaining and protecting *C. lanatus* and plant biodiversity. Secondly, the KNC is also an area that has been undergoing a lot of socio-economic changes after the area was proclaimed as Conservancy therefore people are involved in a search for diverse sources of market-related livelihoods including tourism and forestry related activities which might negatively affect the plant biodiversity in the area including wild plants such as *Vangueria infausta*, *Strychnos cocculoides* and *Strychnos rautanenii*. Lastly, this area is mostly in a rural setting within a subsistence agricultural area and was expected to provide a rural dimension in the data collected.

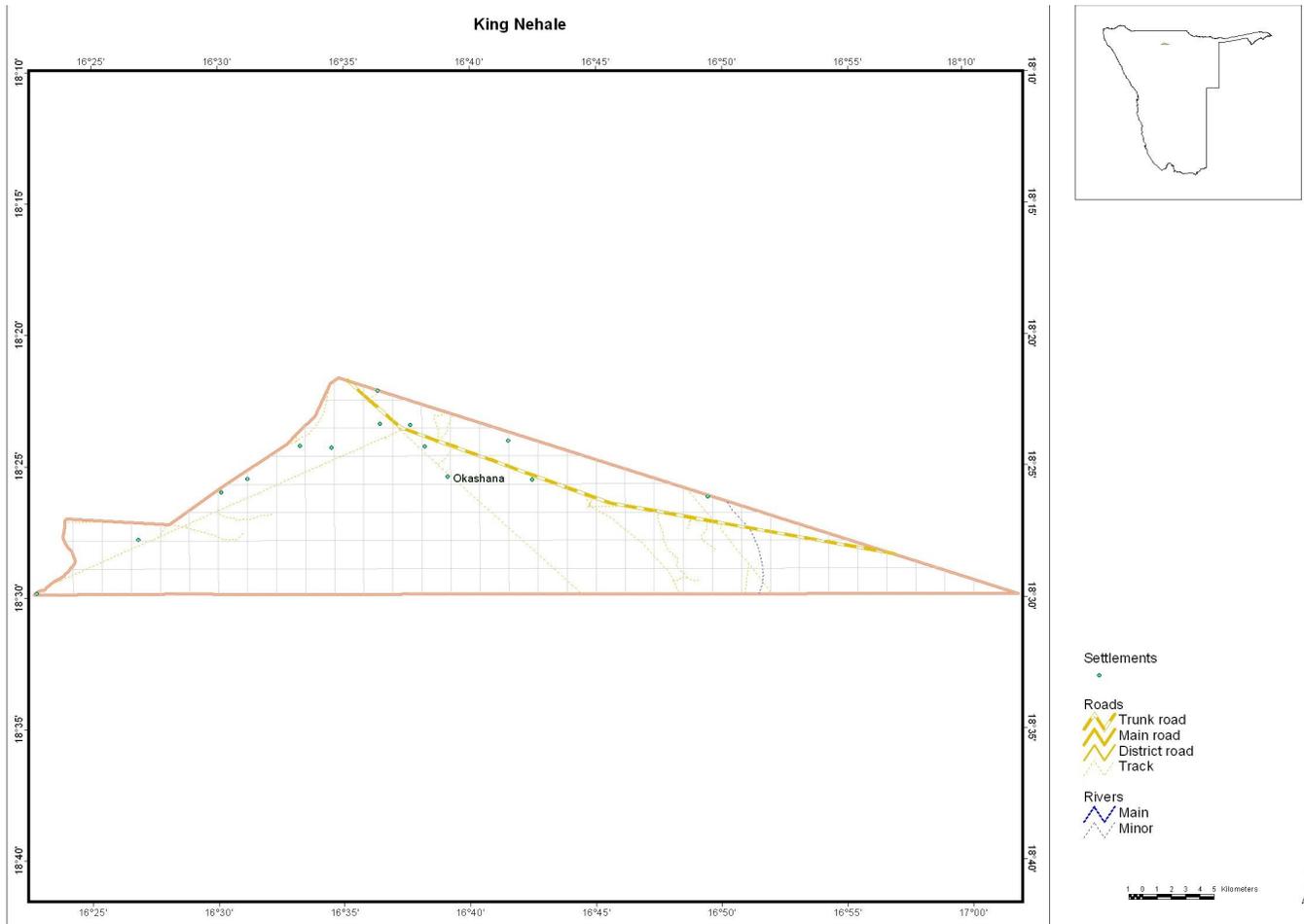


Figure 3.1 The map of the King Nehale Conservancy showing the settlements in the conservancy (drawn from GIS ARC-VIEW)

Ethnobotanical studies

The researcher recorded some of the ethnobotanical information associated with *C. lanatus*. The full methodological approach of the data collection and interview sessions are fully explained in the Ethnobotany section.

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 has the advantage of being flexible and allows a wider range of freedom for the respondent to embellish as he or she wishes (Maggs, 2000). A checklist of the questions was compiled prior to the mission (Appendix 1, p91). While in the field an initial analyses of the data was made to assess if the measurement criteria developed while doing the desk study was appropriate for field research. The questionnaire included the management and the harvesting system of *C. lanatus* and possibilities of co-cultivation with traditional crops. The survey also recorded harvesting methods used by the fruit collectors. Villagers were requested to rank livelihood activities; namely crop production, livestock production and the utilization of natural resources based on self-assessed significance. The villagers were also asked to rank the utilization of Kalahari melon seed.

Additional interview questions centered on the villagers' livelihood activities and participation in managing wildlife resources as well as their views on plant conservation. Their economic profile was also reviewed through questions about their employment status and other occupational or income generating activities (IGAs). This information from the communities was augmented and cross-checked with that obtained from key informants, mainly from government institutions in charge of plant resource protection. The ethnobotany study was done during the harvesting period of the melons in May 2006.

Measurement of seeds per fruits and measurements of fruits weight

One-hundred and fifty (150) harvested fruits were collected, weighted and the circumference measured. The collection of the fruits was representative of the fruit size classes i.e. 50 fruits per class of small, medium and large according the determined weight given in Chapter 4. A battery operated scale was used for the convenient weighting and recording of the fruit weights. Each fruit was then cut open to count the 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. This determined if a certain number of fruits are harvested, the community will be able to get sufficient income to maintain the business, while maintaining adequate fruits numbers in the wild to recruit for the next season.

Seed viability tests

The test for viability was done on seeds from all classes. 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).

Limitations of research

Germination experiments were carried out in a plot 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.

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 keeping of seeds at a constant temperature in an oven. Methods indicated were carried out at Ondangwa and in the laboratory at UNAM unless otherwise indicated.

Standard germination procedures

In all experiments, unless otherwise indicated standard germination procedures were followed. The imminent chapters will separately deal with the specific seed germination treatments.

Growth medium

Seeds were planted directly in plastic pots (60 cm x 40 cm) filled with sterilized soil that was bought from Ferreira Gardens in Windhoek. This soil was deemed suitable as Cucurbitaceae are adapted to a wide variety of soil types which have good drainage and adequate soil-holding capacity (Maggs-Kölling *et al.*, 2000). The soil was aerated and preferred as the sterilization process it undergoes at the factory frees it of micro-organisms which negatively affects germinating seedlings.

Sampling design

After each of four specific germination enhancement treatment and tests; a total of four planting trays were each sown with fifty (50) seeds in ten (10) rows and five (5) columns i.e. 50 seeds per tray (50 seeds x 4 replicate trays). Four trays with seeds treated with

specific germination enhancers were compared with 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 replicates), hence 200 seeds for the germination treatment. The germination tests for the seeds were carried out separately depending on the fruit size, i.e. small, medium and large.

Seed germination

All seeds were sterilised by placing them in 10% fungicide mixture for 5 minutes in order to kill fungi before being germinated.

At UNAM, greenhouse temperatures averaged 23°C to 43°C (8 a.m. to 5 p.m.) for the season when the experiments were performed. These 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 temperature 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 at Windhoek and Ondangwa respectively.

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.

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

Data analyses

Ethnobotanical studies

Descriptive statistics such as histograms and direct matrix ranking were used to portray trends in the ethnobotanical data collected. A direct matrix ranking was used as part of

the preference ranking to order various activities on 'value' or 'desirability' by considering various attributes based on melon utilization.

Germination percentage

Germination rate was expressed in percentage. Observation was daily for 21 days to observe the emergence of new radicles and the total number radicles for each planting tray. The germination was calculated as the rate at which new radicles were produced per day over the period of 21 days. These aspects can predict the degree of success of a species based on the capacity of their seed to spread the germination through time.

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 which was after 21 days.

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:

$$\Sigma n/\Sigma(t*n); \text{ and}$$

The coefficient of the rate of germination (CRG) equals to:

$$R*100$$

Data manipulation

Data collected was primarily computed statistically by using Statistics Package for Social Students (SPSS). For statistical analysis, germination percentage values were transformed to the arcsine of the square root to normalize distributions.

A One-way or single factor ANOVA with five germination treatment levels was used. An Independent means t-test was used to compare the rate of germination of the seeds of the test against the control. A Kolmogorov-Smirnov test was used to test whether the distribution of the data treated was significantly different from a normal distribution with a significance level of $p \leq 0.05$. For data not normally distributed i.e. more than 5% (>5), a Kruskal-Wallis test, a non-parametric test, was used. Two-way factorial Analysis of Variance (ANOVA) was used to test whether group means i.e. seeds from small sized fruits differed for normal data at a 5% probability level; this included comparing germination rates of seeds from different fruit sizes. A Bonferroni correction test was

used as a Post-Hoc test at tests significantly different to each other at a confidence level of 95%.

Germination was rated as illustrated in Table 3.1 as adapted from Shikongo (2003) which was advocated by the International Board for Plant Genetic Resources (1985).

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
15 – 21 days	Sporadic	0 %	Very poor

CHAPTER 4

ETHNOBOTANY OF *C. LANATUS* IN THE KING NEHALE CONSERVANCY

Introduction

The use of indigenous plants, by rural communities plays an important role as a source of livelihoods (Maggs, 2000). *Citrullus lanatus* seeds play an economically vital role in the cosmetic and pharmaceutical industry. The increasing international demand for Kalahari melon seed-oil may possibly expose *C. lanatus* to over-harvesting which eventually may lead to low number of fruits in the wild, and consequently reduced recruitment in the wild. Currently, enormous harvesting pressure is put on the wild populations in north-central Namibia. In the absence of proper sustainable harvesting mechanisms in place, this plant species may face possible local extinction. There are no previous studies with regard to harvesting of *C. lanatus* within the King Nehale Conservancy (KNC), in the north-central Namibia.

According to van Wyk & Gericke (2000), wild fruits 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 enormously as an important source of income for rural households. These important trade fruits include the sourplum (*Ximenia caffra*), corky monkey apple (*Strychnos spp.*) amongst many other fruits.

There was no reliable data and literature available on regarding the cultivation and other local cropping practices of *C. lanatus* in the North-Central areas of Namibia thus a study in this regard had to be carried out.

The main objective of this study was to investigate the traditional management and harvesting structures of *C. lanatus* in the King Nehale Conservancy and the north-central regions of Namibia, with special emphases on the control measures to reduce the over-exploitation of the species by conducting an ethnobotanical study.

Material and Methods

An in-depth understanding of the processes related to planting and post-harvesting procedures of *C. lanatus*, was investigated. Qualitative methods were used; involving using individual interviews, focused group discussions and observations to investigate the traditional management and harvest systems of *C. lanatus*.

