DOCTOR OF PHILOSOPHY

Cordeauxia edulis (Yeheb) : resource status, utilisation and management in Ethiopia

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Award date:
2010

CORDEAUXIA EDULIS (YEHEB): RESOURCE STATUS, UTILISATION AND MANAGEMENT IN ETHIOPIA

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June, 2010

ABSTRACT

A study aimed at improving the management and utilisation of *Cordeauxia edulis* was conducted in Boh district, Ogaden, Somali National Regional State of Ethiopia between April 2007 and October 2009. The study had five major objectives: to analyse traditional knowledge of *C.edulis*; to determine the ecological, biological characteristics of the species and nutritional composition of its fruit; to determine population status and associated tree species growing with *C. edulis*; to develop efficient propagation methods; to develop appropriate village level harvesting and storage methods and improved market possibilities for nuts of *C. edulis*. C. *edulis* was found to occur in ten villages in Boh district and all were included in the study. Indigenous knowledge was investigated using PRA tools including structured and semi-structured interviews, key informant interviews, focus group discussions and field observation. Soil characterisation and nutritional composition of the nuts were conducted by laboratory analysis. Phenological study was carried out on 100 randomly selected mature *C.edulis* shrubs (10 from each village) of *C. edulis*. For the study of the population structure of C.*edulis* a total of ten plots (10 x 10 m) were laid out at 100 m intervals along a transect of 1 km in each population. Experiment on propagation from seeds was conducted in Jijiga while vegetative propagation from stem cutting was carried out both at the study site (Boh) and Jijiga in non-mist propagators, nursery and lath house. The results of the study showed that *C. edulis* is a multipurpose shrub species used for food, construction, fodder, fuel wood and medicine by the local communities. The fruit of C.*edulis* is sold in local markets generating a household income ranging from 50 % to 56 %. C.*edulis* is a communal resource with no management or control of utilisation which has led to overexploitation of the species by overcutting, overbrowsing and nut overharvesting. Soil analysis of the study site showed that the soil is sandy loam, slightly alkaline and poor in organic matter and essential nutrients such as, available phosphorus, potassium and total nitrogen. Nutrients including Ca, total N, and organic matter were higher under the *C.edulis* than further away, moreover and with exceptional Ca were higher in the soil surface than in the subsoil. Phenological study indicated that C.*edulis* flowers and produces fruit twice a year due to two rainy seasons (March to June and September to December) and showed strong positive relationship with seasonal precipitation. The result of the nut analyses revealed that it is characterized by high carbohydrate (36%) and fat (13%) contents. C.*edulis* density varied from 30 to 110 clumps ha^{-1}; no seedling was recorded in six of the populations studied and only one seedling was recorded in one plot in each of the remaining four populations. The most common associated species were *Acacia* spp, *Commiphora* spp and *Boswellia neglecta.* Propagation from seed was the most efficient method whereas vegetative propagation was not a success. Seed germination (%) and growth performance were significantly enhanced by seed pretreatment. The highest seed germination (72%) and growth performance were recorded in seeds pretreated with boiling water, sown in the study site soil (Boh) and watered once a day. Harvesting physiologically matured fruits and treating them with biopesticide (Leaf of Neem tree) extended the shelf life of the fruits by one year in storage, while fruit harvested in premature stage were all attacked by insect pests within six months. Immediate actions are needed using information generated by the present study to save the species from extinction.

DEDICATION

To my daughter Mihim Mussa and my wife Ubah Ahmed who shared the feelings of loneliness while I was away for studies. To my mother Safiya Adem and my brother Abdi Mohammed for their invaluable contribution towards my success. Finally, I am dedicating this work to my father Mohammed Yusuf who died when I was in primary school. May your Soul rest in Peace, Amen!

ACKNOWLEDGEMENTS

This thesis was produced with the support of funding from Leverhulme Trust through the project "Improved management and utilisation of wild fruit trees in east Africa, contract number: F/00 174/k''. This thesis is an output of studies supported by many people.

First of all, I would like to express all my gratitude to my supervisor Dr. Zewge Teklehaimanot of the Bangor University, Wales, for his tireless guidance, support, advice, constructive criticism, encouragement, dedication and patience during production of this work. This work could not be performed without him. Dr. Deribe Gurmu, Forestry Research Centre, Addis Ababa, Ethiopia, to whom I am most grateful, supervised the field work.

Special thanks are extended to administration and management teams of Somali Region Pastoral Agro-pastoral Research Institute (SoRPARI) Jijiga Agricultural Research Centre (JARC). I want to mention Dr. Ahmed Shekh Mohammed (Director of SoRPARI), Takele Dejene (Entomologist in Crop Department), Zelalem Fisaha (Agronomist in Crop Department), Iwqet Taye (Nursery technician in Forestry Department) and all other staff of Forestry Department.

I would like to thank local leaders, pastoralists and Boh district administration of the study site for their support, encouragement and participation during my field work. I won't forget Bureau of Agriculture in Jijiga, who allowed me to carry out soil analysis in their laboratory.

I wish to say thank you to Dr. Asha Yahya who helped me in providing previous literature on *Cordeauxia edulis*. The tireless effort of technical assistances; Abdinur Yusuf, Abdi Abdulahi, Amin Mumin and Hussein Mohammed are highly appreciated.

Laboratory analysis on nutritional composition of fruit was carried out in Bangor University with the help of Dr. Jacqualyn Eales and her assistance is highly appreciated. I

am highly indebted to my colleagues Jacob Agea, James Kimondo, Rafat Abuhassan, Clement Okia and others who encouraged me during writing this thesis in Bangor University.

Last but not least, I express my heartfelt gratitude to my family and whoever contributed directly or indirectly towards the completion of the thesis.

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LIST OF SYMBOLS AND ABBREVIATIONS

Av.P:	Available Phosphorus
ANOVA:	Analysis of Variance
CEC:	Cation Exchange Capacity
C/N:	Carbon Nitrogen Ratio
CSA:	Central Statistical Authority
DPPC:	Disaster Prevention and Preparedness Commission
EC:	Electrical Conductivity
FAO:	Food and Agriculture Organization of the United Nation
IUCN:	International Union for Conservation of Nature
NAA:	Alpha-Naphthalene Acetic acid
NAS:	National Academy of Science
NGO:	Non-Government Organization
OM:	Organic Matter
OC:	Organic Carbon
P+C:	Pure local soil plus Compost
P+S:	Pure local soil plus Sand
P+S+C:	Pure local soil plus sand plus compost
PRA:	Participatory Rural Appraisal
SERP:	South East Range Project
SNRS:	Somali National Regional State
SPSS:	Statistical Package for Social Sciences
SS:	Site soil
SSI:	Semi-Structured Interview
SSh:	Somali Shilling
TN:	Total Nitrogen
US:	United States of America
UK:	United Kingdom

CHAPTER-I

INTRODUCTION

1.1 Background and Justification

Cordeauxia edulis Hemsley (Yeheb, Yicib, Ye-eb) is a multi-stemmed ever green shrub or small tree (Thulin, 1983). It belongs to the family *Fabaceae (Caesalpinioideae)* and is the only species within the genus *Cordeauxia* (Kucher, 1987; Ali, 1988). Its native distribution is restricted to open bush savannah in arid and semi-desert regions of Ogaden, Ethiopia and central Somalia (Kazmi 1979; FAO 1988; Bally, 1966; Chiovenda, 1929).

C. edulis is a nut producing wild plant with multipurpose usage. The seeds and the leaves are important sources of food for humans and fodder for livestock, particularly during the dry season (El-Zeany and Gutale, 1982). Moreover, it is used for fire wood, building material and for dyeing of textiles for garments (Booth and Wickens, 1988) and medicinal value is also reported by local people (Brink, 2006).

C. edulis is highly valued for its nut which is locally called *Yeheb.* The nut constitutes one of the staple foods of the nomads of the regions, where it occurs (Bally, 1966). Furthermore, Brink (2006) emphasised that it is a nutritious quality food that the local people prefer to stable crops such as maize and sorghum. The nuts are eaten fresh, roasted, boiled or dried and used as an energy rich food (especially valuable during droughts) for the local population in the border areas of Somalia and Ethiopia (Booth and Wickens, 1988). The harvested nut is sold on the market and is exported to the coastal cities of Somalia as source of income to the local people (Miège and Miège, 1978).

C. edulis plays a vital role for livestock production as a dry season feed (Kucher, 1987; Ali, 1988). Animals mostly camels and goats, but also including sheep and cattle browse it (Brink, 2006; Bally, 1966). Pastoralists claim that meat from animals fed on yeheb is particularly tasty and that teeth and bones of foragers become stained bright orange due to the cordeauxiaquinone present in the leaves (Booth and Wickens, 1988).

Because the cordeauxiaquinone forms vividly coloured and insoluble combinations with many metals, leaves have been used to dye cloths, calico and wool (Booth and Wickens, 1988). Leaves are also used to make tea (Greenway and Raymond, 1947). Yeheb wood is used as fuel wood and as a construction material by villagers and nomads (Vietmeyer, 1985). Villagers use yeheb nuts as medicine to regulate gastric secretion and for treatment of ulcers. It is also believed that the nuts can be used to alleviate anaemia by augmenting the number of red blood cells (Brink, 2006).

The population of *C. edulis* is in great danger of extinction (Bally, 1966) and today remaining stands are progressively being destroyed (Hemming, 1966). This is due to over-exploitation including long term heavy grazing pressure, over-harvesting of seeds for food, and over-cutting for fire wood and construction (Booth and Wickens, 1988; FAO, 1988). According to Vietmeyer (1985), Ali (1988) and Assefa *et al.*, (1997) periodic droughts, wars, fire and erosion in the region during the last decades, have resulted in a decline in yeheb populations over most of its former habitats, where it was once the dominant shrub species. Moreover, Bally (1966) emphasised that its distribution area is rapidly diminishing because of the increase of the population and their herds; the plant is very much exploited, men harvest almost all the seeds for their own consumption and for sale. This leads to poor, or no natural regeneration (Kazmi, 1979; Nerd *et al*, 1994). As a result yeheb is now listed as an endangered species for extinction by International Union for Conservation of Nature (IUCN, 1997).

Brink (2006) recommended that it is necessary to make efforts to domesticate yeheb in order to prevent its extinction and to develop its commercial and economic benefits for the local people to contribute to poverty reduction and food security. According to Bally

(1966), Kazmi (1979) and Nerd *et al,* (1994) previous efforts to domesticate the species and also to introduce it outside its natural habitat have met with failure as a result of poor seed supply, lack of agronomic techniques and water necessary for establishment. Protection of the species in its natural habitats and the use of the species in afforestation projects were also recommended by Bally (1966) and Hemming (1966).

The present research was undertaken in the Somali region of Ethiopia to provide answers to some of the issues that arose from past efforts in the protection, cultivation and domestication of *C. edulis.* The main aims of the present project were to assess the current status of the species in the region and to develop methods and strategies for its improved management and utilisation.

1.2 Objectives:

The research project had five major tasks.

Objective 1: To collect and analyse traditional knowledge, local opportunities and constraints and develop strategies for improved management and use of *Cordeauxia edulis*.

Objective 2: To describe the ecological and biological characteristics of the species in the study area and the nutritional composition of its fruits.

Objective 3: To describe the population status and associated tree/shrub species of *Cordeauxia edulis* in study area

Objective 4: To develop efficient and low technology propagation methods as well as produce improved planting materials for domestication of *Cordeauxia edulis*.

Objective 5: To develop appropriate village level improved harvesting and storage methods, and improved market possibilities for nuts of *Cordeauxia edulis*, thus increasing the value added and income from the nuts.

1.3. Thesis outline

This thesis contains eight chapters. Chapter one provides the background to the present study, project objectives and description of the study sites including geographical location, population and livelihood, and biophysical environment. Chapter two provides a literature review of the species. Chapter three consists of an introduction to the indigenous knowledge and local opportunities and constraints of *C.edulis,* the methodology used in the study of indigenous knowledge and local opportunities and constraints, the results of the study and a discussion are presented, respectively. Chapter four consists of an introduction to the ecological and biological characteristics of *C.edulis* and nutrient composition of its fruit, methodology used in the study of ecological and biological characteristics of *C.edulis* and nutrient composition of its fruit, the results of the study and a discussion are presented. Chapter five an introduction to the population status and associated tree/shrub species of *C.edulis,* a description of the methodology used to conduct study on the population status and associated tree/shrub species of *C.edulis*, the result of the study and a discussion. Chapter six is concerned with the study of efficient propagation methods of *C.edulis*. Chapter seven deals with improved harvesting and storage method, and improved market possibilities for nuts of *C. edulis* also divided. Finally, chapter eight provides general discussion on all the results of the previous chapters and general conclusions and recommendations of the present research.

CHAPTER-II

LITERATURE REVIEW

2.1. The Species

2.1.1. Nomenclatural history and synonymy

Cordeauxia edulis was first documented by the Italian, Robecchi, in 1871 when exploring Somaliland (Michelozzi, 1957). It was next recorded by the British Captain Wellby in his report of a journey to Somaliland in 1895. About 10 years later, seeds were forwarded to the Imperial Institution in Kensington, England by Colonel Swayne, Commissioner of Somaliland Protectorate. A second shipment from the same source was again sent to Professor Church, who then took them to the Royal Botanical Garden, Kew, England for identification. Unfortunately their identity could not be established from the seeds. Thus, the early effort to obtain botanical specimen failed (Hemsley, 1907).

However, in July 1907, the botanical samples of *C. edulis* (Yeheb) were obtained by Captain H.E.S CORDEAUX in the Ogaden province, Ethiopia. To commemorate Capt. CORDEAUX's successful endeavour W.B. HEMSLEY (1907), who drew up the description, named the new genus *Cordeauxia* and gave the species the epithet edulis = "edible". Thus, it is now botanically known as '*Cordeauxia edulis* Hemsley' (Bally, 1966)

In addition to Captain Cordeaux's specimens, several other colonial officers collected specimens and seeds which were sent to different institutions. Major Glover sent a consignment of fruits and seeds to the Amani Institution Herbarium in England from which they were distributed then to Kew, South Africa, Jamaica and United States for cultivation (Greenway and Raymond, 1947).