Qualitative approaches were preferred in this study because of their focus and attention on people's experiences and the meanings they attach to their social surrounding as opposed to quantitative approaches, which tend to reduce studies to numbers and statistical models. It was assumed that a combination of different qualitative data collecting techniques would help bring out the experiences of the people.

The study adopted the ethnographic approach outlined below as the specific approach for data collection.

Ethnographic Approach

This approach seeks to understand the world as it is “seen through the eyes” of the participants (Kitchin & Tate, 2000).

The Selection of Respondents

The principal target group for this research was the local rural communities who depended on *C. lanatus* for cash income in the KNC and the surrounding areas within a 60 kilometers radius around Okashana (Fig 3.1). These communities were targeted to shed light on the factors that inform their decision-making process in the use of *C. lanatus*. The respondents were picked randomly based on their availability and willingness to be interviewed.

Data Collecting Techniques

The techniques used in collecting primary data in the field included interviewing and observation. These were important tools in capturing people's views, opinions and

experiences. Two types of interviews were used; individual interviews and focused group discussions both of them utilising unstructured interview guides as instruments. The use of these multiple techniques was intended to improve validity of findings as it ensured that information obtained through the other technique or category of respondents could be cross-checked and verified.

Interviews

All interview guides employed open-ended questions and topics allowing the respondents the flexibility to express their adequately.

Individual Interviews

Thirty community respondents were interviewed from several villages in the KNC. This number of respondents among principal respondents was adequate as qualitative research does not aim at coverage but depth and so the interviews were intensive. The interviews were conducted at the homes of respondents.

Key Informant Interviews

These were individual interviews from ten officials of Ministry of Agriculture, Water and Forestry (MAWF), the Rössing Foundation, Eudafano Women's Cooperative (EWC) and the Center for Research-Information-Action for development in Africa - Southern Africa Development and Consulting (CRIAA SA-DC), who spoke in their official capacity and provided specific 'expert' information.

The information supplied by these officials was cross-checked with that obtained from the KNC communities to establish similarities and differences in perspectives.

Focused Group Discussions

Focus group research is based on facilitating an organized discussion with a group of individuals selected because they are representative of some class, such as same resource

users (Kitchin & Tate 2000). The discussion is used to bring out insights and understandings in ways which simple questionnaire items may not be able to tap.

A focused group discussion was held based on interview guide topics with the villagers in at the Okashana settlement. The aim of this discussion was to get the views of the communities on the status of forest products, livelihoods and the changes that has undergone over time, what they consider to be the root causes of the changes and their suggested solutions. The session also intended to find out the group views on conservation in general and its impact on their livelihoods.

Data Analyses

The data were analysed mainly through an interpretative approach relying on pie charts, same response patterns, matrix ranking, and main themes as basic descriptive units.

Results

Cultivation of economically important indigenous plants

Women were 83% (n=30) of the respondents, and were the majority of the crop cultivators in the area. There is high reliance of households on arable production. 100% of all villagers interviewed indicated that they dependent on arable production, which comprised of about 80% of household income. All villagers interviewed were busy in their fields near their homesteads harvesting Pearl millet, beans, sorghum and in some households, melon fruits. 80% of the respondents owned the crop fields.

The harvest of wildfruits including Marula fruit and *Ximenia spp* occurred mainly around the town of Oshikuku, while the areas around the King Nehale Conservancy experienced limited fruit trees. *C. lanatus* were harvested either for household consumption or trade. Harvesters did not discriminate between the melon sizes and the collection of the melons was not controlled at the community level. *Citrullus* melon cultivars were recognized as wild bitter melons, sweet melons and cooking-melons. With the fruit surface coloring, the inner flesh colour and the seed colour as important features to distinguish between the types of melons. Whole fruits were collected in large baskets in the cultivated fields or in the wild.

The ripe fruits are harvested, cut open for seed collection and then the harvested seeds are spread under the sun for the seeds to acquire appropriate moisture levels. The seeds are dried on corrugated iron for two weeks so that they can be fried and eaten and for other uses. The seeds are preserved for long periods by spreading them with ash to prevent insect infestation.

Of the 30 respondents, two-thirds indicated that they sowed *C. lanatus*, with some households indicating that they experienced problems with seedling growth. The seeds were planted in December to January, when rain had fallen, intercropping with Pearl millet and Sorghum. According to the respondents, the melons grew best with Pearl millet as they grew better on well-drained soils, rather than the water-logged Sorghum fields.

As illustrated in Figure 4.1, 18% of households rated millet as an important crop production 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 8th.

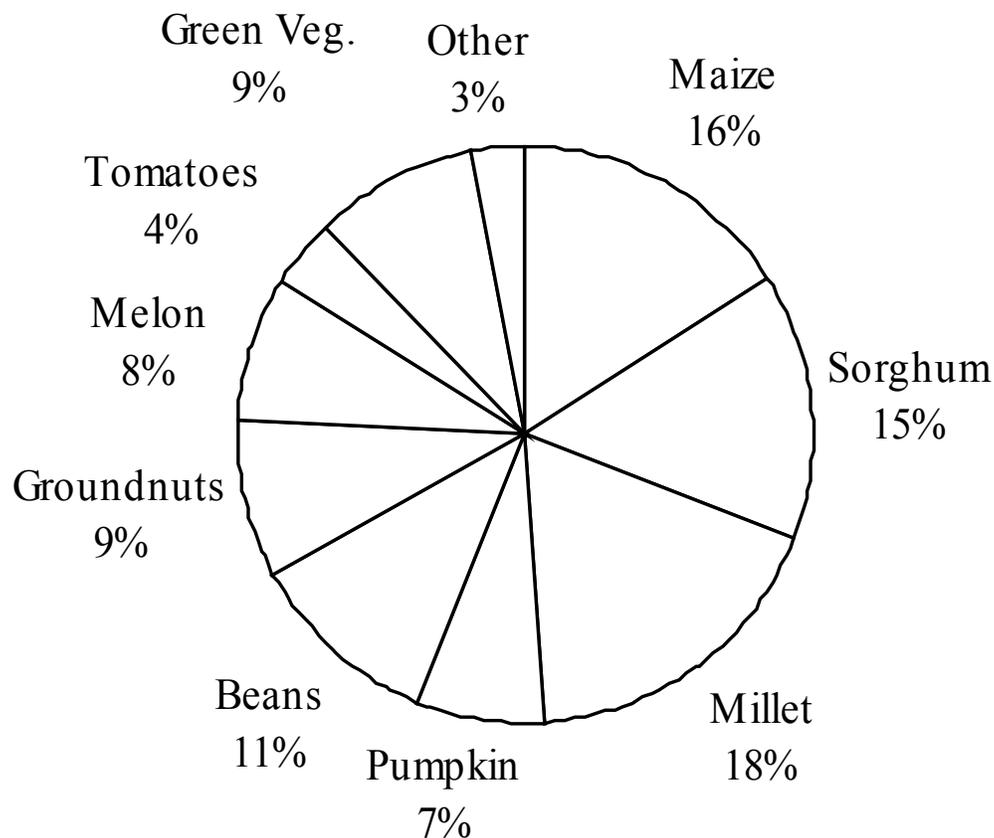


Figure 4.1 The combined rating in the cultivation of important crops compared to melon cultivation by community members. Melon is only cultivated by 8 % of the respondents, compared major crops such as Maize (16%) and Sorghum (15%).

Harvesting of wild C. lanatus

All respondents indicated that they left some fruits in the field for herbivores to feed and browse on. However, many felt that the fruits left in the field are gathered by the other villagers who had no consideration of leaving some fruits in the field. All households interviewed indicated that they consumed *C. lanatus* within their households. The fruit

flesh was cooked with traditional Pearl millet porridge and the seeds were fried on a pan over an open-flame to extract-oil. Of the 30 individuals interviewed from the different areas, 23 indicated that they sold excess *C. lanatus* seed-oil to the KNC which is utilized as body-oil.

The melon cultivation was not intensive, and the seeds were just spread in the soil to germinate. The melons were cultivated mainly for household utilization. Villagers indicated that the fruits and the leaves of *C. lanatus* attracted insect pests, rats, mongoose and livestock such as cows and donkeys.

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 as goats, pigs and poultry.

The KNC 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. The pressed-oil price is low as compared to similar oils.

There are currently efforts by the KNC to establish management committees to control the harvesting of the melon to be on par with other wild foods such as *Ximenia* and Marula. 67% (n=30) of the respondents were unaware of the existence and the roles played by various institutions such as the Indigenous Plant Task Team (IPTT) and the National Botanical Research Institute (NBRI) based at the Ministry of Agriculture, Water and Forestry (MAWF). These institutions are mainly involved in conducting research, protecting and promoting the sustainable utilization of indigenous plants. 25 of the 30 respondents interviewed 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.

Compared to the previous seasons, 2000 - 2005, with 83% of the respondents claimed that there was no notable decline in the availability of *C. lanatus*, with no overexploitation of this resource with only the lower yield of the fruits seen as a setback. However, on investing these issues further with key informants from MAWF and CRIAA SA-DC, it was found that with quick ground assessments that they have carried out over the past year (2005), melon fruits in wild have reduced considerably, so has the supply to clients. This decrease has also been observed by the EWC in 2006 as they have received low number of melon seeds during the year 2005 – 2006, thus reducing the volume of oil export to The Body Shop in the United Kingdom. The decrease in the wild fruits was attributed to over-harvesting, lack of control mechanisms and the lack of information available on the germination of the melon.

Discussion

Ethnobotanical data revealed that the respondents were 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. 100 % of the community depended greatly on the utilization of natural resources for wild food for household consumption and for commercial purpose.

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. This confirms the concerns that there is a decrease in the recruitment potential of *C. lanatus* in the field. This could be attributable to a lack of proper harvesting systems and the community management of the resource. Community resource management should be in such a way as to maximize the benefits from a natural resource whilst enhancing its status, there should be essentially a dynamic equilibrium between the renewal and utilization of the resource.

One major problem that besets the melon seeds is storage mechanisms used by the villagers as seeds deteriorate quickly due to fungal infection. The effect of the fungal attack on melon seeds include decreased nutritive value, change in colour, increase in peroxide value, reduced seed germination and mycotoxin production (Bankole, 2005). Thus storage conditions can compound the germination problems in melon seeds. In the north-central areas of Namibia, respondents indicated that most sown seeds were obtained from those of the previous season. The extended drying and storage periods often results in the in foreign matter contaminating the seeds, with a significant loss due to rodents and beetles. It is thus important to pay attention to seed drying and to storage design to enhance the germination of melon seeds. Seeds must be stored in a way which maintains their viability for long periods. Seeds left at ambient temperatures and relative humidities will lose their viability quickly whilst seeds stored in conditions of low moisture content and temperature will retain their viability for longer periods (IBPGR, 1985).

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, and thus extensive cultivation was not seen as a priority. The melons were therefore not extensively cultivated to reduce the pressure put on the wild populations of the melon (Fig. 4.1).

As indicated in the results, there were very few observed melon fruits growing in the wild, however, some 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. The KNC and the EWC are currently the major suppliers of Kalahari melon seed-oil for export. The seeds trade at about N\$ 2.50/kg, which is currently less than the price obtained from other oils such as Marula and *Ximania*. For communities to extensively plant the melons, they 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 Pearl millet. However, sufficient research on the cultivation of the melon and its subsequent harvest will greatly reduce the pressures currently exerted on the wild populations.

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.

CHAPTER 5

FRUIT SIZE AND SEED VIABILITY

Introduction

It's important to determine the viability of seeds, which may reveal a high percentage of seeds unable to germinate (Shikongo, 2003). The method of storing and packaging of *C. lanatus* seeds, and rough handling before sowing will potentially lower melon seed viability (Demir & Mavi, 2004). According to Demir and Mavi (2004), both seed viability and seed vigor are directly related, as both decline with time. Generally, vigor begins to decline before the observations in the decline of viability as environmental conditions become more stressful (Demir & Mavi, 2004).

There are various definitions of the term 'viability'. This study adopts the one by Copeland & McDonald (1995: p 3), who defined viability as: 'the degree to which a seed is alive, metabolically active and possess enzymes capable of catalyzing metabolic reactions needed for germination and seedling growth'. Environmental factors and storage conditions have an effect on the life span of any given seed, 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 in addition to factors determined by seed dormancy (Copeland & McDonald, 1995). The loss of viability is not a sudden failure to germinate by seeds in a certain population, rather the percentage of seeds which will germinate in any given population will decrease with time. 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 formazan, the reaction is catalyzed by NADPH dehydrogenases (Hendry & Grime, 1993).

According to the International Board for Plant Genetic Resources (1985), the most accurate test of viability is the germination test. The germination test is made under controlled conditions to find out how many seeds will germinate and produce normal seedlings, which could develop into normal reproductively mature plants.

The global increase in productivity within the cucurbit crop species over the past decade has been primarily due to cultivation practices and development of disease-resistant , rather than to direct selection for increased yield *per se* (Maggs, 1998). It is therefore important in the selection of best melon cultivars to select best fruits by determining their total seed production, the individual fruits weight to get a maximum yield of fruits reaching maturity. In China, where edible seed watermelon has been grown for several hundred years the area under cultivation has increased, up to 140 000 hectares with seed yields of over 200 000 tons, as the economy develops and demand for seed and seed-oil to be exported increases (Maggs, 1998). This means that when investigating melon seed production, to get commercial oil-seed crops, the variation in sizes and weights of seeds, and number of seeds per fruit have to be investigated.

The specific objectives of this study were to:

- i. Quantify the number of seeds in relation to fruit size;
- ii. Determine relationship between seed weight and fruit size;

Material and Methods

Fruit size and seed production

Fruits were collected, weighted, and grouped into three class sizes of 15 fruits in each class. The first class, consisted of small-sized fruits of up to 150g; the second class, medium- sized consisted of fruits of more than 150g up to 300g and a third class of large-sized fruits weighted more than 300g. It was assumed that larger fruits have more seeds than smaller fruits. Each fruit was then cut open to count the number of seeds per fruit.

A 100 seeds from each fruit within a class size were weighted to get an average mass (g) with the purpose to compare seed weight between fruit of different sizes.

Viability of seeds per size class

Fruits were divided into the three size classes with the assumption that larger fruits have the most mature seeds, and that smaller fruits were the least mature, and therefore less viable. A sample of 50 seeds per fruit size class 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 splitting them cross-sectionally in half. Seed viability was interpreted according to

the topological staining pattern on the embryo and the intensity of the coloration with the purple coloration considered as viability and a white coloration non-viable.

Seed germination

Germination tests were carried out under controlled greenhouse conditions in accordance with the requirements of the International Board for Plant Genetic Resources (1985). The trials assessed seed germination between the three fruit size classes. To test for germination rate, four planting trays were sown with fifty (50) seeds in ten (10) rows and five (5) columns i.e. 50 seeds per tray (50 seeds x 4 replicate trays). Seeds obtained from the three size classes were compared those obtained from stored melon seeds and this was treated as control. A seed was considered to have germinated when the radicle reached 2 mm in length after it has protruded from the seed and the growth medium. The seedling numbers were recorded daily for 21 days thereafter the samples were discarded.

Statistical Analysis

Fruit size and seed production

Seed production and germination were computed statistically using Statistics Package for Social Students (SPSS). A Kolmogorov-Smirnov test was used to test whether the distribution of the data was significantly different from a normal distribution with a significance level of $p \leq 0.05$. It was found that data was normally distributed i.e. more than 5% ($\alpha 5$), thus a one-way factorial Analysis of Variance (ANOVA) was used. Bonferroni a post-hoc procedure was used to further analyse significant ANOVA results. The relationship between fruit size and seed production was tested using the Pearson correlation. .

Viability of seeds per fruits

Viability was observed in 100% of the seeds tested, thus was not statistically tested or graphically presented.

Seed germination

Germination rate was expressed in percentage; the germination was calculated as the rate at which new radicles were produced per day over the period of 21 days. The rate of germination was calculated by using formulae adapted from Bewley and Black (1994).

For statistical analysis, germination percentage values were transformed to the arcsine of the square root to normalize distributions. A Kolmogorov-Smirnov test was used to test whether the distribution of the data treated was significantly different from a normal distribution with a significance level of $p \leq 0.05$. When computed jointly i.e field vs the greenhouse, it was found that data deviated from normality. It was found that data did not deviate from normality, a one-way ANOVA was performed. Bonferroni a post-hoc procedure was used to further analyse significant ANOVA results.

Results

Fruit size and seed production

In the test for seed production from the various fruit classes, the Kolmogorov-Smirnov test indicated that the data for seed production from the three fruits size classes normally distributed.

The result of one-way ANOVA showed significant differences between seeds produced from three fruit size classes, thus there are significant differences between the classes ($p > 0.0001$).

Table 5.1 Results of one-way ANOVA used to determine the differences between the seed production of the three fruit classes.

Seed production	Df	SS	MS	F value	Pr<F
Between Groups	2	26804411.200	13402205.600	30.842	0.0001

Within Groups	42	18250945.600	434546.324		
Total	44	45055356.800			

here was a positive relationship between the seed production and fruit size, $r=0.746$, $P<0.001$, $n=45$. Smaller fruits produced fewer seeds with a mean of $1287.8\pm 89.15SE$, compared to larger fruits with seed production of a mean of 3116.60 ± 247.52 .

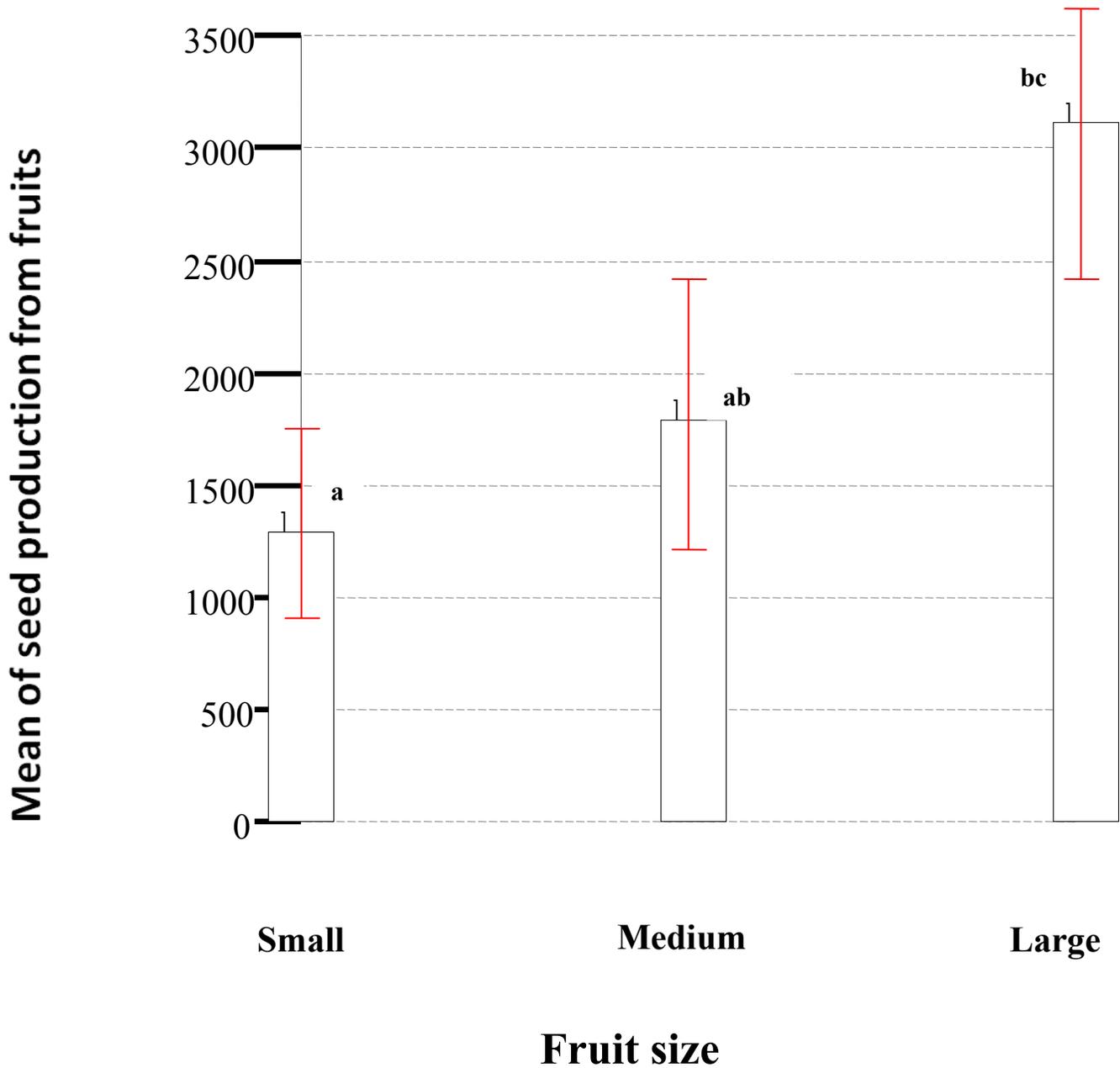


Figure 5.2 The mean production of *C. lanatus* seeds from fruits of three size classes.

Mean seed production of 15 fruits are here presented. Error bars show mean ± 1.0 SE

The Kolmogorov-Smirnov test indicated that the mass of a 100 seeds in each class group was normally distributed $p=0.247$. The ANOVA test showed no significant differences in the mean seed weight with $F(2, 42) = 3.41$, $p=0.042$ (Table 5.1). To test the differences between groups, the post-hoc Bonferroni was used. There were significant differences from the 100 seed weight of small fruits ($10.8\pm 0.59SE$) compared to large fruits ($14.3\pm 1.35SE$), $p=0.038$. However, there was no significant difference from seed production of seeds obtained from small fruits compared to medium fruits ($12.8\pm 0.66SE$) with $p=0.46$ and seeds obtained from large fruits compared to medium fruits, $p=0.768$.

Table 5.1 Results of one-way ANOVA used to determine the differences between the seed weight of 100 seeds of the three fruit classes.

Weight of 100 seeds	Df	SS	MS	F value	Pr<F
Between Groups	2	89.152	44.576	3.410	0.042
Within Groups	42	548.996	13.071		
Total	44	638.148			

Viability of seeds

Viability tests with 2, 3, 5 triphenyl- tetrazolium-chloride indicated that seeds from all class sizes were viable, this is due to the resultant dark purple coloration distinguished in the sectionally cut seeds, thus no statistical analysis was necessary.