The local vernacular name for *C.edulis* is Yeheb. However, there are different guttural sounds or pronunciations of Yeheb including, Yecib, Yicib,Yeceb, and Ye-eb that are used by local communities to name the species. In central Somalia, around Beledweyne, it is also called Jeheb (jicib, Jecib giaeb, giaheb, gieheb) (Cufodontis, 1955). The name of plant is actually `Gud` with yeheb designating the fruit. Internationally, however, yeheb has been used interchangeably for the plant and its fruits (Kuchar, 1987).

2.1.2. Systematic position

Yeheb belongs to the family *Leguminosae* and the subfamily *Fabaceae* or *Caesalpinioiceae* (Booth and Wickens, 1988). Well-known members of *Caesalpinioiceae* in Somali region include lebi (*Delonix elata*), jaleelo (*Senna, Cassia*) and hamar (*Tamarindus indica*). *C.edulis* is the only species within the genus *Cordeauxia* (Kucher, 1987; Ali, 1988).

2.1.3. Description

Seedling

Germination of yeheb seeds is epigeous, producing sprouts with thick cotyledons, and with the number of leaflets varying between individual plants (Plate 2.1). The leaves are alternate (Miège and Miège, 1978). It shows initial fast growth of a tap root and slow shoot growth; plants of 60 cm shoot have roots of 2 m (Booth and Wickens, 1988).

Plate 2.1 *Cordeauxia edulis* seedling, about 2 months after sowing (Source: Liew, 2003)

Mature tree

Mature tree is allied to Schotia and Stuhlmannia and is a multi-stemmed shrub or small tree with thick and erect branches (Miège and Miège, 1978); the numerous stems are ascending, much-branched, forming a tightly bunched crown; the branchlets close to the ground are foliated where they are not denuded by browsing cattle (Bally, 1966). In the early stages of growth, C.*edulis* is single stemmed. Mature plants are multi-stemmed shrubs in which most of the stems arise from the base of the plant near the ground. Stems branch and rebranch at rather narrow angles forming an erect crown with a conic shape. It is an evergreen small tree, with height of not more than 2-3 meters (Ali, 1988). It can be higher in sheltered spots where the plant is not grazed. Yeheb can reach 3-4 m and for this reason it is sometimes classified as a small to medium sized tree (Miège and

Miège, 1978; Kazmi 1979). However, it is reported that *C. edulis* is usually dwarf and not taller than 1.6 m because of browsing of its tender shoots and leaves by livestock (Kazmi 1979). Bally (1966) confirmed that the mature yeheb plant is many-stemmed shrub not exceeding and rarely reaching a height of 7ft (about 2 m).

Plate 2.2 Matured shrub of *Cordeauxia edulis* in Boh, Ogaden, Ethiopia

Foliage: Yeheb foliage is persistent, leathery, paripinnate and measures 2-8 cm in length, with 2-4 pairs of leaflets that are oval to oblong, 1.7-3.6 cm long and 0.43-2.0 cm wide (Ali, 1988; Miège and Miège, 1978; Bally, 1966). Leaves are olive green above and lighter on the underside with numerous purple to orange red glandular hairs on both sides and numerous and characteristic stomata (Miège and Miège, 1978; Bally, 1966). The glands contain a red pigment, cordeauxiaquinon, which can stain the hands red when touched (Lister *et al*, 1955; Bally, 1966). The stomata occur both on the adaxial and abaxial surfaces of the leaflets. Both sides of the leaf are covered by an extremely thick cuticle. All of the mesophyll cells consist of 'concertina' palisade cells. These are suggested to shrink under water stress, and thereby causing the cell walls to fold, which leads to curling of the leaves. This happens as soil moisture content drops.

At the onset of the first rain, indicating the end of the drought period, the leaves uncurl and regain their turgidity (Miège and Miège, 1978).

Roots: The root system is dominated by a central taproot, which reaches a depth of greater than 2 m. Lateral roots form 10 cm and 40 cm below the soil surface, and spread horizontally a distance of 2.3 m. These lateral roots rebranch at intervals forming a profuse network of medium and fine roots (Ali, 1988). Different information was written about whether root has nodules or not. Nodules have been reported on younger roots (Booth and Wickens, 1988). However, Assefa *et al.* (1997) did not find any nodulation on roots, neither in field excavations nor in rhizobial inoculation trials in containers.

Inflorescence and flowers: Floral and vegetative auxiliary buds develop apically and laterally from the branchlets (Ali, 1988). The inflorescence is few-flowered corymbs that form at the end of the branchlets. The flowers are 2-5 cm in diameter and each flower is composed of 5 obtuse glandular sepals about 1 cm long. Sepals are covered with red glands like leaves, 5 spatulate unguiculate yellow petals 1.5 cm long, and 10 free stamens with hairy filaments on the lower half. The ovary is short- lay stalked and heavily glandular, surmounted by an obtuse stigma (Miège and Miège, 1978; Bally, 1966).

Pod and Nut: The rather leathery, compressed, ovoid, more or less shrivelled pod is 4-6 cm long (Figure 2.2). The pods with fairly hard walls leathery skinned terminate in a protuberant beak, contains usually one, occasionally two ovoid seeds about the size of an almond (El-Zeany and Gutale, 1982; Bally, 1966). Miège and Miège (1978) reported that pod contains 1-4 seeds; on 191 fruits counted, 27.8% containing one seed, 50.8% with 2, 18.3% with 3, and 3.1% with 4 seeds. Ali (1988) also found that large-leaf forms of *C.edulis* (Muqleey) have pods that contain more than one seed but the small-leaf form (Suuley) produces pods that contain a single large seed. Each or single seed weighs about 2-3 g (Nerd *et al.*, 1994) and the number of chromosomes are 2n=24 (Miège and Miège, 1978; Brink, 2006).

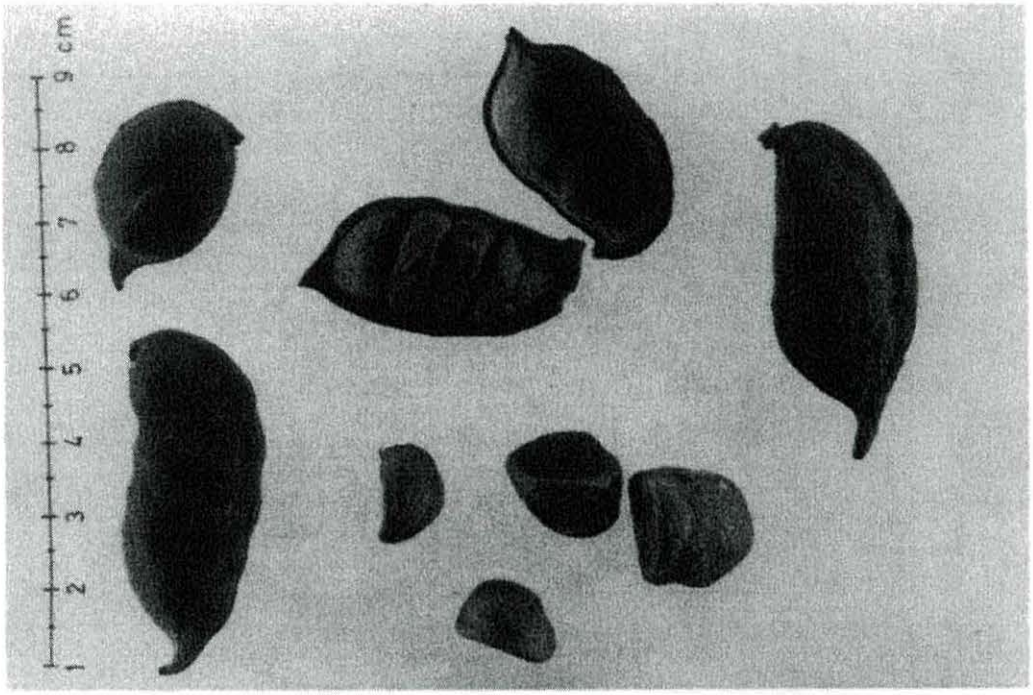

Plate 2.3 Pods containing a variable number of seeds (1 - 4), and seeds

(Source: Miège and Miège, 1978)

Two different forms of yeheb were described, usually in pure stands. The *`Suuley'* form is smaller, usually less than 1.5 m in height with an open spreading habit and ovoid sweet tasting seeds of 1.8 g. The *`Muqleey'* form is more common, taller and erect with less sweet seeds of 1.3 g (Booth and Wickens, 1988; FAO, 1988).

2.2. Biology

2.2.1. Life cycle

Flowering of *C.edulis* commences a few days before rainy season (Ismail, 1975). There is no information on pollinating insects. Floral parts fall soon after pollination, leaving a fertilized ovary (Wickens & Storey, 1984). Fruits take 10-14 days to mature depending on the amount of rainfall (Brilli and Mulas, 1939). If the rains fail, fertilised ovaries remain undeveloped up to 4-5 months, until the next rains when they may ripen in 5-6

days (Ismail, 1975). Seeds are self seeding and germinate rapidly after dispersal, between a few days and up to two weeks (Booth and Wickens, 1988; Ismail, 1975; Greenway and Raymond, 1947). It takes 3-4 years from germination until the plant begins to bear seeds (Kazmi, 1979) and longevity is estimated in excess of 200 years (Ismail, 1975).

2.2.2. Phenology

C.edulis starts new vegetative and floral development, initiated in the previous rainy period, at the onset of the rainy season, flowers develop to the first stages of fruit formation (Ali, 1988). Booth and Wickens (1988) also reported flowering starts when relative humidity increases, a few days before the rainy season. If abundant water/rain is available, yeheb can flower twice but usually only once annually (Booth and Wickens, 1988). Miège and Miège (1978) reported that flowering occurs throughout the year, but is more profuse during the rainy season. The pollinating insect is not known but floral parts fall soon after pollination leaving only the fertilised ovary (Booth and Wickens 1988), but, can remain underdeveloped for up to 4-5 months if rain fails (Ismail, 1975). Besides, Ali (1988) found that sometimes fertilized ovary or fruits go into a diapauses stage and maintain that form through the dry season. Fruits continue their development at the onset of the next rainy period and mature within a few days.

Unlike most plants, seeds of C.*edulis* mature when the plant is at its highest water content. A water content of less than 55% was found in the leaves during vegetative periods when there was still considerable water in the soil (Ali, 1988). The leaves exist for more than one season, but the lifespan of individual leaflets are not known (Curtis *et al*, 1996; Ali, 1988).

2.2.3. Reproductive biology

C. edulis is bisexual or monoecious (Brink, 2006), that is, both male and female flowers occur on the same individual plant. As mentioned in the phenology section, the pollinating insect is not known, but floral parts fall soon after pollination leaving only the fertilised ovary. Depending on rainfall fruits normally take 10-14 days to mature (Booth and Wickens, 1988), but fertilized ovary go into a diapauses stage (if not enough rainfall), in which they remain throughout the dry season or 4-5 months. It can develop and ripen within 5-6 days in next rainy season (Ali, 1988; Ismail, 1975). Seeds are self reseeding or dispersed by other agents (Booth and Wickens, 1988).

2.3. Ecology

2.3.1. Geographical distribution

2.3.1.1 Origin and affinities

C. edulis is native to the semi-desert and arid zones of the horn of Africa (Central Somalia and Ogaden of Ethiopia) (Kazmi, 1979). Brink (2006) also mentioned that *C.edulis* is endemic to south-eastern Ethiopia (Eastern Ogaden) and central Somalia. It grows in Ogaden, Ethiopia, south of Damel, west of Boh and Gherlogubi, north and north-east of Scillavo and El Abed along the Ethiopia and Somalia border. Furthermore, it occurs in Somalia around Dusamareb, to the south of Bura and Galcayo, to the west of Uarandi and to north of Adwalif and Gofaddo. It almost reaches the shores of the Indian Ocean at the level of Obbia, to the south-west, but does not reach the Shebelle valley (Kazmi, 1979).

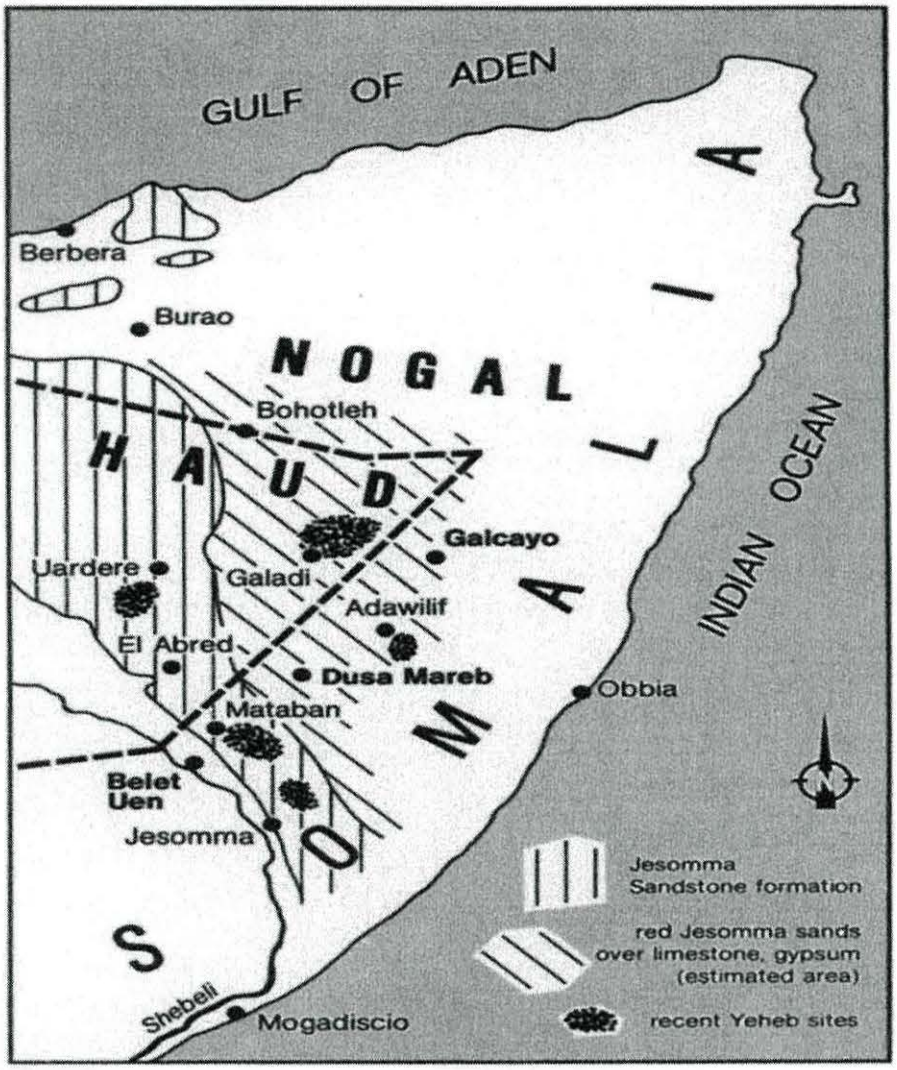

Figure 2.1 Natural distribution of *Cordeauxia edulis* and the dominant red sands (Source: Bally, 1966; Hamming, 1966)

2.3.1.2 Present distribution and Range

No previous literatures nearly on current distribution of *C.edulis*, however it reported that Yeheb areas are now considerably reduced and that the shrub has disappeared from many regions cited by earlier travellers; this impression appears to be borne out by other recent collectors like P.E Glovers and C. Hemming who seem to have encountered it only between Scillavo and Uardere in the Ogaden, Ethiopia. The enquiries made in Galkayo, Somalia, where Wellby and Gilligan as well as Drake-Brockman had found it

in earlier years, elicited that the nearest locality was now some 50 miles away to the north-west, south of Bohotleh, in the neighbourhood of Boh, the very region whence Capt. Cordeaux obtained his botanical specimens. This seems to the most important yeheb concentration at present (Bally, 1966).