Seed germination

The Kolmogorov-Smirnov test indicated that germination data was normally distributed with $p > 0.05$ in all classes (Table 5.2).

Table 5.2 P-value results of the Kolmogorov-Smirnov test for normality of for seed production from three fruit classes.

Fruit Size	Greenhouse	Field
Small	P=0.139	P=0.125
Medium	P=0.119	P=0.057
Large	P=0.149	P=0.100

When tested with one-way factor ANOVA, there was no significant differences ($p > 0.05$) in germination, the fruit size did not improve the seedling germination ($p > 0.05$).

In the greenhouse, the rate of germination was highest in seeds obtained from smaller fruits ($R = 0.40$) and lowest in the seeds obtained from the larger fruits ($R = 26$) (Appendix VIII, p91). However, a second order interaction effect of site and fruit class size showed no significant differences ($df=2$; $F=0.189$; $p=0.828$) (Table 5.2) in the germination percentage. For field studies, the seeds from medium fruits sized attained lower germination percentage (14 %). The overall germination rate of all the seeds did not reach the arbitrary 50 % for the maximum germination (Fig. 5.3). The rate of germination was highest in medium fruits ($R = 0.34$) and lowest in the seeds obtained from the larger fruits ($R = 26$) (Appendix VIII, p91).

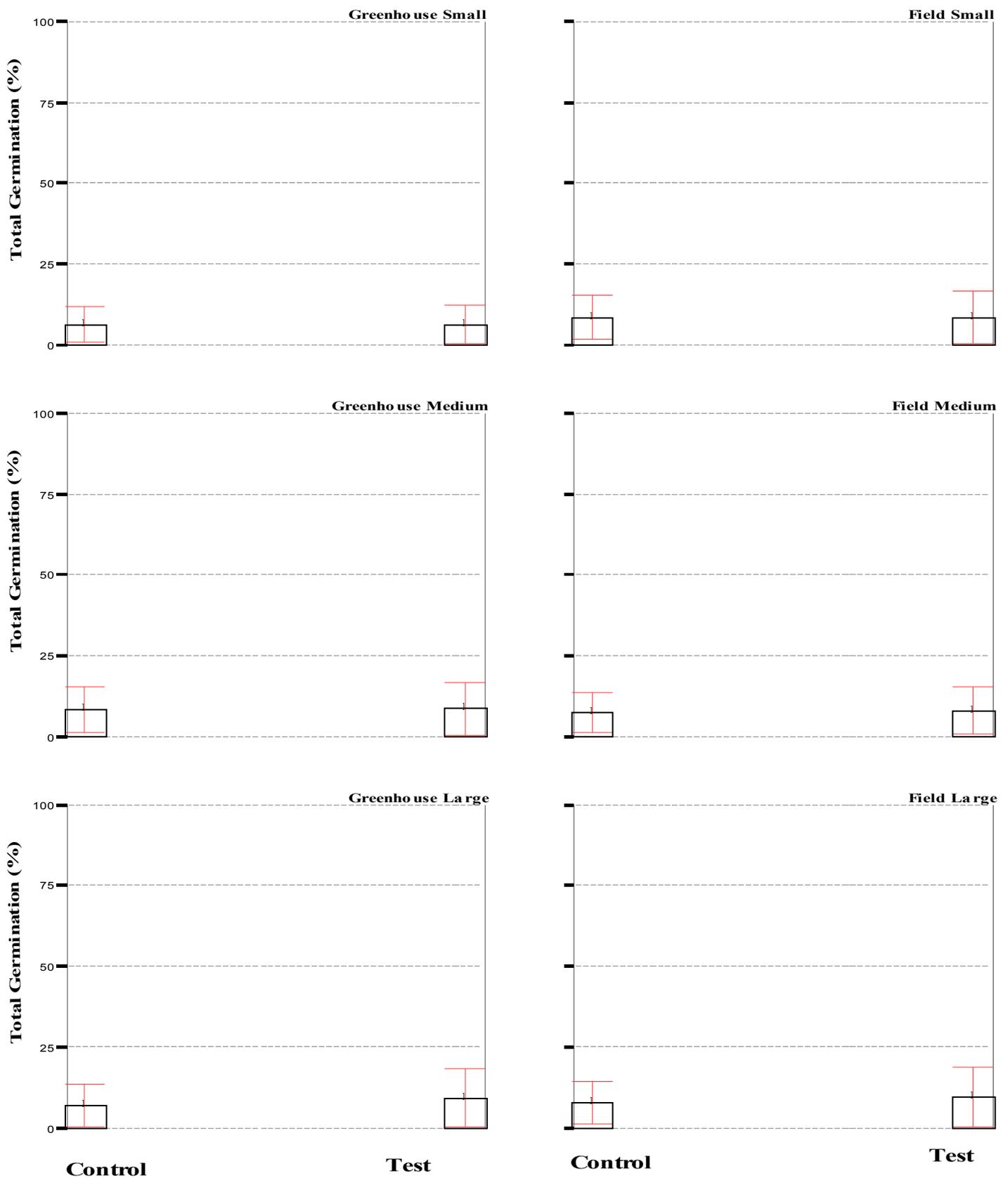


Figure 5.3 Total germination of *C. lanatus* seeds obtained from fruits of three sized classes planted in at the greenhouse and in the field. Mean of 4 replicates (\pm SE) are presented.

Discussion

The study showed that the significant differences between the seed weight of the different fruit classes is an indication that the weight of a fruit is directly proportional to the weight of its seeds i.e. small fruits had a low seed weight when compared to large fruits and 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 %. Maggs-Kölling & Christiansen (2003), revealed that the relationship between melon seed yield and fruit weight was more pronounced in commercial varieties, whereas the number of fruit was more critical in local watermelon yields. This is important for village nurseries to plant fruits that are able to obtain high seed yields, however, studies on obtaining fruit yield were not in the scope of this study. According to Maggs-Kölling & Christiansen (2003), literature indicates that the mean fruit weight had marked effect on fruit yield.

Fruit size did not influence seed germination; smaller fruits do not necessarily presuppose immature seeds. More studies are needed to determine the factors influencing fruit sizes in *C. lanatus*. The determination of fruit maturity was not in the scope of this study, thus it cannot be assumed that small sizes indicate immature fruits. Bewley & Black (1994) reported that the fruit size in certain cucurbits like melons is positively correlated with seed number, developing seeds found in small fruits control the growth of the ovary wall.

Seed weight did not play a role in determining the germination percentage. This is contrary to the work of (Nerson, 2002) that hypothesized that the harvesting of small fruits result in poor germination over long period as can be observed by the poor germination rate of smaller melons. However, it can also be biologically argued that bigger seeds have better chances at seedling establishment than smaller seeds. This is attributed particularly to a larger food reserve within the embryo of larger fruits. The removal of the seeds from fresh fruits at the end of the growing season i.e. May/June, when fruit abscission is in a state of primary dormancy, can result in the failure of seeds to germinate. The poor germination rate can be attributed to the limited inability of embryos of young, immature embryos 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. This can be attributed to the fact that the seeds were air-dried for 6 days before sowing. It is important for seeds to first desiccate before germination is promoted. The drying of the seeds for longer period was not possible for this experiment due to the time limit. 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.

CHAPTER 6

THE EFFECT OF WATER IMBIBITION AND TEMPERATURE ON THE SEED GERMINATION OF *C. LANATUS*

Introduction

Seed maturation stage can be an influential factor in germination performance at low temperatures and response to priming treatment. According to Botha *et al* (1982a), mature melon seeds tend to show a better germination performance at optimum temperatures between 25 – 35°C.

In a study carried out by Demir & Mavi (2004), on the hydration of melon seeds, it was observed that significant differences existed among the seedlots and between hydration treatments for emergence performance, moisture absorption and emergence force exerted by seedlings. In the study, it was observed that triploid seeds had a lower emergence percentage than diploid seeds, possibly due in part to their higher seed coat splitting strength and weak seedling emergence strength. Hydrating the seeds in moist vermiculite is an effective means of improving seedling emergence. The improved emergence

percentage of vermiculite-hydrated seeds might be attributable to the hydration-strengthened seedling emergence strength (Demir & Mavi, 2004).

The poor germination of polyploid melon seeds can be related to the greater extent of lipid peroxidation and lower activity of peroxide-scavenging enzymes during seed imbibition (Nerson, 2002). The imbibition of seeds in water is known to improve the rate and uniformity of germination in watermelons species. Nerson *et al.*, (1985) found that soaking the polyploid watermelon seeds in distilled water for 24 h, followed by 6 days of air-drying was successful in increasing seed germination percentage. They attributed this germination improvement to the increased embryo growth of the seeds. Similar studies are also reported by Copeland & McDonald, (1995), that soaking of seeds in water prior to planting enhances germination, seedling growth by controlling imbibition and reducing the vagaries of adverse weather and soil conditions.

The main objective this specific experiment was to test the effect of water imbibition and temperature on the germination of *C. lanatus* seeds under controlled and natural conditions.

Material and Methods

Water imbibition

Seeds were fully imbibed for 24 hours in 100 ml of distilled water in a glass beaker at: room temperature (20 °C), in cold water at a constant temperature of 4°C in a refrigerator, warm water at a constant temperature of 30 °C in an oven and warm water allowed to cool off at room temperature. In the field, the oven methodology was not used due to lack of equipment. After soaking, the seeds were air-dried in the open for 6 days and then planted in pots to germinate. A total of four planting trays were each sown with fifty (50) seeds in ten (10) rows and five (5) columns i.e. 50 seeds per tray (50 seeds x 4 replicate trays).

Dry seeds

Seeds were exposed to temperatures: room temperature and pressure at 20 °C, at a constant cold temperature of 4°C in a refrigerator and at a constant temperature of 30 °C in an oven. A total of four planting trays were each sown with fifty (50) seeds in ten (10) rows and five (5) columns i.e. 50 seeds per tray (50 seeds x 4 replicate trays).

Statistical Analysis

Water imbibition

Germination rate was expressed in percentage; the germination was calculated as the rate at which new radicles were produced per day over the period of 21 days. The rate of germination was calculated by using formulae adapted from Bewley and Black (1994).

For statistical analysis, germination percentage values were transformed to the arcsine of the square root to normalize distributions. Seed germination was computed statistically by using SPSS. A Kolmogorov-Smirnov test was used to test whether the distribution of the data treated was significantly different from a normal distribution with a significance level of $p \leq 0.05$. It was found that data did not deviate from normality ($p > 0.05$), one way ANOVA was used to compare means. A t-test was carried out to compare the germination rate of the greenhouse conditions and the field. For significant ANOVA results Bonferroni was used as a post-hoc procedure.

Dry seeds

The statistical analysis of seeds exposed only to varying temperatures was done as those for the germination of seeds imbibed in water were appropriate.

Results

Water imbibition

The Kolmogorov-Smirnov test on all germination methods treatments revealed that the data did not deviate from normality ($P > 0.05$) (Table 6.1).

Table 6.1 P-value results of the Kolmogorov-Smirnov test for normality of for germination percentage at the two study sites.

Germination method	Greenhouse	Field
Warm water	P=0.086	P=0.117
Cold water (4°C)	P=0.205	P=0.108
Water at rtp	P=0.100	P=0.117
Warm water (30°C)	P=0.194	P=n/a

A one-way ANOVA test revealed that there was no significant difference between the germination of seeds from the various germination methods at both sites.