Little progress has been achieved in introducing *C. edulis* outside of its natural habitat. Attempts to grow the species have been made in Kenya, Tanzania and Israel (Bekele *et.al*, 1993; Nerd *et al.*, 1994), Sudan, Yemen, India, Australia and USA (Veitmeyer, 1985; FAO, 1988). The seeds seem to germinate well (up to 80% germination) but establishing the seedlings in the field has been less successful. Seedlings were planted at four sites in the Negev Desert (Israel), but plants established and grew at only one of the sites. The reason for failure is not known but Nerd *et al.* (1994) suggested that the climate was unsuitable.

2.3.2. Environmental factors in distribution

Elevation: In its native habitat, yeheb grows in open bush savannah at altitudes of 100-1000 m (Kazmi 1979; Zimsky 1990; Anonymous, 2004). But Polhill & Thulin (1989) reported that yeheb grows at altitude of 400-500 m, with a minimum distance of 100 km to the Indian Ocean (Brink, 2006)

Geology and soils: It is suggested that the plant's limited geographic distribution may be due to its special soil requirements (Drechsel and Zech, 1988; Seegeler, 1983). The main attributes of the soil of the area where *C. edulis* is found are deep red loamy sand with poor fertility and usually slightly alkaline (pH 6.7 - 8.4) (Bally, 1966; FAO, 1988). Polhill and Thulin (1989) also described that the species grows naturally in semi-desert bush land and scrub on sandy soil. Native people to the area believe that yeheb does not grow anywhere except in the "*Haud*". This name indicates a particular soil and vegetation of the area (Anonymous, 1908; Glover 1950). *Haud* is a region which includes the north-eastern corner of Ethiopia and in Somalia northeast of Mataban, and southeast to Jesomma. Yeheb occurs in some of these areas (Hemming, 1966)

The characteristic of the soils is mainly homogenous deep red sands with high rainwater infiltration (Table 2.1). Surface runoff is negligible. These areas have no incised drainage system, and nearly all the rainfall quickly percolates into deeper soil layers; loses due to evaporation remains low (Glover, 1950; Watson *et al,* 1982). The population of yeheb is well adapted to these soil conditions. Its long taproot system is able exploit water that is reserved in deeper soil for survival in drought periods (N.A.S, 1979).

Table 2.1 Soil profile description of the *Cordeauxia edulis* stands near Mataban of central Somalia

Horizon	Depth	Description
A	0–5 cm	yellowish red (5YR 5/8 dry), red (2.5YR 4/8 moist), loose granular structure, dry, clear boundary to
B_1	5–15 cm	red (2.5YR 4/8 dry), dark red (10R—2.5YR 3/6 moist), more dense, single grained and partly subangular blocky, dry, less clear boundary to
B_2	15–45 cm	red (10R–2.5YR 4/7 dry), dark red (10R–2.5YR 3/6 moist), similar to B_1, diffuse boundary to
B_3	45–110 cm	similar to B_2, except more compact.

(Drechsel and Zech, 1988)

Climate: The area is known by two rainy and two pronounced dry season. The south-western monsoon brings the main rains for a few days in March/April to May/June; the north-eastern monsoon brings the short rains from October to November. Mean annual precipitation at the yeheb sites does not exceed 220 mm, but seems to be generally higher than 150 mm (Drechsel and Zech, 1988). However, Kazmi (1979) reported that the area is a frost free region, with two rainy seasons, and an annual rainfall of 250-400 mm. But yeheb can survive on as little as 150 mm (Zimsky 1990). Anonymous (2004) found that the species grows naturally in areas with mean annual temperatures of 27-30°C. The relative humidity at 8.00 am is about 75% and at 14.00 pm about 55-65%. The local monthly range is ± 4% (FAO, 1977; Hunt, 1951). The mean monthly wind speed is 2-3 km h^{-1} except during the south-western monsoon, when they are 4-5 km h^{-1} (FAO, 1977; Griffiths, 1972).

2.3.3. *Cordeauxia edulis* as vegetation component

C.edulis is an evergreen shrub growing in a rangeland dominated by deciduous plant species mainly thorn bushes of *Acacia* and *Commiphora* (Kucher 1987; Ali, 1988). The vegetation is described by the *Haud*-type mixed bush with associated vegetations and fauna (Hemming, 1966). Different bush types occur in the Haud; it varies from thickets to low open scrub. *Cordeauxia edulis* patches are one expression of the community which is open grassland (*Aristida kelleri*) with scattered but dense clumps of dominant yeheb shrubs and other shrub species of mainly *Acacia* spp, *Commiphora* spp, *Grewia* spp, and *Cordyla somalensis*. Some taller trees of *Acacia tortilis*, *Delonix elata* and *Albizia anthelmintica* also occur (Bally, 1966; Hemming, 1966; Watson *et al*, 1982). Many plants of the *Haud* are drought resistant and semi-succulent. Termitaria of the conical pillar and columnar type also occur in the area (Macfadyen, 1950).

2.3.4. Prominence, population and representation

Among the few plants of economic importance indigenous to horn of Africa yeheb is of particular interest, although it is little known outside its region (Bally, 1966). Its prominence in the Somali-Masai floristic zone of horn of Africa is through a combination of an evergreen growth form and codominant or even dominant status in the strongly deciduous zonal vegetation of *Acacia-commiphora* bush lands (White, 1983). Other ever green species, mainly *Capparis*, inhabit these bush lands but their contribution is fractional (Kucher, 1987). Generally, reports early in this century indicate that C.*edulis* constituted 50% of the woody vegetation in many areas of the region. Today it appears to be much reduced over most of its original range, and has vanished from many locations noted by earlier travellers (Bally, 1966). The species have been chronically reduced by conflict, drought, over-grazing, over-collection of fruit for food and income, even before it is ripe, and destruction for charcoal and firewood (Anonymous, 2004) and has, therefore, become rare nowadays. As a result, it has already been declared as an endangered species by IUCN. Fortunately, the Somali people know well about its usefulness, and some have already started growing it by

producing tree seedlings in Boh, Warder Zone, SNRS (Guinand and Lemessa, 2002). Moreover, according to Yahya (2004), yeheb is threatened with extinction because of competition between humans and squirrels for the seeds as food. When people have harvested the fruits for their needs and the squirrels have had enough to eat, no seeds remain on the shrubs, and therefore, no natural regeneration occurs. In view of the high risk of extinction the National Range Agency of the Government of Somalia took the initiative to preserve this important species. An area of about 50 hectares was reserved in 1975, in Mudug region at Bali Busle and later in 1977 a small area of 25 hectares was fenced at Salah Dhadhab between Beletwen and Dusamareb. This was later abandoned due to no-productivity (Kazmi, 1979). At present, there are no reserves as a result of Somalia civil war.

2.3.5. Interactions with natural and spontaneous communities

C. edulis has the potential to be used for soil conservation, mulching, hedgerow and nitrogen fixation (Von Carlowitz, 1986; FAO, 1988; Bekele *et al.*, 1993). No information is found in the literature about the relation of *C.edulis* with natural fauna; nevertheless, according to Yahya (2004), one type of rodent called earth squirrel may facilitate the establishment of new plants by burying seeds as a food reserve, thus, giving seeds better germination conditions. Bekele *et al.*, (1993) reported that bees are visitors or consumers of flora. This hints that *C.edulis* could be used for bee forage. Despite the fact that humans, livestock, earth squirrels and wildlife, (especially baboons) are consumers of yeheb nuts (Ali, 1988), it is reported that seeds of yeheb to be self-seeding (Baumer, 1983). Yahya (2004) also confirmed that yeheb is self-seeding and because the seeds are quite large and heavy they usually germinate close to the mother plant.

2.3.6. Parasites associated with *Cordeauxia edulis*

Yeheb shrubs are essentially free from parasites (insect pests), but whitefly nymphs have been found feeding on stems. Seeds however can be infested with different kinds of parasites, weevils and moth larvae (Booth and Wickens, 1988).

2.4. Husbandry and management

2.4.1. Traditional management of *Cordeauxia edulis*

Stands of *C. edulis* have been reported as being progressively destroyed through poor management (Drechsel and Zech, 1988; Yahya and Durand, 1993; Johnson, 1996). The last decades have seen many years of droughts in the region, which has led to over-exploitation of the plant. Since few nutritious plants grow in *C. edulis'* native habitat, it is always heavily exploited; animals graze the foliage and people remove virtually all seeds. Natural regeneration is therefore believed to be slow or non-existent (Ali, 1988; Yahya and Durand, 1993).

Due to the high demand and free access to all *C. edulis* stands, the fruits are often collected from the shrubs before they have reached full maturity (Wickens and Storey, 1984). Because the fruits are collected prematurely they become susceptible to attacks by weevils and larvae. The indigenous method to combat this is roasting the freshly picked nuts, which kills insect's eggs and harden the shells, thus making them less penetrable (Kazmi, 1979). This practice of premature harvesting might be detrimental for seed viability during storage and have an impact on germinability of fresh and stored seeds. These factors are probably the main causes for poor seed supply for planting (Yahya, 2004).

2.4.2. Professional management

Seed viability of *C.edulis* is reported not to exceed a few months (FAO, 1988). Bekele *et al.*, (1993) also found that, in addition to losing viability, the seeds are susceptible to insect attack and should not be stored for a long time. Hence, it is important to use seeds quickly, within a few months after collection (Anonymous, 2004).

Yeheb occurs naturally in poor soils hence fertiliser application is probably unnecessary. Booth and Wickens (1988) found that much water is needed for establishment of seedlings. Post establishment, however, water is not necessary as it can survive up to 2 years without rainfall, but it does not flower or fruit in droughts nor if it is too humid. Once established little care is necessary, and may survive up to 200 years (Baumer, 1983).

2.4.3. *Cordeauxia edulis* as a nursery subject

Propagation by seed: The species is usually propagated by seeds (Bekele *et al.*, 1993). The number of seeds per kilogram is about 300 (Bekele *et al.*, 1993). Seeds germinate rapidly within two weeks (Greenway and Raymond, 1947; Ismail, 1975). Nevertheless, information on germination rate in the literature varies. Assefa *et al* (1997) reported 30-50% germination rate, while 70%-80% was reported by Kazmi (1979) and FAO (1988). Miege & Miege (1978) also found 80% germination rate with sound sprouts.

Nursery production of seedlings from seeds is complicated and difficult since tap root is fast developing. Thus, plantation establishment has been poor, since the plant dies if the root is broken (Kazmi, 1979; Liew, 2003). And therefore, seedlings need to be transported with care so as not to damage the taproot (Anonymous, 2004). But Kazmi (1979) suggested that seeds that are sown directly in the field will probably bring better results.

Vegetative propagation: According to Booth and Wickens (1988), exposed secondary rhizomes may regenerate vegetatively. Despite no information about how successful the method can be, vegetative propagation by cuttings can also be used. Booth and Wickens (1988) suggested that cut end must be treated with fungicide and growth hormone and rooting is induced under mist propagation. Myers (1988) reported that studies on micro propagation resulted in no success.

Protection: Long term heavy grazing pressure and fire lead to poor or no natural regeneration of *C.edulis* as it cannot withstand heavy grazing/browsing pressure of animals and the species is not fire-resistant (Kazmi, 1979; Booth and Wickens, 1988; Kucher, 1987). Many shrub species are adapted to fire, but not yeheb. Once a grass fire has swept through a yeheb stand, the shrubs cannot re-sprout, they are killed for good. Yeheb is very slow in establishment and growth. The nuts are so frequently harvested that regeneration potential is low and the chance of post-burn recovery is, therefore, essentially nil. Fortunately, fires appear to be relatively localised and sporadic in most of its range, though this has yet to be assessed, particularly in the Ogaden (Kucher, 1987).

Yeheb shrubs are essentially free from insect pests but whitefly nymphs have been found feeding on stems. Seeds can be infested with different kinds of weevils and moth larvae. Non crop specific, storage pests such as dried fruit beetle, flat grain beetle, rust red flour beetle, tropical warehouse moth and Mediterranean flour moth have been found in seeds. There seem not to be any reports of fungal, bacterial, viral or physiological diseases on yeheb (Booth and Wickens, 1988).

2.4.4. Resource character

Seedlings and vegetative shoots growth: *C.edulis* (yeheb) seedlings have poor growth of aerial parts during the early stages of development, but the root system grows very rapid. The tap root pushes deeply into the ground, exploiting as much of the water reserves as noticed in other species of desert areas (Miège and Miège, 1978). Brink (2006) also confirmed that growth of the aerial parts is very slow, especially in the seedling stage, whereas the root system grows rapidly. It is usually browsed by livestock and shoot development is reduced but expanding laterally by the formation of new branches (Ali, 1988).

Established tree growth and fruit production: The character of slow aerial growth is continuing in established trees as tap root growth is given higher priority. A 60 cm tall plant might have roots reaching 2 m. Thus, once established, the shrub can survive up to

2 years without rainfall (Booth and Wickens, 1988). It takes 3-4 years from germination until the plant begins to bear seeds (Kazmi, 1979). A shrub yields 5-8 kg of fruits per year, or none in drought years (Brink 2006; Anonymous, 2004).

2.5. Uses

2.5.1. Uses of nuts

Yeheb is a multi-purpose plant where most parts of the plant are used (Booth and Wickens, 1988). Seeds from yeheb, which are sometimes called nuts, are eaten fresh or boiled, occasionally roasted. They are mostly consumed locally and are considered as a staple food for the people of the region where it occurs (Bally, 1966). The seeds have a thin easily cracked testa and a chestnut-like flavour, eaten fresh, or boiled for sweet liquor, occasionally roasted, and make nourishing and balanced food (FAO, 1988; Miège and Miège; 1978; El-Zeany and Gutale, 1982). The water, in which the seeds have been boiled, is sweet and is sometimes used as a beverage (El-Zeany and Gutale, 1982). The plant has recently attracted much interest as a potential food crop for arid areas (N.A.S, 1979). In times of drought and famine, the nuts may be one of the few natural foods available for Somali nomads (Anonymous, 2004). Guinand and Lemessa (2002) reported that yeheb nuts are of high economic value and are considered as *'famine food'* in times of exceptional drought conditions, even though the plant needs some rain in order to develop its fruits (Ali, 1988). Wildlife, such as baboons also eat the seeds (Ali, 1988).

2.5.2. Nutritive quality of nuts

The nuts are of high nutritional value (Polhill & Thulin, 1989; Bekele *et al.*, 1993; Guinand and Lemessa, 2002). The seeds are rich in energy containing 31-41% starch, 12-25% sugars, 11-16% protein, 10-13% fats and various minerals (Miege and Miege, 1978; Seegeler, 1983; Booth and Wickens, 1988) (Tables 2.2, 2.3 & 2.4). The main characteristics of the seeds are their high sugar and fat contents compared to other seeds

of species in the Fabaceae family (N.A.S, 1979). El-Zeany and Gutale (1982) stated that yeheb seeds provide balanced diet, especially in areas where the usual legumes are impossible to grow. The energy value, 4460 kcal per kg, is twice that of the carob, *Ceratonia siliqua*, and as much as that of soya, *Glycine max* (N.A.S, 1979). Seeds are low in anti-nutritional factors and are free of toxic phytohemagglutinins, lectins, alkaloids and glycosides, however, trypsin inhibitors are present in similar proportions to *Lablab purpureus* (hyacinth bean) (Miège and Miège 1978). The major components of the fatty acids are palmitic, oleic and linoleic acid together with stearic acid (26-31%, 32%, 25-30% and 12-13%, respectively) (Table 2.3). There are only traces of linolenic acid. The oil is a non-drying type of oil (El-Zeany and Gutale, 1982).

Table 2.2 Proximate composition of the seed of *Cordeauxia edulis* and other food crops (g/kg)

Item	*C.edulis*	Maize	Sorghum	Wheat	Rice
Moisture	80 - 100	56	46	51	38
Crude protein	110 - 160	82	108	165	123
Crude oil	100 - 120	33	36	44	129
Ash	22 - 37	25	26	50	57
Total nitrogen	25	16	18	19	13
Sucrose	116 - 216	49	46	39	35
Cellulose	27 - 33	16	21	14	12
Reducing Sugar	23 - 53	-	-	-	-
Tests for Alkaloids & Glycosides	Negative	Negative	Negative	Negative	Negative

(source: Seegeler, 1981; Burns, 1971)

Table 2.3 Amino acid composition of *Cordeauxia edulis*

	Amino acids in g/100g of protein	
Essential Amino Acids	Miege & Miege (1978)	El Zeany & Gutale (1982)
Lysine	6.8	3.9
Histidine	3.5	1.3
Arginine	10.8	9.1
Threonine	3.6	2.1
Valine	4.8	1.3
Methionine	0.7	2.4
Isoleucine	3.9	Trace
Leucine	6.4	3.8
Phenylanine	3.9	1.4
Tryptophan	-	-
Complementary amino acid		
Cystine	0.6	Trace
Tyrosine	1.9	3.0
Other amino acid		
Aspartic acid	9.1	18.7
Serine	3.9	6.7
Glutamic acid	23.8	20.8
Proline	6.6	8.8
Glycine	4.9	8.2
Alanine	4.5	8.6

Table 2.4 Mineral Composition of *Cordeauxia edulis* (mg/100g)

Mineral	Bally (1966)	El Zeany and Gutale (1982)
Calcium	29.6	31-33
Magnesium	75.3	79-82
Sodium	74.5	452-493
Potassium	1211	625-633
Phosphorous	250	221-232
Chlorine	19.6	92-94
Iron	2.3	----

2.5.3. Production levels

Studies carried out on *C. edulis* stands in Central Somalia showed an average forage availability of 322-453 kg ha^{-1} and seed production of up to 1527 kg ha^{-1} $year^{-1}$ (Ali, 1988; Yahya and Durand, 1993). Considering the dry conditions and poor management at which *C. edulis* grows, its yield in forage and particularly in seeds may be considered high (Yahya, 2004).

2.5.4. Harvesting and processing

The fruits of *Cordeauxia edulis* are picked (harvested) from the plant, the fruit wall is peeled off and the seeds are placed in sacks. The nomads compete with each other for the yeheb seeds, and are often harvested before maturity (Brink, 2006), fearing someone else may harvest ahead of them (Ali, 1988). This may be a factor in the low seed viability often encountered. Usually all seeds are removed from the plant at the same time, hampering regeneration of natural stands. Fruits can be harvested twice a year, provided rainfall is adequate during both rainy seasons (Brink, 2006).

To prevent fruit from being attacked by insects, nuts are processed in such a way that, freshly picked seeds are roasted or boiled to kill insects and harden the seed coat. In this form they fetch a higher price on the market, but the practice contributes to the difficulty of obtaining viable seed for planting (Ismail, 1975).

2.5.5. Marketing

The seeds of *Cordeauxia edulis* are mostly consumed locally, but are also sold in local markets. From Ethiopia the seeds are exported to Somalia and Arab countries, but no quantitative information is available. Seeds have export potential for European market as 'dessert nuts' (Brink, 2006). There is a high demand for them; demand exceeds supply because of rapidly diminishing plant populations (Anonymous, 2004). In

Mirafadle settlement in Boh Woreda, Warder Zone, Somali National Regional State (SNRS), a tin full of nuts was sold for 4000 Somali Shillings (*ca.* 0.25 US $) in July 2001. As the nuts have a nice taste and are on top very nutritious, the tree has a considerable potential as a food crop in the driest of the semi-arid areas in the Horn of Africa (Guinand & Lemessa, 2002).

Bally (1966) also confirmed that the seeds are also sold on the local market and exported to the coastal area, where they are much in demand. However, according to Kazmi (1979), relatively small quantities of the nuts ever enter the commercial trade, and are brought to the markets in Somali towns. It is usually sold by volume measured by "*kombo*" a container which holds about 500 g.

2.5.6. Other uses

Foliage: The species is 'evergreen' and produces abundant fodder for camels and goats during the dry season (Anonymous, 2004). Plants may contribute up to half the biomass of the area and it is used by camels and goats as an important dry season browse. The estimated average forage production is 325-450 kg ha^{-1} (1.4-2 kg/plant) (Brink, 2006). Some of the livestock coming from the Central Zone of Somalia, are highly appreciated especially for the taste of their meat by domestic and foreign consumers, have a characteristic pink colour on their bones. To most Somali consumers this is a mark of quality meat from animals that have browsed *C. edulis*. Most probably the pigment found in glands in the leaves of *C. edulis,* Cordeauxiaquinone or its metabolites bring about this phenomenon as only animals that feed on *C. edulis* get this pink colour on their skeleton. This natural pigment Cordeauxiaquinone, with a brilliant pink colour, is not known elsewhere in the plant kingdom (Lister *et al.*, 1955; Harborn *et al.*, 1971).

Yeheb foliage is rich in energy when compared to standard energy content of good quality fodder available in tropical areas but, some mineral levels (P, Mg, Mn and partly Zn) would not satisfy the demands of animals if yeheb were the only source of fodder (Drechsel and Zech, 1988).

Zn) would not satisfy the demands of animals if yeheb were the only source of fodder (Drechsel and Zech, 1988).

Leaves have been used to dye cloths, calico and wool since the cordeauxiaquinone forms vividly coloured and insoluble combinations with many metals (Booth and Wickens, 1988). This pigment is easily extracted from the leaves and easily crystallised: from 380 g dry matter of leaves about 2.7 g Cordeauxiaquinone can be obtained in crystal form. The crystallised pigment can be dissolved in Chloroform, Benzol, Ethanol, but little in Ether or water. Cordeauxiaquinone does not contain nitrogen, sulphur or halogens and its molecular formula was elucidated as $C_{14}H_{12}O_7$ (Lister *et al.*, 1955). They are used by the Somalis and were used by the Italians in wartime, when there was a shortage of aniline dyes as a dye. The Somalis use approximately ½ 1b (0.2 kg) of pulverized leaves to dye 10 yards (9.1 m) of 36 inch (91.4 cm) wide calico (Bally, 1966). The leaves can also be infused to make a tea (Greenway and Raymond, 1947).

Wood: The hard wood is used as fire-wood for cooking (Vietmeyer, 1985). The twigs are also used as constructing material for houses. As yeheb is resistant against termite attacks, houses and fences made of yeheb persist for decades. The plant also protects the soil from erosion (Liew, 2003).

Medicine: Yeheb nuts and Cordeauxiaquinone is used medicinally to stimulate hemopoiesis (blood cell formation). It is used to regulate gastric secretion and for treatment of ulcers. It is also believed that the nuts can be used to alleviate anaemia by augmenting the number of red blood (Anonymous, 2004; Brink 2006). Animals fed on yeheb nuts before export to foreign countries or to the slaughterhouses, do not show any noticeable anomalies in their appearance and when examined for the most common diseases (Gutale and Ahmed, 1984).

Oil: Yeheb seed is used to produce oil. It is intermediate between liquid oils and solid fats, tastes less pleasant than olive oil, possibly useful for soaps, with a by-product that can be used for fodder or manure (Davis *et al*, 1983).

Other uses: the species is used for various purposes, including, bee forage, mulch, and nitrogen fixation (Bekele *et al.*, 1993).

CHAPTER-III

TRADITIONAL KNOWLEDGE AND LOCAL CONSTRAINTS

3.1 Introduction

Cordeauxia edulis (yeheb) produces a nutritious and tasty nut with a chestnut like flavor (El-Zeany and Gutale, 1982). Traditionally, all people living in the Somali hinterlands rely on it for subsistence. It is a staple food of nomads and sometimes the only food plant left surviving during periods of drought in the Ogaden desert (Vietmeyer, 1985).

The seeds or nuts are often eaten after boiling or roasting (Ismail, 1975). The water in which the seeds are boiled is sweet, and is drunk traditionally by Somalis (El-Zeany and Gutale, 1982). The nuts are relished by the people that the encouragement of people to work is very commonly given by quoting an old Somali proverb "Fadhi iyo fuud yicibeed lays la waa" which means "one who sit idle will not get yeheb" (Kazmi, 1979).

Yeheb leaves are palatable and mainstay of livestock fodder, especially camel and goat (Kuchar, 1987). Herdsmen claim that meat of animals fed on yeheb is particularly tasty (Bally, 1966).). *C.edulis* produces a hardwood is used by villagers and nomads as fire wood (Ismail, 1975; Kasmi, 1979; Baumer, 1983). Yeheb is also used as construction material for houses. As it is resistant against termite, houses, fences and sheds made of yeheb persist for decades (Yahya, 2004). The plant is possibly useful for soil conservation, mulching and hedgerows (Von Carlowitz, 1986). Medicinally, the cordeauxiaquinone in the leaves is useful to stimulate hemopoesis (red blood cell synthesis) in livestock (Gutale and Ahmed, 1984).

Indigenous knowledge about plant utilisation is dynamic, and is continually influenced by internal creativity and experimentation as well as by contact with external world.

Thus, there is a need for constant up-dating of plant utilisation information. There is also little information on the management that local people apply to sustain the production of this important resource. Indigenous knowledge on the use and management of yeheb is essential if the resource is to be promoted for poverty alleviation and income generation. The present research was, therefore, conducted to illicit from indigenous people the traditional use and management of yeheb to help develop strategies for the future development of the resource for poverty alleviation and income generation.

3.2 Specific Objectives:

1. To acquire, document and evaluate local people's use and management of *Cordeauxia edulis*.
2. To assess the development potential of the species to improve livelihoods of the population
3. To establish local people's criteria for selection of good quality *Cordeauxia edulis* fruits.
4. To evaluate institutional and legal opportunities and constraints to domestication of *Cordeauxia edulis*.
5. To recommend options for community based management of the species and livelihood improvement at community level.

3.2.1 Research questions

1. Do local people use *Cordeauxia edulis* (yeheb)?
2. Do local people know how to manage *Cordeauxia edulis*?
3. How does *Cordeauxia edulis* improve the livelihood of the local communities?
4. Do local people have criteria for selection of good quality fruit yielding shrubs?
5. Are there institutional and legal opportunities and constraints for domestication of *Cordeauxia edulis*?

3.3 Material and Methods

3.3.1 Description of the study area

3.3.1.1 Geographical Location

The study was carried out in Boh District, Warder Zone, Somali National Regional State (Ogaden) of Ethiopia. It is the only place where yeheb population currently found in Ethiopia.