The seeds exposed in cold water (4 °C) conditions resulted in 56 % germination and the control had the highest germination rate (R = 0.40), 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 T-test comparing the germination rate of the seeds between the two sites revealed that there was no significant difference (P > 0.05).

A second order interaction effect of site and germination method showed no significant differences ($df=12$; $F=1.452$; $p=0.141$) (Table 6.2) in the germination percentage, thus the site did not have an effect on the germination of the seeds.

Table 6.2 Results of two-way ANOVA used to determine the interaction effects between the two sites and germination methods.

Source	SS	Df	MS	F	Pr>F
Corrected Model	36.556(a)	31	1.179	7.556	.000
Intercept	210.436	1	210.436	1348.387	.000

Site	.021	1	.021	.132	.717
Arcsine values	23.503	18	1.306	8.366	.000
Site * Arcsine values	2.720	12	.227	1.452	.141
Error	47.444	304	.156		
Total	840.000	336			
Corrected Total	84.000	335			

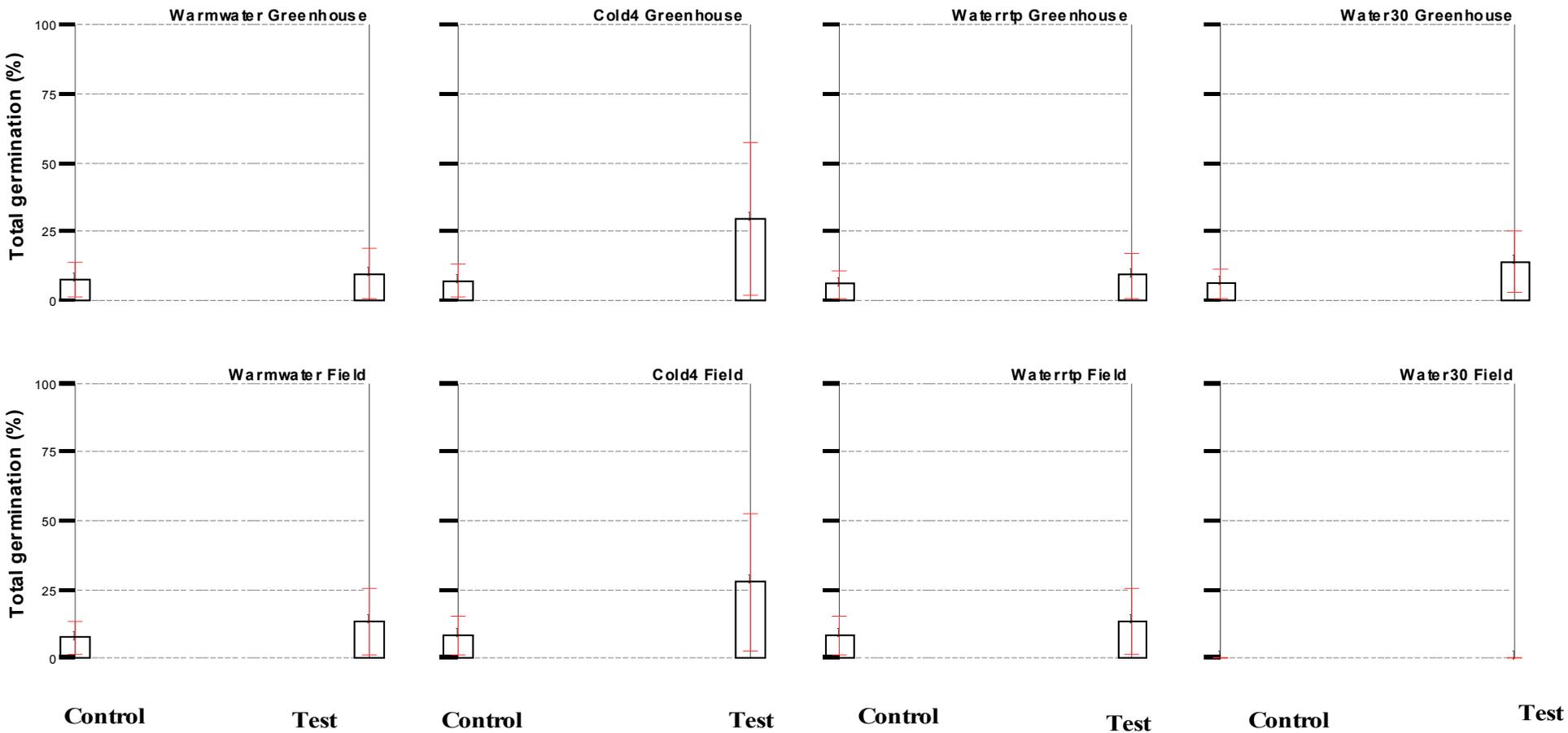


Figure 6.1 Total germination of *C. lanatus* seeds planted in at the greenhouse and in the field treated with water imbibition.

Mean of 4 replicates (\pm SE) are presented

Dry seeds

The Kolmogorov-Smirnov test on germination some treatments revealed that the data was not normally distributed ($P < 0.001$).

The germination of the dry seeds at the greenhouse were statistically analyzed with the Kruskal-Wallis test. It was revealed that the seeds left under cold conditions were significantly different from the other treatments ($H(1) = 18.82$, $P = 0.001$). The germination percentage of the seeds exposed to cold conditions was rated good, as it resulted in 70 % germination; the control resulted in 11 % germination.

Similarly, in the field, the germination of dry 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 in 14 % germination.

The coefficient rate of germination for pre-chilled seeds was low ($CRG = 34.01$), with the control obtaining a high rate of germination ($R = 0.34$).

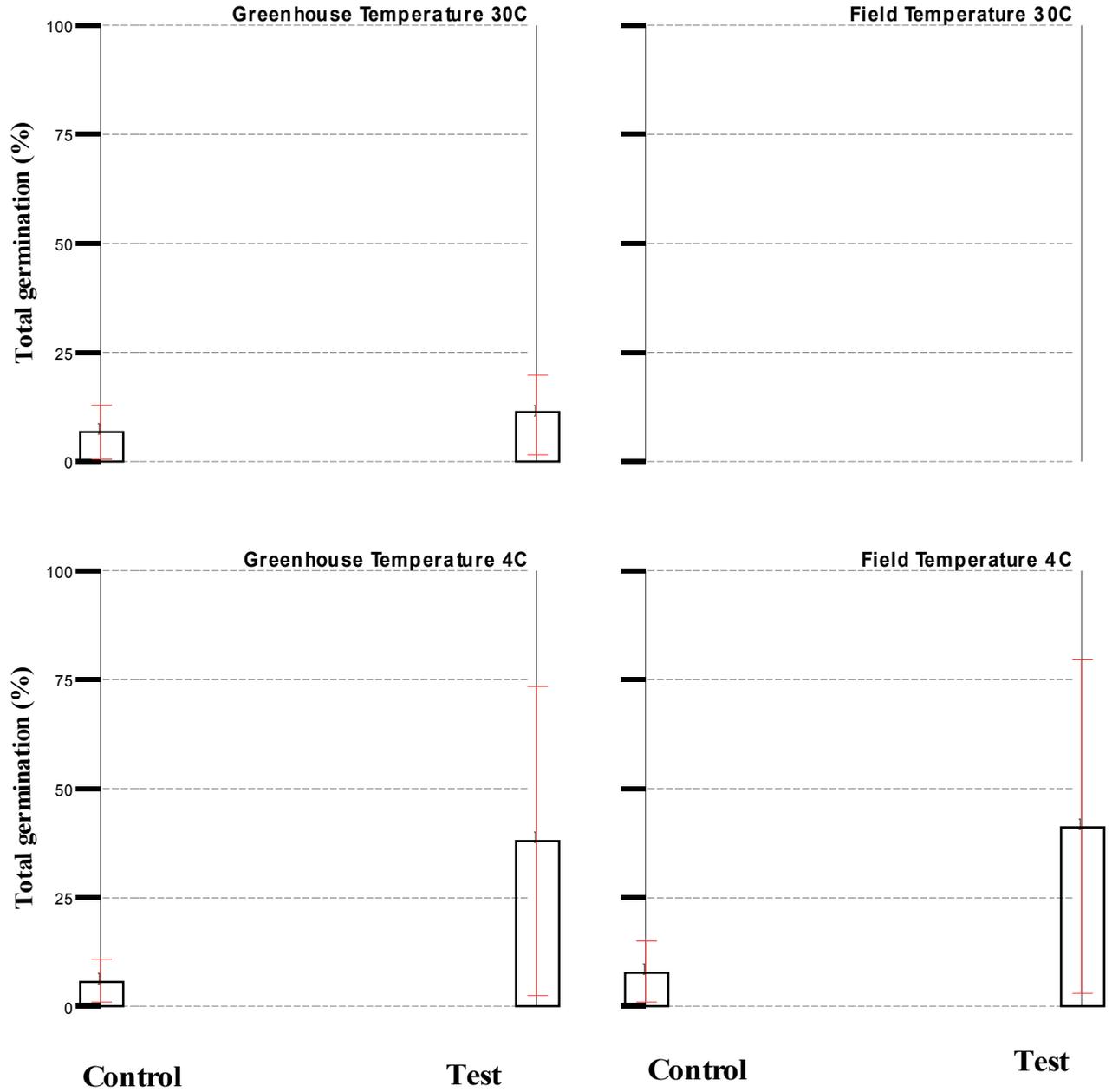


Figure 6.2 Total germination of *C. lanatus* seeds planted in at the greenhouse and in the field treated with varying temperature. Mean of 4 replicates (\pm SE) are presented.

Discussion

The overall treatments show 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. 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.

CHAPTER 7

THE EFFECT OF SEED COAT SCARIFICATION ON THE GERMINATION OF *C. LANATUS* SEEDS

Introduction

Many seeds do not germinate well when placed in conditions which are normally regarded as favourable for germination, namely an adequate water supply, a suitable temperature and an atmosphere of normal composition (Bewley & Black, 1994). Nevertheless seeds can be shown to be viable, as they can be induced to germinate by various artificial treatments, or under specific external conditions (Bewley & 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. The decline in the recruitment and

the low germination of *C. lanatus* can be attributed to the occurrence of seed dormancy due to the water impermeability of the seed coat.

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 & Poljakoff-Mayber, 1989). 'Primary dormancy' is 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 of light, or the presence of substances inhibiting germination (Copeland & McDonald, 1995). Other seeds will germinate readily after they shed if conditions are favourable. However, these seed may lose their readiness to germinate, and this phenomenon is called secondary dormancy.

Seed scarification is one of the most economical approaches to improving seed performance as seed germination can be restricted by mechanical restriction exerted by the seed coat (Nelson *et al.* 1985). According to Nelson *et al.* (1985), permeability limitation of water and gases is typical of hard seed coats, but not uncommon, in thin-coat seeds. The seed 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 cannot overcome (Mayer & Poljakoff-Mayber, 1989). According to Bewley & Black (1994) embryo dormancy is common in woody species especially in the Rosaceae, but sometimes found in herbaceous plants 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 stored 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 which includes 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.