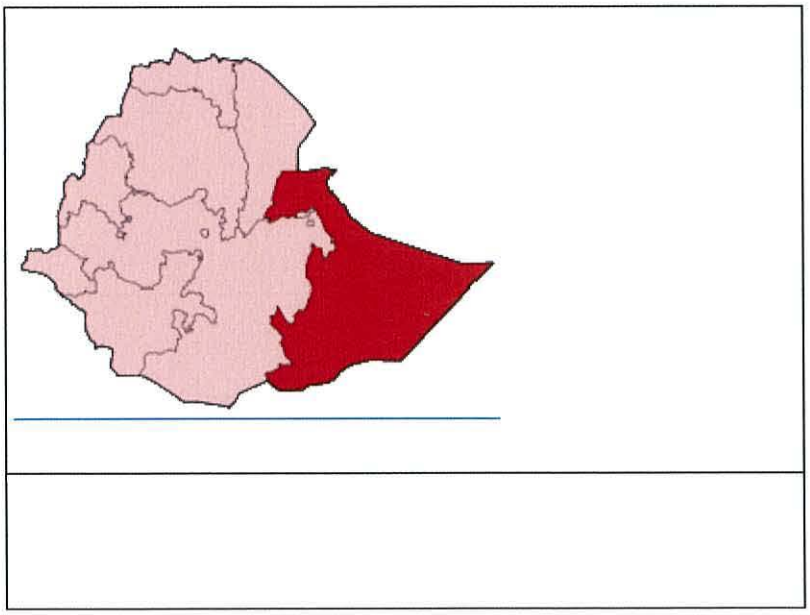

Figure 3.1 Map of Ethiopia highlighting Somali Regional State

The Somali National Regional State is situated in the eastern and south-eastern Ethiopia located between 4°- 11° North and 40° – 48° East (Figure 3.1). It is a large geographical area covering about 280,252 square kilometres, nearly equivalent to one third of the total area of Ethiopia. It shares borderline of over 2000 km with Kenya in the south, Djibouti in the north, and the Republic of Somalia in the east and northeast. It also borders Ethiopian Afar region in the north, and Oromiya region in the west (Mersie, 2005). The region is the eastern-most of the nine ethnic divisions of Ethiopia It is often

called Ogaden as the region covers much of the traditional territory of Ogaden. The capital of Somali State is Jijiga.

Warder zone is one of the nine zones in the Somali National Regional State (SNRS). It is located in the eastern 'horn' of (SNRS). It borders the zones of Degahbur to the North and Korahai to the west. It also shares borders with Somaliland (northeast), Puntland (east), and Somalia (south). Warder zone includes four districts: Warder, Danot, Geladi, and Boh.

Boh (Somali Bokh), the study district, is one of the 47 districts in the Somali Regional state of Ethiopia. Part of the Werder Zone, Boh district is located in the easternmost part of the country, at the point of the angle jutting into Somalia (Figure 3.2). It is bordered on the southwest by Geladin, and on the northwest by Danot. Towns in Boh include Boh, Dimeriad, and Marqaan Wayn (CSA, 1999).

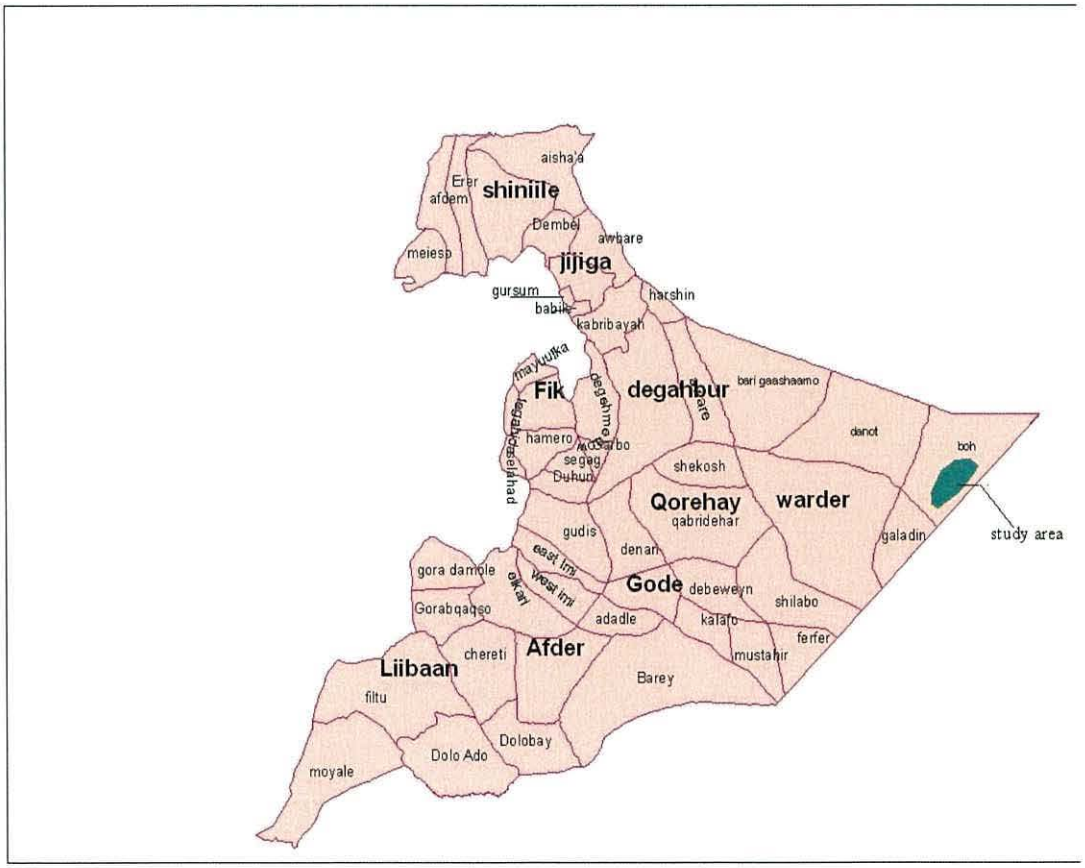

Figure 3.2 Map of Somali Regional State (Ogaden) of Ethiopia showing study site

Figure 3.3 Map showing villages of *Cordeauxia edulis*

3.3.1.2 Population and livelihoods in the study area

3.3.1.2.1 Human Population

According to 2007 census, Boh District has an estimated total population of 103,074, of whom 58,620 are males and 44,454 females; 9,188 or (9%) of its population are urban dwellers where as 93,886 or (91%) are rural inhabitants (CSA, 2007). The district has 72 villages of which 48 are large ones. A village constitutes an average of 400 - 600 households and the average household size is 7 persons (DPPC, 2004). The district is primarily inhabited by the Majerten, a sub-clan of the Somali Darood clan (CSA, 2007).

3.3.1.2.2 Livelihood

Over 85% of the population in Boh, the study area, is pastoralist and dependent upon their livestock (DPPC, 2004).

The district town also called Boh is an important trading centre for surrounding villages. The main commodities sold by the pastoralists and agropastoralists are livestock and to a lesser extent livestock products (milk and ghee). Agropastoralists also sell cereals – mainly maize and sorghum (DPPC, 2004) (Table 1.1).

Wild food consumption is frequent in pastoral societies of the district. Among the wild foods, the most frequently collected are nuts of *C. edulis* and seeds of *Acacia tortilis*. They are collected, consumed fresh and sometimes sold or traded on the local market. Nuts from *Cordeauxia edulis* are widely consumed when available. *C. edulis* usually produces nuts twice a year after the two rainy seasons locally called *'gu'* and *'deyr'* rainy seasons. The nuts are highly valued and fetch a relatively high price in local markets. In Mirafadle settlement around 30km from Boh towards Degob on the Somalia border, a tin full of nuts costs 4000 SSh (Guinand & Lemessa, 2002)

Table 3.1 Average Market prices in Boh Town between 1999-2001and in 2007 (in Somali Shillings)

Traded goods	**July 2007**	**July 2001**	**July 2000**	**July 1999**
Milk per 1Lt				
Cattle milk	10,000	6,500	3000	4,500
Camel Milk	9,000	6,000	2000	3,500
Sheep & goat milk	---	--	--	4000
Livestock per head				
Cattle	900,000	no market	500,000	600,000
Goat	175,000	135,000	100,000	160,000
Sheep	155,000	125,000	90,000	160,000
Donkey	no market	no market	no market	400,000
Camel	950,000	no market	380,000	600,000
Cereals per 50kg				
Maize	185,000	150,000	--	70,000
Wheat	120,000	95,000	90,000	45,000
Sorghum	275,000	250,000	100,000	100,000
Rice	450,000	310,000	210,000	180,000
Other basic goods				
Sugar (50kg)	500,000	380,000	180,000	190,000
Oil (1Lt)	14,348	12,667	10,000	18,000

Note: The exchange rate for Ethiopian Birr against Somali Shillings in 1999-2000 = 1EB/1000 SSH
The exchange rate for Ethiopian Birr against Somali Shillings in 2001 = 1EB/2000 SSH
Exchange rate for Ethiopian Birr against Somali Shillings in 2007 =1EB/3000SSH
Exchange rate in 2007 1 US$ = 8 EB

Sources: (Guinand & Lemessa, 2002; CSA, 2007)

3.3.1.2.3 Livestock Population

Although there are no data on exact figures of livestock in Boh district, cattle, sheep/goats (shoats) and camels are the main productive livestock reared by pastoralists. For Warder Zone which includes Boh district, 274,000 cattle, 1,372,000 sheep, 1,960,000 goats, 480,000 camels and 5,000 equine were reported in 2005 (Mersie, 2005)

Pasture surveying is common throughout the region, and it is used to inform decisions about migration. In normal (good) years, migration tends to be within home districts or zones, whereas poor years may result in migration across to other zones, neighbouring regions or even into Somalia, Kenya or Djibouti. Households often split in the dry season, with the hardier animals (*horoweyn)* being taken further field to find suitable water and pasture, usually closer to rivers and boreholes (DPPC, 2004).

3.3.1.3 Biophysical environment

3.3.1.3.1 Soil

Soils of the study area are characterised by deep and salt-free soils of red *Haud* sands. The soil has low levels of exchangeable cations, and also low levels of Zn, B, P and N, which indicate poor fertility. pH ($CaCl_2$) is 7.27-7.34, throughout the soil profile. Fe levels are high, and lime is absent (Drechsel and Zech, 1988). According to Drechsel and Zech (1988), these homogeneous deep red sands are red sandstones of continental non-salty origin and a high rainwater infiltration. Booth and Wickens (1988), Bally (1966) and FAO (1988) also described the soils as poor in fertility, extremely low in nitrogen and usually slightly alkaline (pH 6.7-8.4).

People native to the area claim that yeheb usually does not grow anywhere except in the "*Haud*". This name indicates a particular soil and vegetation type of the area (Anonymous, 1908; Glover, 1950). The *Haud* is a region which includes the north-

eastern corner of Ethiopia and in Somalia northeast of Mataban, and southeast to Jesomma. These areas are locations where yeheb stands occur (Hemming, 1966)

Surface runoff in the study area is negligible. There is no incised drainage system, and nearly all the rainfall quickly percolates into deeper soil layers; and losses due to evaporation remains low (Glover, 1950; Watson *et al*, 1982). Furthermore, N.A.S (1979) described that the population of yeheb is well adapted to these soil conditions. Its long taproot system is able to exploit water reserves from deep within soil for survival in drought periods. Macfadyen (1950) and Hunt (1951) indicated that besides the homogenous deep red sands, non-homogenous reddish sandy soils also occur in the area. The soils vary in texture from sand to loam and vary in depth. Frequent outcrops of the underlying limestone and petrocalcic horizons with a poor rainfall infiltration and pronounced runoff phenomena occur.

3.3.1.3.1 Climate and Topography

According to Vietmeyer (1985) the study area is classified as a semi-desert region, where rainfall is only 150-200 mm a year The rainfall in the natural habitat of yeheb is bimodal, in which there are two main rainy seasons, of varying reliability in April-June and October-November, and two pronounced dry seasons (Yahya, 2004). The south-western monsoon brings the main rains in a few days in March/April to May/June; the north-eastern monsoon, the short rains from October to November. Mean annual precipitation at the site does not exceed 220 mm (FAO, 1977). The amount of rainfall is higher in April and October of the two wet season. Daily rainfall pattern is unevenly distributed that of high in one day and low in the other day (Zerihun, 1999).

The area is frost free with mean annual temperature of 28°C (Drechsel and Zech, 1988). Plants in the study area can withstand extreme drought and water stress that cause leaves to fold and, in extreme conditions, to fall (Booth and Wickens, 1988).

According to Kazmi (1979), the study area is situated at altitude ranging between 300 and1000 m.a.s.l. Zimsky (1990) confirmed that yeheb requires a yearly rainfall of 250 - 400 mm, and can survive on as little as 150 mm at an altitude of 300 - 1000 m.

The relative humidity at 8.00 am is about 75% and at 14.00 pm about 55-65%. The local monthly range is ± 4% (FAO, 1977; Hunt, 1951). The mean monthly wind speed is 2 - 3 km h^{-1} except during the south-western monsoon, when they are 4 - 5 km h^{-1}. Mean annual potential evapotranspiration varies between 1,700 - 2,600 mm (FAO, 1977; Griffiths, 1972).

3.3.1.3.2 Vegetation

The study area (Boh) is described by the *Huad*-type mixed bush with associated vegetation and fauna (Hemming, 1966). Different bush types occur in the *Haud*; it varies from thickets to low open scrub. *Cordeauxia edulis* patches are one expression of the plant community which is an open grassland dominated by the grass species *Aristida kelleri* with scattered but dense clumps of the dominant yeheb bushes and other shrub species mainly *Acacia* spp, *Commiphora* spp, *Grewia* spp, and *Cordyla somalensis*. Some taller trees of *Acacia tortilis*, *Delonix elata* and *Albizia anthelmintica* also occur (Bally, 1966; Hemming 1966; Watson *et al*, 1982). Many plants of the *Huad* are drought resistant and semi-succulent (Macfadyen, 1950).

3.3.1.3.3 Water Resources

There are two sources of drinking water in the study area (Boh district) - birkats (deep wells) and boreholes. Birkats are by far the main source (DPPC, 2004). Before 1960, there was little water available during the dry season in Boh; although the Geladi wells and other shallow wells in their vicinity were used, they did not always yield sufficient water in the dry season to serve as a reliable permanent water source. So the pastures in

the district were traditionally abandoned by the local nomadic pastoralists for areas with abundant water with the advent of the dry season, like the wells of Werder, and Galkacyo, Las Anod or Garowe across the border in Somalia. Water points in the area increased when the Boh borehole was drilled in 1963 followed by Docmo and Dogob boreholes in the 1970s. Another development in the 1970s was the construction of private *birkas* (underground concrete water tanks). The building of *birkas* has also been stimulated with the arrival of refugees fleeing Somalia since 1988. While this has enabled the area that was previously grazed mainly in the wet season to be grazed throughout the dry season, it has also led to a serious decline in the native species of plants most favoured for fodder and grazing (Sugule & Walker, 1998).

3.3.2 Data collection

The study was conducted in Boh district, Somali Regional State of Ethiopia (Ogaden). It is the only place in Ethiopia where yeheb is currently found.

The overall research methodology was participatory, multidimensional and gender reflective. Study data was collected in three stages. In the first stage, secondary information relevant to the study was collected from various published and unpublished sources. Secondary information available from Regional, Zonal, District and Development Station Offices of Agriculture, Research bodies, Educational centres, NGOs, shrub user groups and other private sectors were reviewed. The secondary information was on issues of *Cordeauxia edulis* (Yeheb) local use by the pastoralists, the management of these fruit shrub and their importance in the diets and economies of the pastoralist's families. This stage helped to get the general understanding of the subject matter related to the objectives of the research before the researcher went to the grassroots level. It also contributed to develop a checklist that was used in the second stage.

In the second stage, preliminary data was collected mainly using a checklist with the application of PRA tools. Some of the most important PRA tools that were used in this

study were Semi-structured Interviews (SSI), Key informant interviews, focus group discussions, field observation, and pair wise and direct matrix rankings.

Semi-structured interviews are method conducted with a fairly open framework which allow for focused, conversational, two-way communication. It can be used both to give and receive information. Semi-structured interviewing starts with more general questions or topics. Key informant interviews are qualitative in-depth interviews with people who know what is going on in the community. The purpose of key informant interviews is to collect information from a wide range of people including community leaders, who have firsthand knowledge about the topic. These community experts, with their particular knowledge and understanding, can provide insight on the nature of problems and give recommendations for solutions. A Group Discussion is a formal discussion involving 10 to 20 participants in a group. It is a methodology used to gauge whether the candidate has certain personality traits and/or skills that it desires in its members. In this methodology, the group of candidates is given a topic, given a few minutes to think about the same, and then asked to discuss it among themselves for 15-20 minutes. Pairwise ranking is a method for ranking a small list of items in priority order. It helps to prioritize a small list and make decisions in a consensus-oriented manner. Direct matrix ranking is a method used to get preferences to be prioritised. These could be by ranking uses, general problems of tree species among the community (Carter and Beaulieu, 1992).

Focus group discussion was held using checklist of questions. Sixteen participants (including women) who have knowledge on *C.edulis* were selected from each village with the help of the local area leaders to participate in the discussion. During the group discussion, consensus was reached on the study species with regard to selected topics.

In the third stage, focused formal survey was conducted following PRA survey. A structured questionnaire was designed (attached as Appendix 1) based on the reports of PRA survey collected in the first and second stages related on the issues mentioned in the first stage. The questionnaire was pre-tested for its consistency and time required to

fill it. Enumerators were recruited and trained both theoretically and practically on how to fill up the questionnaire and interview the selected households.

The survey was conducted in all the ten villages where yeheb is currently growing. A household was the focus of the study and both men and women were interviewed for this study. The list of the households in each village was collected from local administration offices to select the samples. A minimum of 10% of the households in each village was selected randomly from the list. The number of samples in each village thus varied from 10 to 32 households depending on the number of households in each village. A total, 182 household samples were randomly selected for interview from ten villages and six enumerators were involved for completing the questionnaires.

A majority of the interviewed household heads were male, in the age category of 36 – 45 and from the Mejarten clan (Table 3.2).

Table 3.2 Sampled households and their characteristics

Village	Total No of HHs	No of sampled HHs	Sex of HH head		Age category			Clan category			
			M	F	25-35	36-45	>45	Meja	Lel	Dul	Oga
Maned	312	32	28	4	11	18	3	32	0	0	0
Godir wayis	190	20	18	2	5	10	3	1	19	0	0
Gambare	224	22	19	3	7	11	3	22	0	0	0
Mirafadle	148	14	13	1	3	11	1	13	1	0	0
Afardod	178	18	16	2	4	12	2	17	0	0	1
Damerjog	124	12	11	1	2	8	2	11	0	1	0
Dalhamur	156	16	14	2	4	12	2	14	0	2	0
Dudun	210	22	20	2	5	14	3	22	0	0	0
Foye ade	168	16	15	1	5	11	0	15	0	1	0
Dabhabalan	108	10	10	0	4	5	1	9	0	1	0
Total	1881	182	164	18	50	112	20	156	20	5	1

HH-Household, Meja-Mejarten, Lel-Lelkase, Dul-Dulbahante, Oga-Ogaden

3.3.3 Data analysis

Yin (1989) points out that data analysis consists of a number of stages, i.e. examining, categorising and tabulating in order to address the initial goal of a study. Hence, analyses of data in the present study began with preparing data; making an inventory of data for each objective, checking quality, listing and arranging in code to facilitate processing and fit particular analysis.

Data were analysed using descriptive statistics such as percentage, mean and standard error of mean which were calculated using the Statistical Package for Social Sciences (SPSS) version 12. Categorical variables were summarised and presented in frequency tables, column charts, bar charts and pie charts using spread sheet (Ms. *Excel*). Data from focused group discussion were analysed by summarising.

3.4 Results

The results are presented in four major sections: uses of *C.edulis* (yeheb), management of C.*edulis*, characters of good quality fruit yielding shrubs/trees and opportunities and constraints for domestication of yeheb.

3.4.1 Uses of *Cordeauxia edulis* (yeheb)

Figure 3.4 Summarises uses of *C. edulis* by local communities in the study area. The results indicate that 99% of the respondents used C.*edulis*, primarily, for food, followed by construction (89%), forage (86%), fuel (80%), fence (76%), and medicine (68%) in decreasing order. The results show that the species is highly utilised in every aspect by the local people.

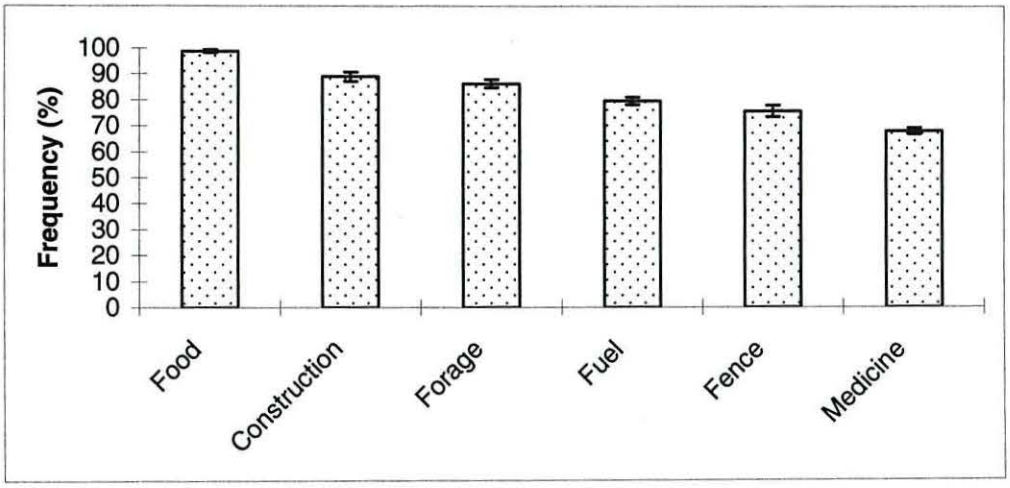

Figure 3.4 Responses (% ± SE) on uses of *Cordeauxia edulis* in Boh district, Ogaden, Ethiopia

3.4.1.1 Food

Fruit of yeheb were consumed locally in different ways (Table 3.3) and these were ranked from 1 to 4; 1 being the most frequently used method and 4 being the least used method of consumption. According to the results presented in Table 3.2, a majority of respondents (74%) consumed yeheb after roasting or boiling, while only 1% of the respondents consumed fresh fruit (Plate 3.1).

Table 3.3 Responses (% ± SE) on methods of consumption of fruit in Boh district, Ogaden, Ethiopia

	Methods of fruit consumption			
Rank	Eaten fresh	Dried	Roasted/Cooked	Soup
1	1 ± 0.7	16 ± 1.8	74 ± 2.9	9 ± 2.5
2	7 ± 2.1	6 ± 1.8	18 ± 1.5	69 ± 2.4
3	11 ± 2.9	69 ± 2.2	7 ± 2.5	13 ± 1.9
4	81 ± 2.2	9 ± 2.5	2 ± 0.9	9 ± 1.3

Rank 1, highly consumed & 4, the least consumed

Plate 3.1 Fruit of *Cordeauxia edulis* in various forms of consumption: a) fresh, b) dried, c) processed, and d) roasted/cooked and soup at Gambare village, Ogaden, Ethiopia
(Photo by: Mussa. M. Yusuf)

3.4.1.2 Forage

Figure 3.5 summarises seasonality of browsing yeheb fodder by livestock. According to the majority of respondents (90%) camels were fed on the foliage of *Cordeauxia* throughout the year, closely followed by goat (81%), while 80% of respondents reported that they fed cattle during dry season only (Figure 3.5).

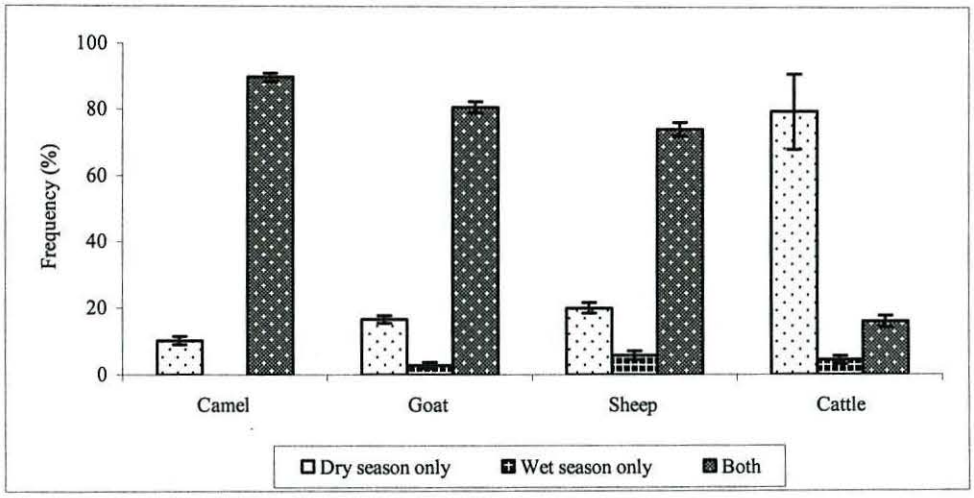

Figure 3.5 Responses (% ± SE) on season of browsing fodder of *Cordeauxia edulis* by livestock category

In Table 3.4, the preference of yeheb as livestock fodder is ranked 1 to 4, 1 being the highly preferred and 4 the least preferred fodder. 64% of the respondents reported that yeheb was highly preferred by camel, followed by goats (54%). It is the least preferred fodder for cattle as reported by 43% of the respondents.

Table 3.4 Responses (% ± SE) on preference of *Cordeauxia edulis* fodder by livestock

	Livestock			
Rank	Camel	Goat	Sheep	Cattle
No rank	20 ± 1.5	20 ± 1.5	24 ± 1.5	39 ± 1.4
1	64 ± 2.0	15 ± 1.6	6 ± 1.2	1 ± 1.1
2	14 ± 1.7	54 ± 3. 1	12 ± 2.4	5 ± 0.9
3	3 ± 1.1	10 ± 2.2	53 ± 2.1	13 ± 1.5
4	0 ± 0	0.5 ± 1.2	6 ± 1.3	43 ± 1.6

Rank 1, highly preferred & 4, the least preferred

Among the livestock, camel is the dominant browser of yeheb foliage throughout the year (Plate 3.2). Since pastoralists of Somali Regional state of Ethiopia (Ogaden) are known for rearing camel mostly, yeheb plays a vital role in the region because of its availability during both the dry and wet seasons.

Plate 3.2 Camel browsing *Cordeauxia edulis* at Maned village, Ogaden, Ethiopia

(Photo by: Mussa. M, Yusuf)

Respondents reported that animals fed on *Cordeauxia* showed unique characteristics that are not seen in those feeding on any other fodder types. Figure 3.6 shows that a majority of respondents (73%) mentioned the foliage of yeheb increased sexual desire of camels. Some of the respondents reported that it also increased camel herd size (60%), enhanced goat meat quality (62%) and production (43%).

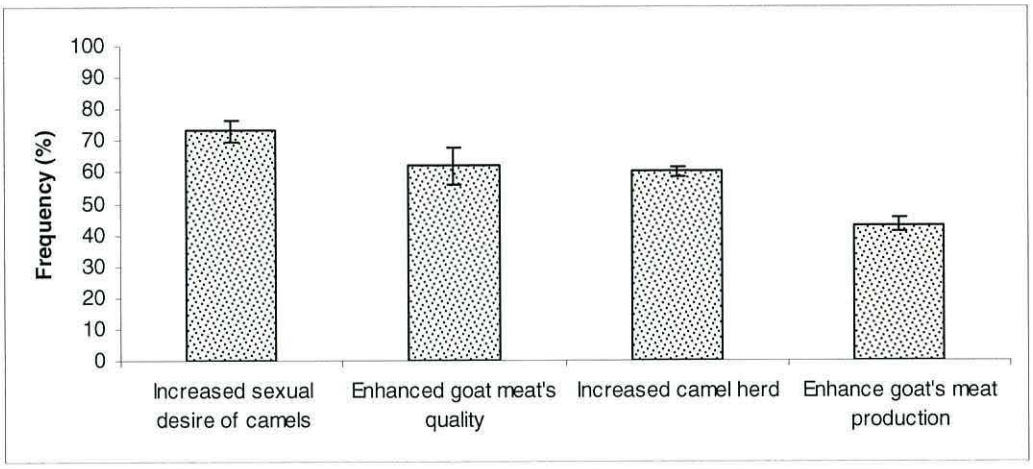

Figure 3.6 Responses (% ± SE) on specific functions of *Cordeauxia edulis* fodder for livestock

3.4.1.3 Construction

Next to fruit, the wood of *Cordeauxia* played a vital role for construction purposes in all localities of the study site (Figure 3.4). Analysis of the data from focused group discussion and field observation revealed that about 90% of local houses were built from wood of *C.edulis* (Yeheb) (Plate 3.3.).