Porter and Lawlor (1991) reported 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. Thanos & Mitrakos (1992), on studies carried out on the Sugar Baby watermelon (*Citrullus lanatus*) on the effect of testa removal, reported that the removal of the lignified testa in wild-grown watermelon seeds only slightly reduced white-light inhibition, but the additional removal of the inner membrane resulted in full germination in the light. It was concluded that the outer, lignified part of the testa, exerts a restrictive

mechanical action upon the expanding radicle (Thanos & Mitrakos, 1992). It is further reported in some studies that in several cucurbitaceous seeds, decoating did not remove photosensitivity, and in certain cases, it even augmented it, as a result of increased light flux density reaching the embryo (Thanos & Mitrakos, 1992).

The main objective of this study was to test the effects of different scarification treatments on the germination of *C. lanatus* seeds under controlled and field conditions.

Material and Methods

Diverse methods of seed scarification were used to determine the best and affordable method for the germination of *C. lanatus*. Scarification techniques used were mechanical scarification and concentrated sulfuric acid. The control was represented by intact seeds. The effect of the immersion duration (one and five seconds due the thickness of the seed coat) of melon seeds in diluted sulfuric acid (18%) was evaluated.

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) was normally used (Wang and Pitel, 1991 in: Shikongo, 2003). 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. The seeds were then rinsed in running tap water to remove all traces of the acid. After soaking the seeds were air-dried for 6 days to retain the appropriate moisture levels within the seeds and then planted in pots. A total of four planting trays were each sown with fifty (50) seeds in ten (10) rows and five (5) columns i.e. 50 seeds per tray (50 seeds x 4 replicate trays).

Mechanical Scarification

In another treatment, a mortar and pestle was used to scarify the 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 scarified seeds were then sown. A total of four planting trays were each

sown with fifty (50) seeds in ten (10) rows and five (5) columns i.e. 50 seeds per tray (50 seeds x 4 replicate trays).

Statistical Analysis

Germination rate was expressed in percentage, the germination was calculated as the rate at which new radicles were produced per day over the period of 21 days. The rate of germination was calculated by using formulae adapted from Bewley and Black (1994).

Data collected was primarily computed statistically by using SPSS. For statistical analysis, germination percentage values was transformed to the arcsine of the square root to normalize distributions. A Kolmogorov-Smirnov test was used to test whether the distribution of the data treated was significantly different from a normal distribution with a significance level of $p \leq 0.05$. If it was found that data was normally distributed thus a one-way factorial Analysis of Variance (ANOVA) was used to test group means. Bonferroni was used as a post-hoc procedure and a t-test was used to compare the germination rate of the seeds between the two sites.

Results

This experiment was done under the assumption that scarification of the seed coat results in a higher 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 ($P < 0.001$).

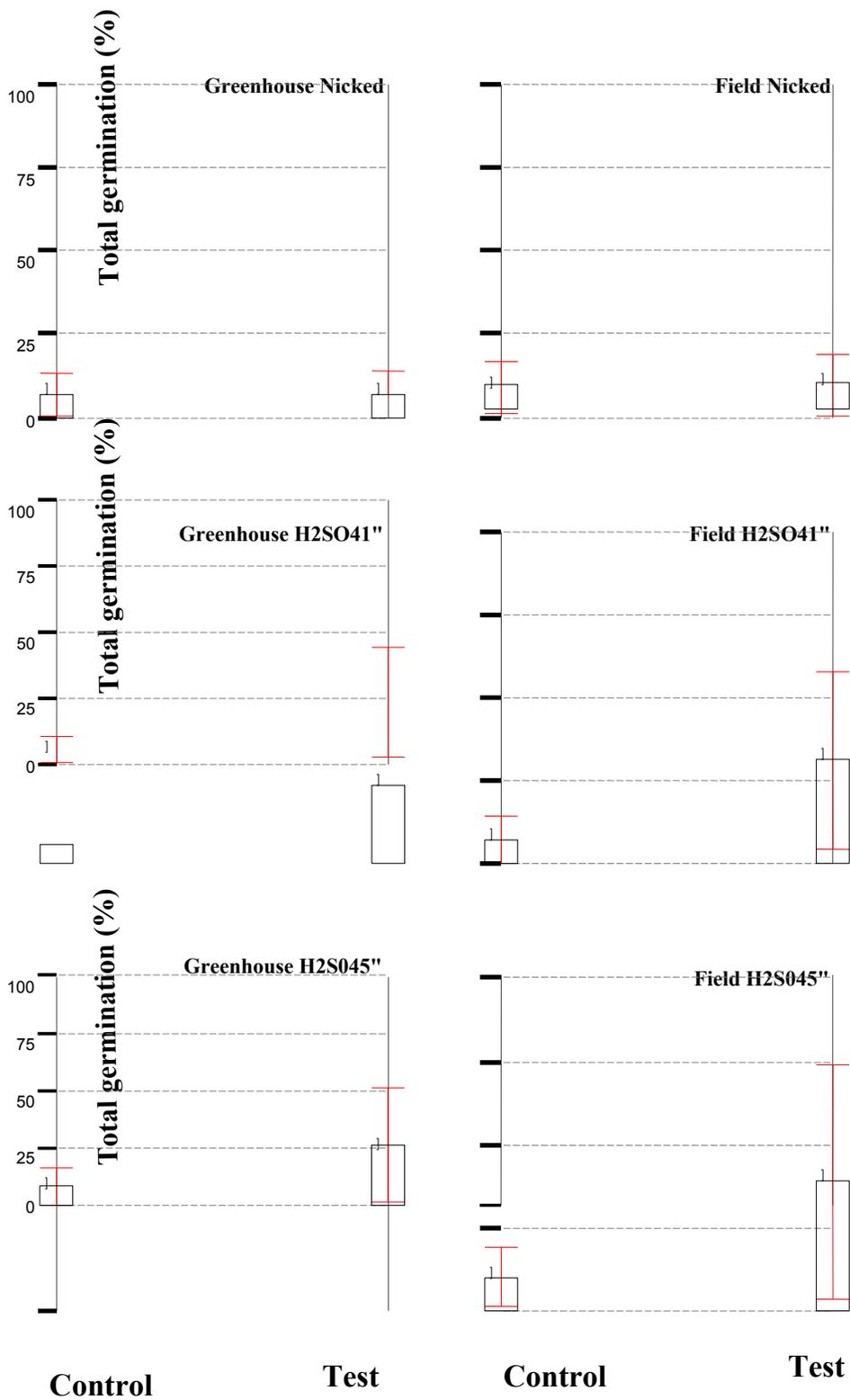


Figure 7.1 Total germination of *C. lanatus* seeds obtained using three different scarification methods at the Greenhouse. Mean of 4 replicates (\pm SE) are presented.

The one-way ANOVA revealed that there was no significant difference between the germination percentages for scarification treatments carried out at the greenhouse ($df=1$; $F= 1.338$; $p=0.249$)

The T-test comparing the germination rate between the two sites revealed that there was no significant difference between them ($P=0.77$).

For trials carried out in the field, the Kruskal-Wallis statistical analysis revealed that the treatments were significantly different ($H(1) = 3.740$; $P= 0.03$). Further analysis revealed that the treatment of seeds exposed to H_2SO_4 for 5 seconds and 1 second were not significantly different ($P > 0.05$) from each other.

The seeds scarified 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.

Discussion

Results reported no significant differences between the various seed treatments. The scarified seeds had 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 break dormancy. The waterproofing can be conferred by several parts of the testa with the main barrier for water uptake, 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 recommended for established nurseries that are able to afford the chemical and are able to apply its basic safety procedures. It is possible that seeds treated with H_2SO_4 can produce better germination rate. In a study carried by Heidari *et al* (2008) with H_2SO_4 results showed that nicking plus stratification of the

seeds of *Prunus scoparia* and *Prunus webbii* increased percentage germination, however the immersion time is species related.

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 (Bewley & Black, 1994).

CHAPTER 8

THE EFFECT OF ESSENTIAL MICROORGANISMS (EM) ON THE GERMINATION OF *C. LANATUS*

Introduction

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 (Higa, 1995).

Soil microbiologists and microbial ecologists have differentiated 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 plants.

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

The objective of this study was to determine germination rate of *C. lanatus* seeds treated with Essential Microbes (EM) under greenhouse and field conditions.

Material and Methods

The EM inoculant was obtained from the Polytechnic of Namibia. Seeds were fully imbibed in 1:0, 1:50, 1:100 and 1:150 ratios of EM and distilled water. These ratios are standard for germination tests as prescribed by the manufacturer at the University of Japan. Tap water was not used as it is chlorinated and would kill the microbes. The seeds were soaked for 24 hours before they were sown as mentioned in the standard germination procedures. A total of four planting trays were each sown with fifty (50) seeds in ten (10) rows and five (5) columns i.e. 50 seeds per tray (50 seeds x 4 replicate trays). A seed was considered to have germinated when the radicle reached 2 mm in length. The seedling numbers were recorded daily for 21 days thereafter the samples were discarded.

Statistical Analysis

Germination rate was expressed in percentage, the germination was calculated as the rate at which new radicles were produced per day over the period of 21 days. The rate of germination was calculated by using formulae adapted from Bewley and Black (1994).

Data collected was primarily computed statistically by using Statistics Package for Social Students. For statistical analysis, germination percentage values was transformed to the arcsine of the square root to normalize distributions. A Kolmogorov-Smirnov test was used to test whether the distribution of the data treated was significantly different from a normal distribution ($p \leq 0.05$). If it was found that data was not normally distributed ($p > 5$), thus a Kruskal-Wallis test was used. A T-test was used to compare germination rate between the two sites

Results

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 EM treatment in the greenhouse showed that the data was not normally distributed ($P < 0.001$), while those in the field was normally distributed.

The Kruskal-Wallis test of the results obtained out at the greenhouse (Figure 8.1) indicate that there was a strong significant difference between the different EM treatment concentrations ($H(3) = 12.55$, $P = 0.001$). There was no significant difference between the germination percentages of the treatment of EM 1:0 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 ($H(1) = 3.35$, $P = 0.07$). There was no significant difference between the

germination percentages of the treatment of EM 1:0 and EM 1:150 ($H(1) = 1.53$, $P = 0.09$). No significant difference was also found between EM 1:0 and EM 1:100 of the treatment ($H(1) = 2.45$, $P = 0.15$). There was no significant difference between the germination percentages of the treatment of EM 1:50 and EM 1:100 ($H(1) = 3.13$, $P = 0.11$). No significant difference was also found between EM 1:50 and EM 1:150 of the treatment ($H(1) = 3.68$, $P = 0.09$).

The T-test comparing the two means of germination between the two sites, the greenhouse and the field revealed that there was no significant difference between them ($P > 0.05$).

Analysis of the results carried out in the field (Figure 8.1) with ANOVA indicate that there were significant differences between the different EM treatment concentrations ($df= 3$; $F= 8.204$; $p= 0.000$).