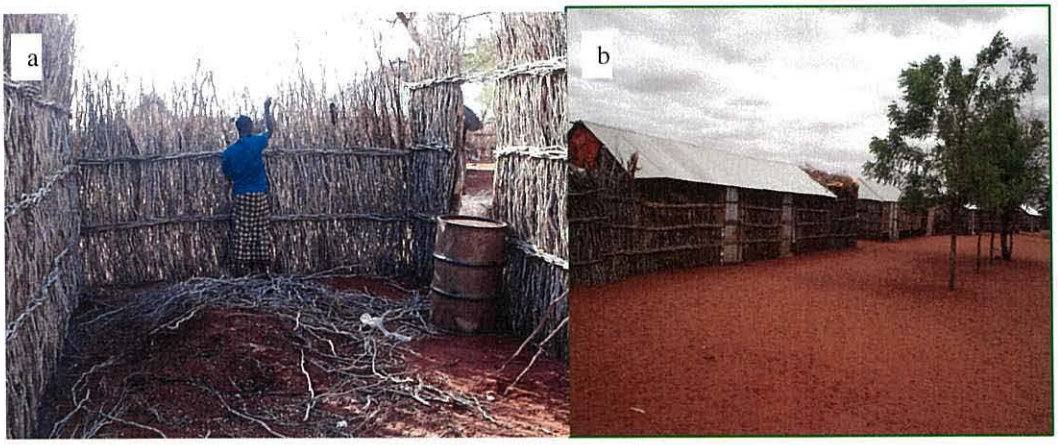

Plate 3.3 a) Man constructing a house, b) homes built from *Cordeauxia edulis* wood at Gambare village, Ogaden, Ethiopia (Photo by: Mussa. M. Yusuf)

3.4.1.4 Medicine

Analysis of data from focused group discussion in all localities indicated that respondents also used fruit of *Cordeauxia* for medicinal purposes to heal stomach constipation (60%), anaemia (50%) and bile problems (20%). Furthermore, respondents claimed that drinking the soup of yeheb nut helped to gain energy (50%), increased appetite (40%) and also enhanced natural immunity (30%). Thus, yeheb seems to play a vital medicinal role in this isolated far rural environment where there are no medical facilities. Furthermore, respondents claimed that livestock fed on yeheb fodder is not usually attacked by any disease.

3.4.1.4 Other functions

The results of the focus group discussion revealed that the wood of C.*edulis* (Yeheb) is also used for construction of fences (plate 3.4) and fuel wood (Figure 3.1). According to the respondents, fences around homestead were constructed from yeheb to keep out livestock or burglars. It was also claimed that the wood of yeheb is highly flammable and burns very well even when it is moist or freshly cut, and is therefore, a good quality fuel wood.

Plate 3.4 Fence constructed from wood of *Cordeauxia edulis* in Boh, Ogaden, Ethiopia

3.4.2 Management of *Cordeauxia edulis*

3.4.2.1. Indigenous management of *Cordeauxia edulis*

100% of respondents reported that yeheb was a communal property and that there has never been any conflict over the use of yeheb. A majority of respondents (80%) reported that there was no management or control on the utilisation of yeheb resource, while a few (20%) respondents mentioned that *Cordeauxia* was managed or controlled by traditional law. None mentioned that the government had controlled or applied any management system to the resource.

3.4.2.2. The role of women in the use and management of *Cordeauxia edulis*

According to 99% of respondents, women were involved in several activities of *Cordeauxia.* A majority (93%) reported that the main activity of women was in the

marketing of fruits, followed by cooking fruit (78%), while 61% reported that they participated in storing fruit (Figure 3.7).

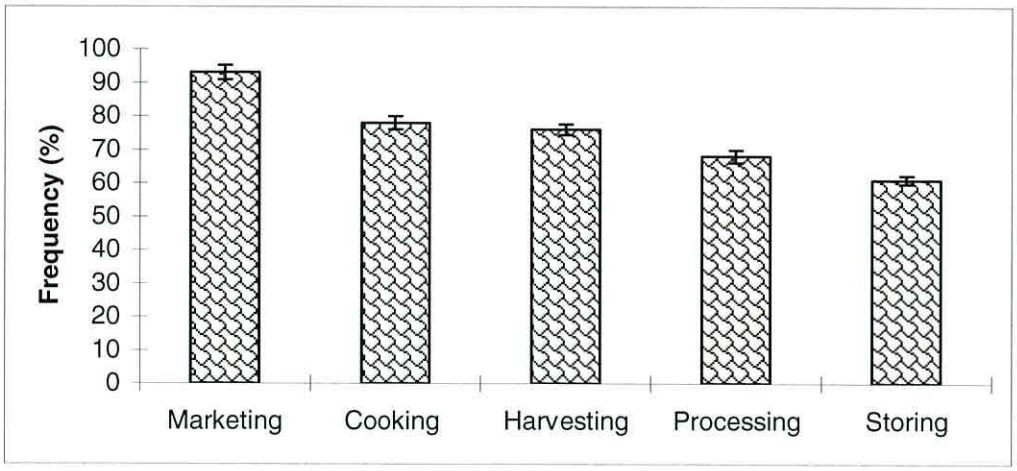

Figure 3.7 Participation (% ± SE) of local women in activities of *Cordeauxia edulis*

Plate 3.5 Women harvesting fruit of *Cordeauxia edulis* during wet season in Maned locality, Ogaden, Ethiopia (Photo by: Mussa. M. Yusuf)

3.4.2.3 Perception of Local people on Population Status of *Cordeauxia edulis*

According to 98% of respondents the population of *C.edulis* (yeheb) is in decline and a majority (94%) of them mentioned this was due to overcutting by humans (Plate3.6), followed by drought (79%) and relatively minority (53%) reported lack of awareness of utilisation (Figure 3.8).

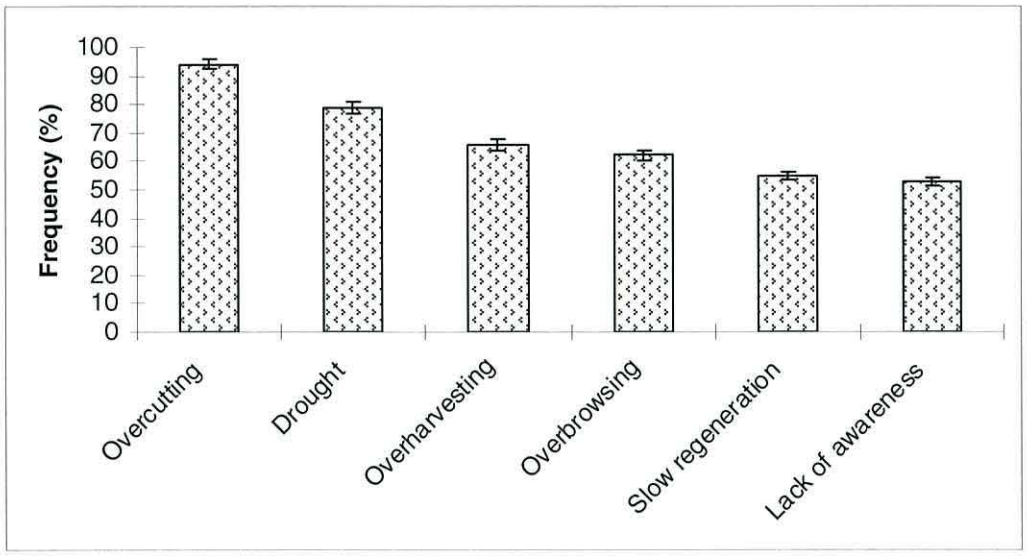

Figure 3.8 Response (% ± SE) on major reasons for declining of *Cordeauxia edulis* population at Boh district, Ogaden, Ethiopia

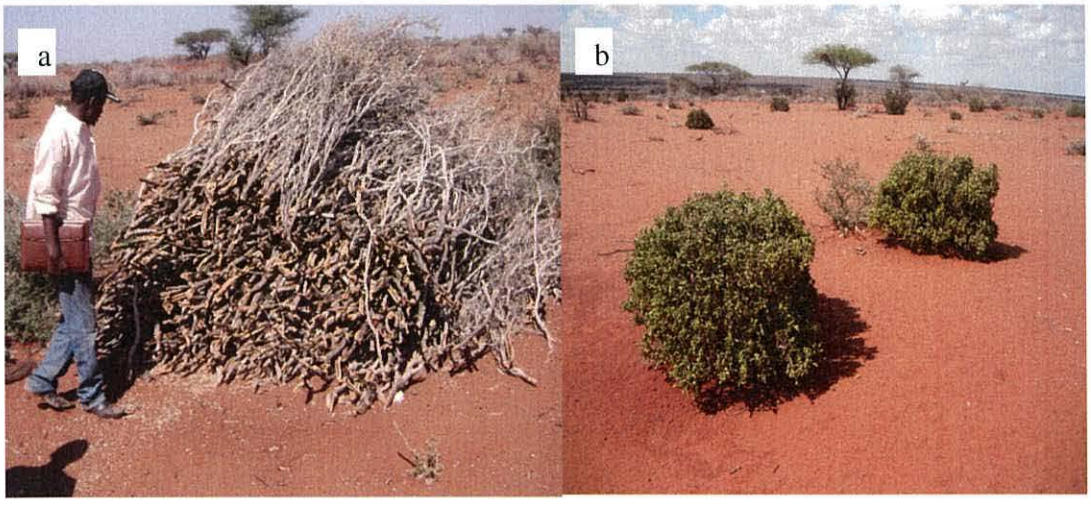

Plate 3.6 a) Cutting of wood b) area *Cordeauxia edulis* is eradicating in Damerjog village, Boh, Ogaden (Photo by: Mussa .M. Yusuf)

Results from the study on the threat to the *Cordeauxia* population in the future and current activities to save the plant is summarised in table 3.5. A majority (93%) of believed that the population of C.*edulis* will disappear in the near future. On top of this 78% reported that no work or ongoing activities were being done to save the species (Table 3.5).

Table 3.5 Responses (% ± SE) on perception of respondents to threat and current status of *Cordeauxia edulis* in Boh, Ogaden, Ethiopia

Do you think yeheb population will disappear in the near future	Responses	What are you doing to save the plant	Responses
Yes	93 ± 1.8	Nothing	79 ± 2.3
No	7 ± 2.1	Protecting by traditional law	21 ± 1.7

The study, however, indicated that respondents believed that measures could be used to mitigate the declining of plant population. As shown in Figure 3.9, majority of respondents (77%) believed that government legislation was required to protect the resource. Some respondents mentioned that raising awareness of the local people was needed (70%). Diversification of source of income was mentioned by 60% while a few (16%) mentioned guarding of shrubs as a method for overcoming the constraints on yeheb population.

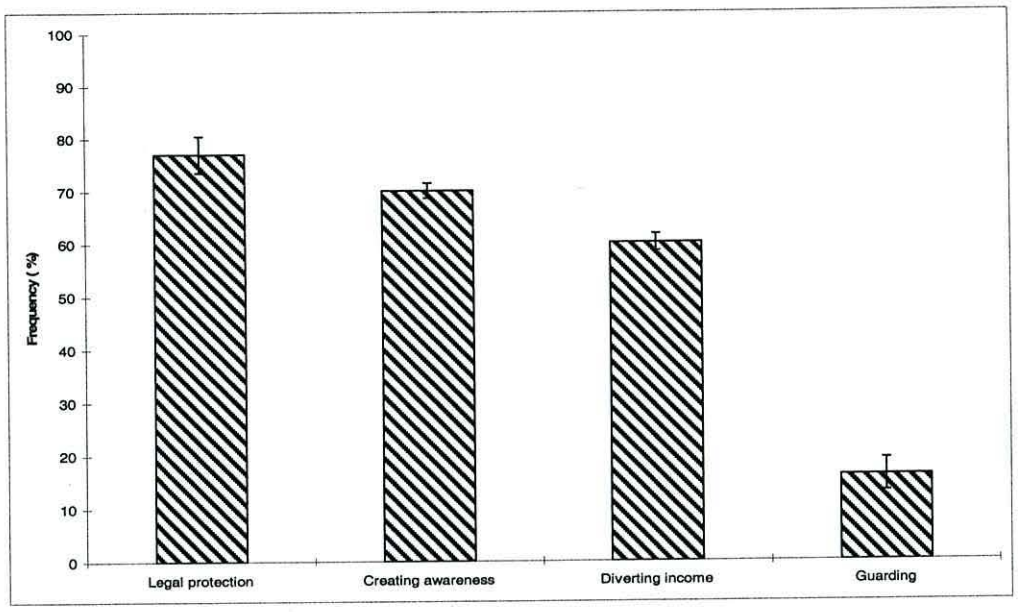

Figure 3.9 Response (% ± SE) on major opinions to mitigate declining of *Cordeauxia edulis* population in Boh, Ogaden, Ethiopia

In group discussions pastoralists (100%) agreed and came to a consensus that population of *C.edulis* is rapidly declining, due to over-utilisation through excessive cutting, over browsing and over-harvesting (i.e. collecting almost all seed) in decreasing order. However, they reported that drought in the area was the main factor for the population decline. In decreasing order of importance legal protection, awareness creation and income diversification or creating other source of income were solutions suggested to save the species locally.

3.4.3 Characteristics of good quality fruit yielding shrubs of *Cordeauxia edulis*

As shown in Figure 3.10, a majority (94%) of respondents reported that the main identifying characteristic of yeheb yielding good quality fruit is large shrub size,

followed by those shrubs possessing many branches (78%). A few (20%) reported that shrubs with good quality fruits were also liked by browsing animals.