Post-hoc Bonferroni tests revealed that there were no significant difference between the germination in the field (Table 8.1)

Table 8.1 P-value results of the Post-Hoc Bonferroni test for EM treatments in the field

Test	(I) Treatment	(J) Treatment	Significance
Bonferroni	EM1:0	EM1:50	1.000
		EM1:100	.000
		EM1:150	.046
	EM1:50	EM1:0	1.000
		EM1:100	.001
		EM1:150	.395
	EM1:100	EM1:0	.000

		EM1:50	.001
		EM1:150	.380
	EM1:150	EM1:0	.046
		EM1:50	.395
		EM1:100	.380

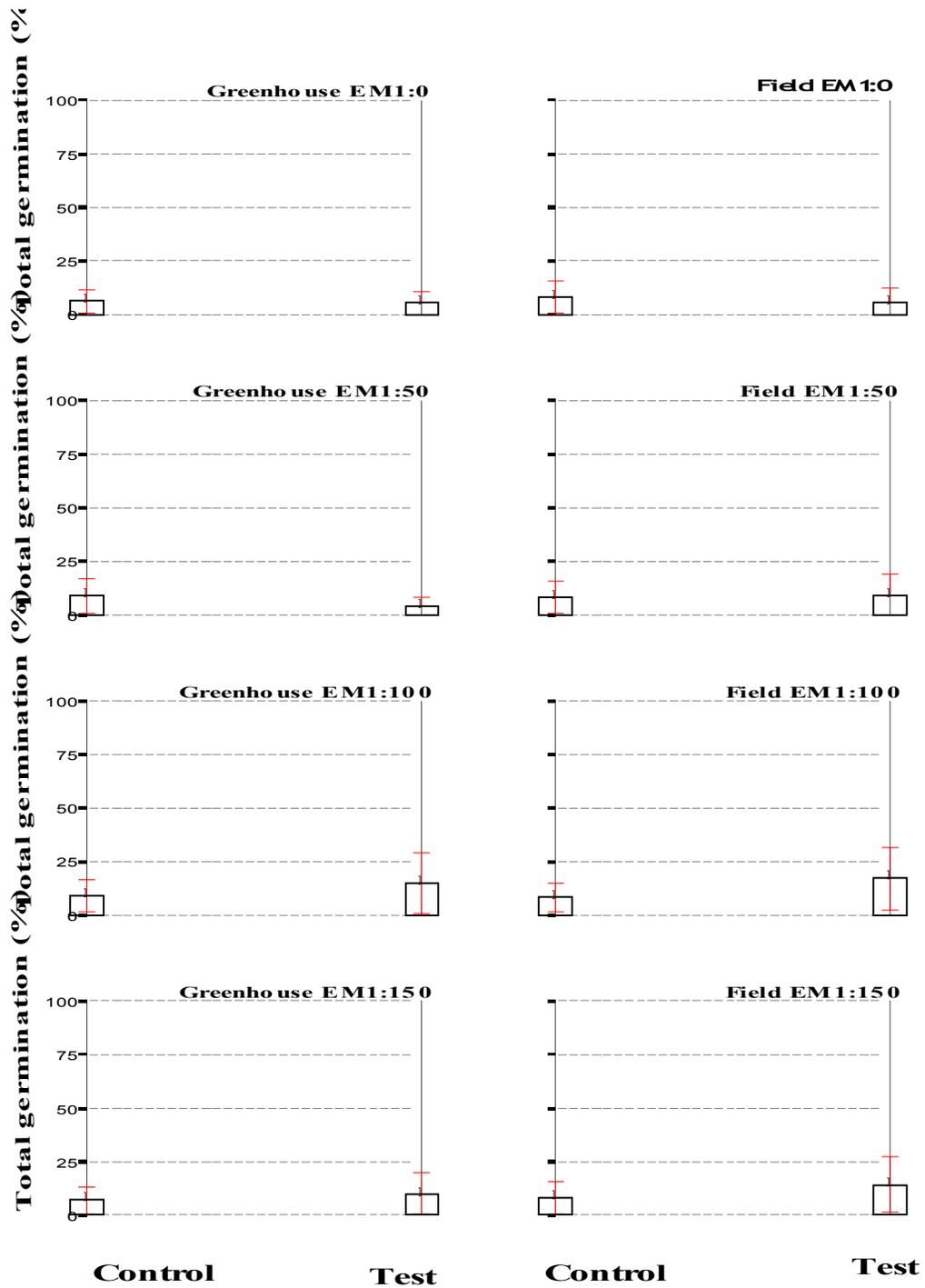


Figure 8.1 Total germination of *C. lanatus* seeds planted in at the greenhouse and in the field treated with Essential Microbes. Mean of 4 replicates (\pm SE) are presented.

Trials carried out in the field, 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 % (Appendix VIII).

Discussion

Our study shows that the various EM formulations had diverse germination percentages. Soaking seeds in only EM may lower the germination of the seeds due to high alkalinity in the mixture, and low ratio formulations does not sufficiently enhance germination. EM1:100 had a higher germination percentage even if there were not statistical differences with other treatments, this formulation is the recommended for treatments of seeds ((Higa, 1995). Work on the effect of microorganisms on the germination of *C. lanatus* seeds is scarce or unavailable.

Watering the trays 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 yeast populations can be cultivated over long periods by allowing it to ferment in water in an anaerobic environment from several days to weeks or months, depending on the goals of application.

CHAPTER 9

GERMINATION OF *C. LANATUS* SEEDS OBTAINED FROM CATTLE MANURE

Introduction

Seeds in their natural environment interact with a variety of other plants and 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 by distributing seeds 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) reported 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 from trees such those of *Acacia* spp 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.

The objective of this study was to determine the germination potential of *C. lanatus* seeds which has been obtained from cattle manure under controlled greenhouse conditions and natural field conditions.

Material and Methods

Melon seeds collected from cattle dung was the most accessible. With the help of the field assistant, these seed were manually collected from cattle manure in the field. Seeds were subsequently washed in water for clear classification as melon seeds. A sample of 200 seed were collected, sterilized with a fungicide and sown for germination tests at the Greenhouse and in the field. A total of four planting trays were each sown with fifty (50) seeds in ten (10) rows and five (5) columns i.e. 50 seeds per tray (50 seeds x 4 replicate trays).

Statistical Analysis

Germination rate was expressed in percentage, the germination was calculated as the rate at which new radicles were produced per day over the period of 21 days. The rate of germination was calculated by using formulae adapted from Bewley and Black (1994).

Data collected was primarily computed statistically by using Statistics Package for Social Students (SPSS). For statistical analysis, germination percentage values was transformed to the arcsine of the square root to normalize distributions. A Kolmogorov-Smirnov test was used to test whether the distribution of the data treated was significantly different from a normal distribution ($p \leq 0.05$). If it was found that data deviated from normally- thus a Kruskal-Wallis test was performed. Pairwise comparison using Mann-Witney was used to compare the differences between the groups.

Results

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 Kruskal-Wallis test revealed that there is no significant difference between the germination percentage for seeds sown at the greenhouse ($p > 0.05$).

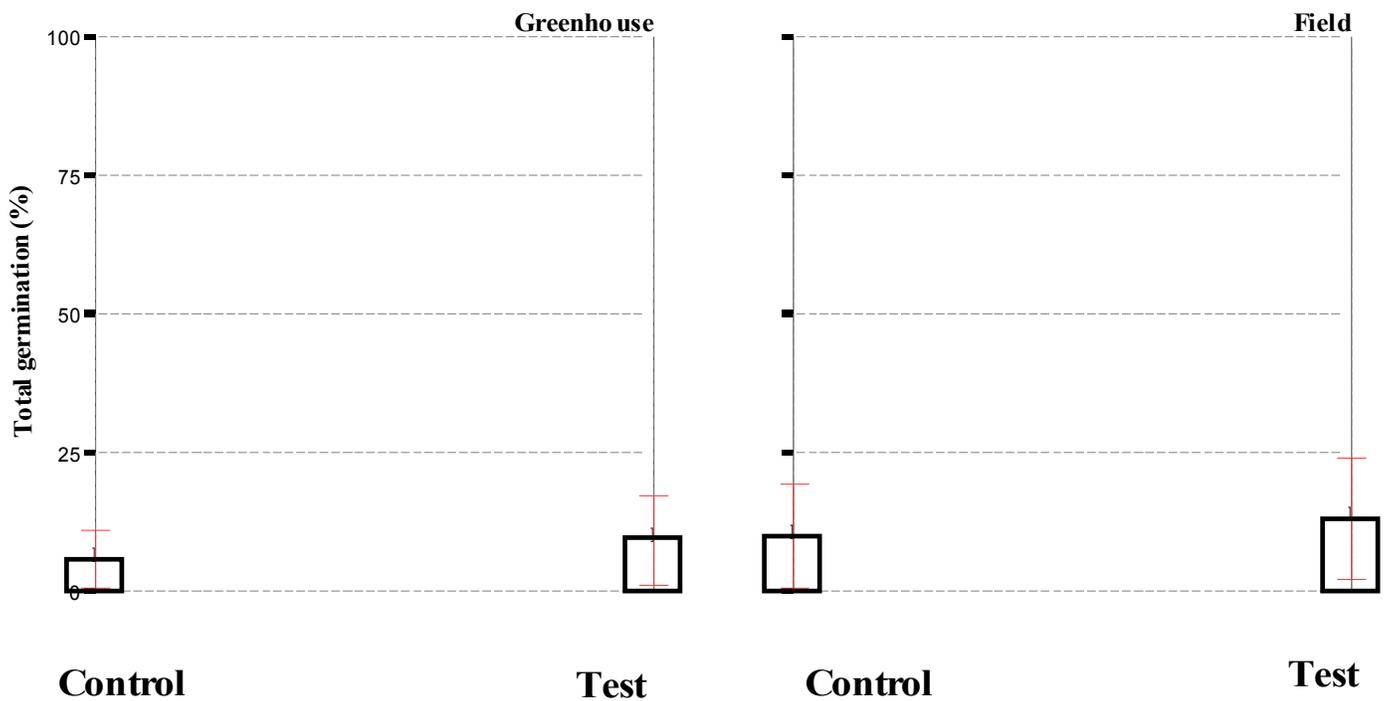


Figure 9. 1 Total germination of *C. lanatus* seeds planted in at the greenhouse and in the field obtained from cattle manure. Mean of 4 replicates (\pm SE) are presented.

There was a significant difference between the germination percentage for treatments carried out in the field ($H(1) = 4.83, p < 0.05$). 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 ($U = 135, P < 0.001$).

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 lower of germination (16 %), compared to the 22 % germination percentage obtained with seeds 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.

Discussion

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 animal 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 plants 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 eat seeds of *Polygonum persicaria*, while some seeds germinated after excretion, others seed 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.

CHAPTER 10

CONCLUSIONS AND RECOMMENDATIONS

The overall aim of this study was set out to determine the seed production, viability and germination potential of *C. lanatus* and potential for cultivation in traditional cropping systems as well as to investigate the management systems of *C. lanatus*. 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 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 study has not been conclusive and recommendations are herewith provided.

Ethnobotanical studies

There is an indication that communities are not aware of the pressure exerted on the wild melon, and unlike other fruits, it does not have sustainable harvesting mechanism in place. Communities should intensify their efforts to have a sustainable harvesting method in place. However, 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*.

Germination studies

The study demonstrated that seeds treated with various enhancements, achieved better germination percentages than the untreated seeds. Many seeds did not germinate; this can be attributed to the fact that an entire seed population of plants adapted for dry regions or dry environments does not necessarily germinate. Plants have adapted strategies for the population to survive during certain seasons, thus, a certain part of the seed population remains dormant, while another will germinate. Seeds exposed to chilling at 4 °C and H₂SO₄ had significantly improved germination.

It can be concluded that seed mass has a positive correlation with fruit mass. A measure of 100 large seeds had a higher weight when compared to those of small fruits. Fruit size is not indication of immature seeds, as the germination percentage of the different fruit classes was not significantly different. 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 they are still in the fruits

The study demonstrated that scarification of the seed coat with sand-filled mortar and pestle does not improve the germination potential of *C. lanatus* when compared to the control. This is contrary to studies which indicated that scarification of the seed coat can essentially improve germination if the seed has been weakened. It can be recommended that future studies can apply other methods such as scarifying the seed coat with sand-paper to obtain uniform germination.

H₂SO₄ as a scarification method greatly enhances germination. However, usage of H₂SO₄ as a scarification method cannot be recommended for village nurseries because of its corrosiveness. This is volatile and dangerous chemical recommended to personnel well trained in handling chemicals. If nurseries do obtain the acid, it should used in low concentrations.

Various enhancements greatly improved the germination potential of seeds. This confirms our hypothesis that treated seeds are more likely to successfully germinate than untreated seeds. The germination percentage will increase substantially due to the seed improvement with enhancements. High temperature regimes of 30 °C did not greatly enhance the germination. The utilization of Essential Microbes can greatly improve the germination potential if the seeds are watered with chlorine-free water such as rainwater.

Seeds obtained from herbivore manure did not have significantly higher germination percentages than those obtained directly from the fruits. Even though low germination percentages were obtained, it is important to encourage villagers to leave some fruits in the field for herbivore feed. It has been biologically proven that animals assist with the distribution and germination of some seeds. The excretion the seeds in new habitats

different from those in which the fruit was eaten greatly enhances the survival of the plant.

Recommendations

Long-term monitoring is needed to assess the harvesting regimes and the recruitment of *C. lanatus* in the wild.

It is clear that there is a lack of awareness on the decrease of the melon in the wild. It is therefore important to develop educational outreach programs with the assistance of community based organizations, to create awareness on the harvesting and suitable methods of intercropping *C. lanatus* with traditional crops. 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*.

Future extensive investigations should be carried out on the fruit and the seed yields of the melon. To gain better scientific knowledge, treatments should be extended to a greater variety of germination stimulators and inhibitors such as Gibberellic and Abscisic Acids. The extraction of oil from the melon seeds of different sized fruits were not in the scope of this study. This is mainly due to the problems experienced with the traditional oil extraction methods for a 100 seeds, the oil extraction process requires more than 5 kilograms of seeds, and it was not feasible in this study. Pressers obtained from CRIAA SA-DC sufficiently work only with large volumes of seeds, it is thus further studies be carried to determine oil from melon seeds.

The study has shown that villagers do air-dry the Kalahari melon seeds for long periods; however it is recommended that that harvested fruits should be left intact to for at least 3 months to complete seed dormancy. Seeds should be further exposed to desiccation for at least a month before been sown, to promote germination on subsequent imbibitions. 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.

Achievement of 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 for communities to ensure the survival of the wild melon and other wild plants, to try and maintain the ecological balance, as there are various factors that regulate the germination of the seeds in its natural environment.

Management and germination protocol for village nurseries

Small-scale village nurseries can use were appropriate the following methods to improve the management and the germination potential of *C. lanatus*:

- There are various community committees managing local and indigenous plant resources. The mandate of these committees can be expanded to include the management of the Kalahari melon. The seeds of this melon are economically important, and if a resource is seen as highly valuable, it is threatened by over-harvesting and over-exploitation if there are no management structures in place.
- Villagers are requested to approach support institutions such as the Ministry of Agriculture, Water and Forestry (MAWF) to establish nurseries and to link to various nursery projects in the country. This will enable them share ideas, and develop best practice methods applied by various nurseries. Villagers are

requested to work closely with the various forestry extension officers posted in rural areas to work closely with community members.

- The establishment of village nurseries to germinate the melon is important as it can become an essential genetic reservoir for the wild population. The villagers should keep nursery record books. Nursery record books are important tools for the community members to improve on the nursery administration, retain valuable information and provide information on seedling distribution (www.cgiar.org/ipgri).
- Harvested melon seeds should be air-dried for up to 3 months. The seed should be carefully stored in ventilated containers and protected from elements such as insect attack and excessive moisture. The traditional storage methods are recommended for village nurseries as they are simple, effective and affordable.

Pre-treatment of seeds:

- Essential Microbes can be an important and affordable treatment for the germination of seeds. Most villages receive portable water, and

have no irrigation structures, thus rainwater can be used in the proper administration of EM. EM contains microbes which can be killed by the chlorine added to tap-water. Once the nursery obtains EM, it can be cultured over long periods without the requiring a new batch. Seeds should be pre-treated with rainwater and EM at a recommended ratio of EM 1:100.

- Pre-chilling can be successfully used to pre-treat seeds before germination. This method is recommended for village nurseries with access to cold storage (< 15 °C). Dry seeds can be placed in foil paper to overnight in the cold storage before planting.
- The removal of the seed coat has been proven to increase the germination percentage of seeds. It is recommended that villagers should attempt to split the seed coat to improve the germination of the seeds.
- Seeds can be planted in trays made from local material or a collection of empty milk containers can be used.
- The young, established seedling can be translocated to the field for transplanting. If an empty field is not available, the young seedlings can be intercropped with Pearl millet as it grows well in well drained soils. Prepared seedlings can be re-planted traditionally i.e. one seedling per hill.

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Interviews were carried out with various individuals who are not listed in the report.

APPENDICES

Appendix I

Individual Interview Questions
Date.....
Location.....**GPS**.....**S**.....**E**
Name of Villager.....

King Nehale Conservancy (Residents or Users of Resources)

(a) Personal Details:

- (i) Sex male () female ()
- (ii) Age: (a) 15 – 25 () (b) 26 – 35 () (c) 36 – 45 ()
(d) 46 – 55 () (e) 56+ ()

(b) Size of household:

- (i) Less than 5 () (ii) Between 6 and 9 ()
- (iii) 10 – 15 () (iv) More than 16+ ()

(c) Occupation

.....
.....
.....
.....

(1) When did you start living in this area?

.....
.....
.....
.....

(2) What attracted you to settle in this area?

.....
.....
.....
.....

(3) Would you describe the activities you do for your living here?

.....
.....
.....
.....

(4) Have you ever had a paying or salaried job?

.....
.....
.....
.....

(5) Explain the status of landownership here and do you own the land you are using?

.....
.....
.....

.....
(6) Would you describe your relationship with government Environment/ Forestry/
Officials in the management of land and natural resources?

.....
.....
.....

(7) Is the community involved in the management of plant resources in this area with
GRN?

.....
.....
.....

(8) What are your comments on the way plant resources are managed in this area by
GRN and communities in general?

.....
.....
.....

(9) What makes plant resources important to you?

.....
.....
.....

(10) Which wild fruits are harvested in this area?

.....
.....
.....

(11)What are your views on conservation or the protection of plant resources in relation
to your livelihood?

.....
.....
.....

.....
(12)Do you harvest Kalahari Melons?
.....
.....

.....
(13)If so, how do you harvest KMS?
.....
.....

.....
(14)How do you compare the abundance of KMS today compared to 2000 – 2002? What
do you attribute this to?
.....
.....

.....
(15)Are you aware of any KMS germination and reproductive methods?
.....
.....

.....
(16)Can you mention KMS distribution patterns that you are aware of?
.....
.....

.....
(17)Do you plant KMS or support initiatives to grow KMS within your area i.e.
intercropping with Mahangu?
.....
.....

.....
(18)What amount of KMS to you harvest in the field and what is the estimated yield?
.....
.....

.....
(19)How do you process your KMS yield?
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.....
(20)What to do or how you use the excess processed KMS?
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.....

(21)How much income do you earn from this, is this income sufficient to maintain your household?

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.....

(22)How many months per year are you involved in the harvesting of KMS?
(days/month)

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.....
.....

(23)Can more people to be involved in the harvesting of KMS and other resources? What are the other alternatives?

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.....

(24)How is KMS managed, or how can it be managed more efficiently?

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.....

(25)Which animals utilize the melon? How do prevent or encourage animals feeding on KMS?

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.....

(26)If the cultivation of KMS is necessary, what do you need assistance with e.g. access to water, treated seeds, land?

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.....
.....

(27)How do see the future of KMS and its expected yield?

THANK YOU

Appendix II

Interview Questions for Key Informants

Ministry Officials/ Community Leaders/ NGOs

1. What is the general state of forests products in the area?

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2. Do the current management policies meet the requirement for the effective management of plant resources?

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3. To what extent is the implementation of the relevant plant protection policies meeting their stated objectives?

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4. Do the provisions of these policies adequately address the needs of the local communities?

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5. What is the status of KMS in the area?

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6. Do you think that the current exploitation of KMS meet the demands of the local communities?

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7. What are the anticipated future management policies of the KMS and other forest products?

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8. How does your organization assist the local communities with regard to forest products i.e. provision of seeds, offering advice on resource use?

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9. How is the relationship between your organization and the local communities in managing forest product resources?

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10. How often to carry out field researches on forest products? What is the current status of KMS today compared to five years ago?

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11. What are some of the constraints faced by your organization in the management of forest product resources?

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12. Are there any measures that your organization is taking to solve some of the problems mentioned?

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THANK YOU

Appendix III

Local Community Group Discussion Topics

1. Livelihood activities and other survival strategies
2. Participation in Forest Resource Management
3. Relationship with government forestry officials
4. Importance attached to forest resources by local communities
5. Views about the state of KMS today, and the future
6. Major problems regarding forests and possible solutions

Appendix IV

The score sheet for rating of crop production and small house gardens from the different villages.

	Responses from villagers (out of 10)													Total score	Ranking
	1	2	3	4	5	6	7	8	9	10	11	12			
Maize															
Sorgum															
Millet															
Pumpkin															
Beans															
Groundnuts															
Melon															
Tomatoes															
Green Veg.															
Other															

Appendix V

The score sheet for the utilization of economically important wild vegetation

	Responses from villagers														Total score	Ranking
	1	2	3	4	5	6	7	8	9	10	11	12				
Construction poles																
Craft making																
Fuelwood																
Thatching grass																
Edible plants																
Medicinal plants																
Other																

Appendix VII

Ranking results from the questionnaire based on the utilization, harvesting and planting of Kalahari melon. Responses from 30 people who participated in the questionnaire. (Rank: Yes – 1, No – 0)

Responses from villagers
(n = 30)

Use	Frequency	Percentage (%)	Rank
Actively plant melons	20	66.7	3
Germination problems	3	10	4
Excellent yield	3	10	4
Household consumption*	30	100	1
Animal feed	30	100	1
Processing of KMS	23	76.7	2
Trading of oils	23	76.7	2
Leave for animal grazing	30	100	1

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

Appendix VIII

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

General treatments	Location	Specific treatments	Results (GP ± SE)
Fruits classes	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	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	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	Greenhouse	Control	13 ± 0.57
		H ₂ SO ₄ (1 s)	42 ± 2.52
		H ₂ SO ₄ (5 s)	48 ± 2.92
		Scarified	14 ± 0.93
	Ondangwa	Control	16 ± 0.80
		H ₂ SO ₄ (1 s)	54 ± 3.30
		H ₂ SO ₄ (5 s)	70 ± 4.12
		Scarified	18 ± 1.21
Essential Microbes	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	Greenhouse	Control	10 ± 1.04
	Ondangwa	Herbivore manure	18 ± 1.83
		Control	16 ± 1.43
		Herbivore manure	22 ± 7.65