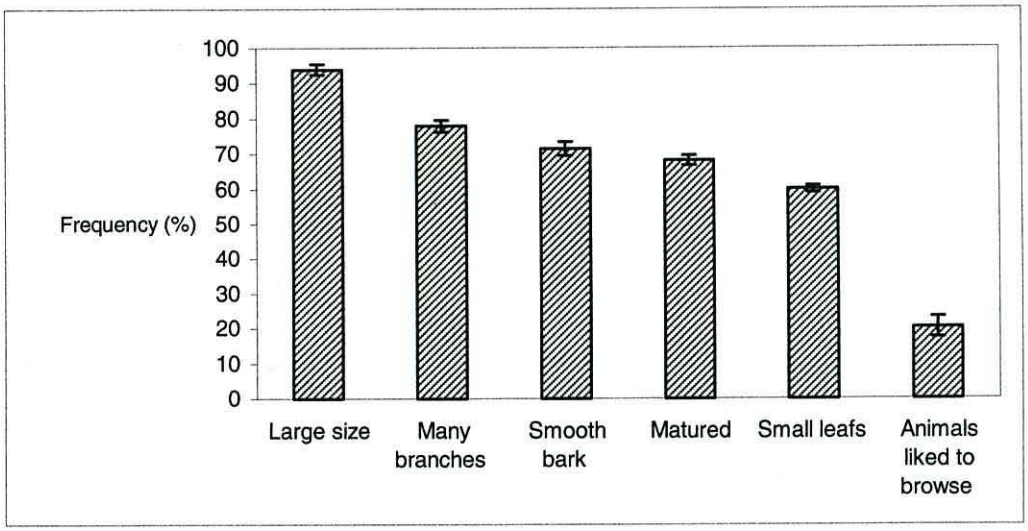

Figure 3.10 Responses (% ± SE) on characteristics of good quality fruit yielding shrubs in the Ogaden

However, according to 97% of respondents, good quality fruit yielding shrubs were not selected during fruit harvesting period, fruits were collected from any shrub that were bearing fruits. This was due to competition which was reported by 86% of respondents, followed by high demand (70%), scarcity or shortage of production (68%) while a minority (20%) mentioned that quality was not considered during collection (Figure 3.11).

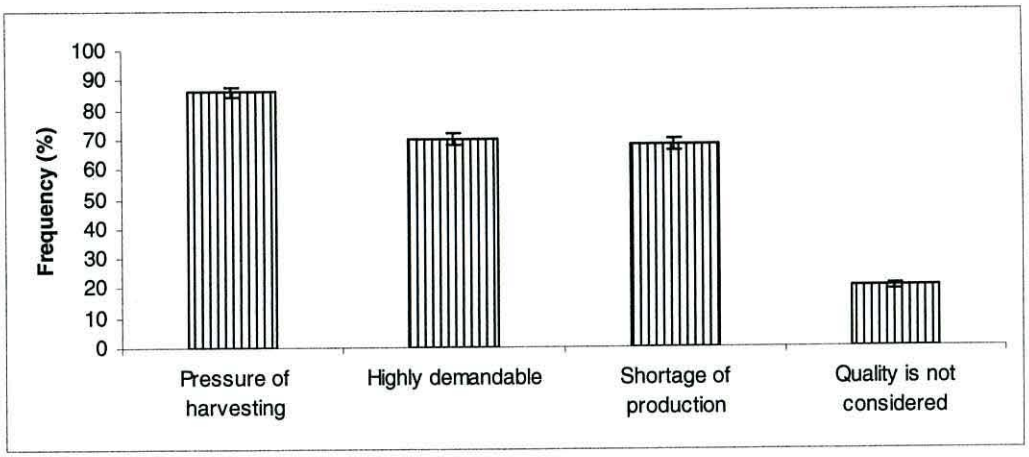

Figure 3.11 Responses (% ± SE) on reasons for not harvesting only good quality fruits of *Cordeauxia edulis*

On the other hand, respondents were able to identify good quality fruits. The results presented in Figure 3.12 indicates that majority of respondents (68%) mentioned large sized fruits to be good quality fruits, while 7% mentioned sweet taste. However 25% reported both large size and sweet taste constituted the characteristics of good quality fruits. In response to the question whether or not there were different varieties of yeheb in their locality, none of them were aware of the existence of any other variety of *C.edulis* (Yeheb).

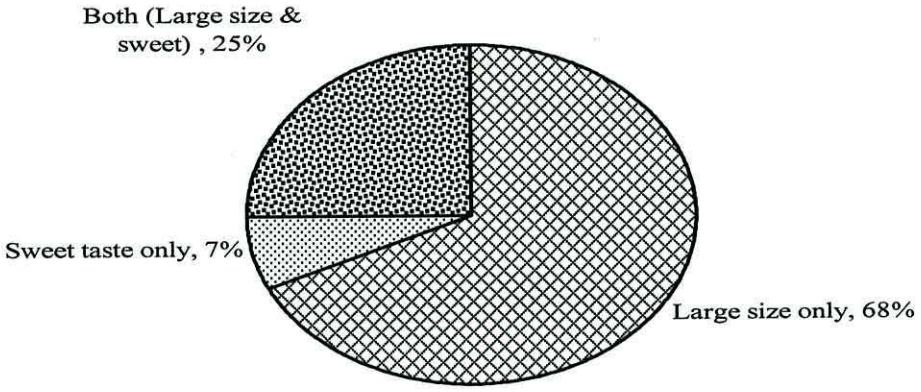

Figure 3.12 Responses (%) on characteristics of good quality fruits in the Ogaden, Ethiopia

The group discussion about vegetative and reproductive period (leaf flushing, flowering and fruiting) of *C.edulis* shows that *C.edulis* is evergreen in nature. Leaves remain curled in dry season, but majority of leaves were dropped a few weeks before seasonal rainfall. According to local users flushing, flowering and fruiting of *C.edulis* is observed only in the rainy season, but, they are usually observed in both annual wet seasons. Flushing starts on the first day of seasonal rainfall and flowering is observed few a weeks later. Fruit matures three weeks later. Maturation is paused if rainfall stops but continues after the next rainfall and matures in about one week. Rainfall was reported to be the main factor influencing production of *C.edulis* and determined fruit size, quantity and quality. According to local people, *C.edulis* flowers even in unexpected rainfall outside the normal rainy season. Further study about the phenology of C.*edulis* is presented in the next chapter (chapter 4).

3.4.4 Opportunities and constraints for domestication

According to 100% of respondents, planting of yeheb has never been practiced in the area. 88% of respondents reasoned that because they are pastoralists, they did not need to plant it while 12% reported that they lacked knowledge of planting yeheb. Focus group discussion with the Boh district, Office of Agriculture, however, revealed that some people had tried to grow it around homesteads in Boh town located 40 km away from study site, but it was not successful.

Despite the fact that *Cordeauxia* has never been domesticated in the area, a majority of respondents (87%) reported that they did have experience of planting other tree species around their homesteads for the purpose of shade. 70% of the respondents mentioned that they obtained seedlings from South East Range Project (SERP) of the Ethiopian Government and 21% reported that they obtained seedlings from the neighbouring Somalia while 16% of them reportedly obtained seed from both SERP and Somalia. Currently, however, there are no local organizations producing yeheb or other tree seedlings.

In response to questions on methods of increasing production of yeheb fruits (Figure 3.13), 95% of respondents reported that controlling overcutting through legislation, and basing harvesting (76%) and browsing (63%) on a permit system was a major method of increasing the production and quality of yeheb fruit, 55% suggested plantation establishment as a means of increasing yeheb production.

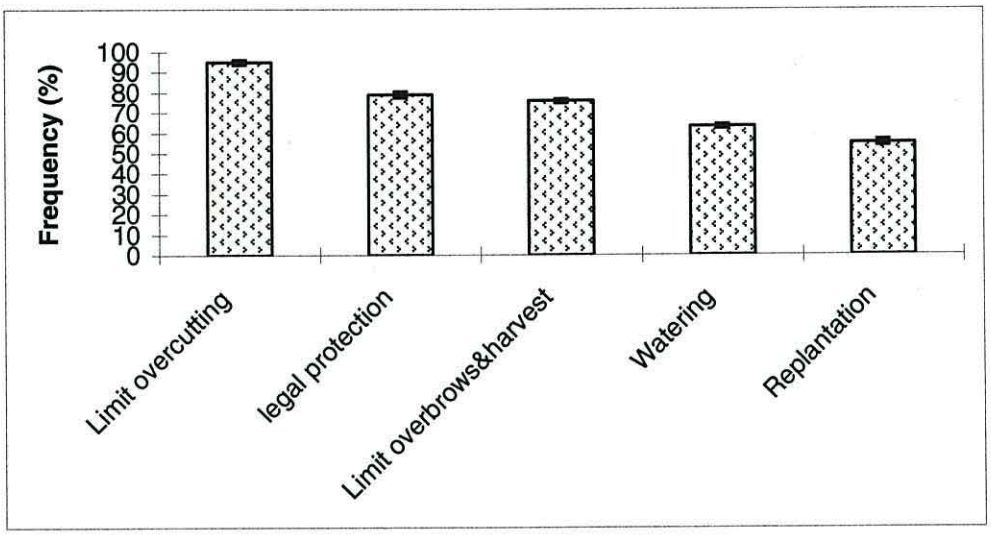

Figure 3.13 Responses (% ± SE) on opinions of increasing production and quality of fruit of *Cordeauxia edulis*

3.5. Discussion

Cordeauxia edulis (Yeheb) produces fruits that are consumed by the local people and is the major use of C.*edulis* as reported by the majority of respondents. Similar findings was reported by previous workers such as El-Zeany and Gutale (1982) and Vietmeyer (1985) who described that yeheb produces a nutritious and sweetish nut with a chestnut like flavour that the people living in the Somali hinterlands rely on for subsistence.

Wild fruit is often reported as a dietary supplement to poor peoples daily food consumption (FAO, 2003), but the present study found that yeheb fruit was used as a major source of food. Like most wild fruits, *Cordeauxia* fruit does not contain hard seeds; it is a dicotyledon similar to peanut beans and is therefore used directly as a food crop. Brink (2006) reported that yeheb is a nutritious quality food that the local people prefer to traditional stable crops such as maize and sorghum.

Pastoralists consume the fruit of *C.edulis* in various forms; roasted or boiled, dried and also eaten fresh as well as in a soup. The majority consumed yeheb after boiling. This is most probably because anti-nutritive factors present in fresh fruits which cause nausea or stomach distress (Miege and Miege, 1978). Prevent consumption of fresh fruit in large quantities. This is consistent with previous finding by El-Zeany and Gutale (1982) and Ismail, (1975) who reported that the fruit is largely consumed after roasting or boiling and fresh fruits are mainly eaten by children to quench thirst. A similar characteristic was found in another dry land wild plant called *Dobera glabra*. It produces edible fruit which is considered as a typical famine food in the Ogaden region, however the fruits must be cooked for a long time before eating (i.e. up to 24 hours), because they have a bad smell, and excessive consumption of fresh fruit causes stomach ache and other intestinal problems (Guinand & Lemessa, 2002).

The present study also found that the foliage of *Cordeauxia* is a major fodder available for livestock in the area. Since it is evergreen, it is the only fodder left for livestock survival during the dry season. Pastoralists from all areas of Boh district travel to the study site which is the only location where yeheb is currently surviving to be able to browse the foliage of *Cordeauxia* to survive seasonal droughts. Similar findings were reported by previous workers. According to Kucher (1987) and Ali (1988), *C. edulis* plays a vital role for livestock production as a dry season feed. The species is 'evergreen' and produces abundant fodder and may contribute up to half of the biomass of the area which was estimated at an average biomass production of 325-450 kg ha^{-1} (1.4-2 kg $plant^{-1}$) (Anonymous, 2004; Brink, 2006). All livestock particularly camel, but also goat, sheep and cattle feed on foliage of *C. edulis*. This finding is in close agreement with reports by Brink (2006) and Bally (1966) who wrote that animals including camels, goats, sheep and cattle browse yeheb foliage but among the livestock mostly camels and goats are the browsers of yeheb foliage. A majority of respondents reported that cattle fed only in dry season. According to Drechsel and Zech (1988), the fodder value of yeheb, although comparable to other tropical tree legumes, has a low mineral content (P, Mg, Mn and partly Zn), and thus, would not satisfy the demands of animals, particularly cattle, if yeheb were the only source of fodder. On the other hand,

Guinand and Lemessa (2002) described that cattle avoid feeding on *C.edulis* in rainy season because the leaves are hard and leathery and are high in tannin content.

According to the respondents, the foliage of *C.edulis* is known by its unique effect on livestock which was not observed on any other type of fodder. This is due to the cordeauxiaquinone present in the leaves. Booth and Wickens (1988) reported that meat from animals fed on yeheb is particularly tasty and that teeth and bones of foragers become stained bright orange. Lister *et al.* (1955) and Harborn *et al.* (1971) also confirmed that some of the livestock coming from the Central Zone of Somalia and Ogaden is highly appreciated by domestic and foreign consumers especially for the taste of their meat and their having a characteristic pink colour. To most Somali consumers, this is a mark of quality meat. Most probably Cordeauxiaquinone or its metabolites present in the leaves of *C. edulis* bring about this phenomenon because only animals that feed on *C. edulis* get this pink colour on their skeleton. This natural pigment Cordeauxiaquinone, with a brilliant pink colour, is not known to be present elsewhere in the plant kingdom (Lister *et al.*, 1955; Harborn *et al.*, 1971).

The wood of *C.edulis* plays a vital role for local construction and about 90% of local homes were built from wood of *C.edulis*. Furthermore, it is also used for construction of fences. Respondents claimed that the wood is hard and has high resistance to termite. This finding agrees with reports of Yahya (2004) who found that yeheb wood is resistant to termite attack and houses and sheds made of yeheb persist for decades. In addition, the wood of C.*edulis* is also used as fuelwood. Respondents claimed that it has a capability of burning immediately after cutting (in wet condition), with no need of drying. Similarly, Liew (2003) described the wood of yeheb as a good firewood, flammable even when wet. Besides, Kucher (1987) found that the smoke from burning wood of yeheb produces a characteristically good smell liked by the local people. Other species with similar characteristics (good quality fuelwood) include *Casuarina equisetifolia, Vitellaria paradoxa, Acacia nilotica, Acacia holosericea, Acacia seyal* and *Prunus persica* as reported by Booth and Wickens, (1988) and Bhatt and Todaria, (1990).

Yeheb is used traditionally for medicinal purposes. Respondents claimed that eating yeheb nuts helped them progressively gain energy, provided resistance against diseases or enhance natural immunity. They reported that it is used as a remedy against constipation, anaemia, bile problem and lack of appetite. They also reported that livestock that feed on yeheb usually are resistant to diseases. The finding is in close agreement with previous studies by Brink (2006) Gutale and Ahmed (1984) and Anonymous (2004) who reported that yeheb nuts are used as medicine to regulate gastric secretion and for the treatment of ulcers. It is also believed that the nuts can be used to alleviate anaemia by augmenting the number of red blood cells and Cordeauxiaquinone is used medicinally to stimulate hemopoiesis (blood cell synthesis) in livestock.

The present study found that no control or management exists for the yeheb resource, 20% of people consider it is controlled by traditional laws, but this is not effective due to excessive drought in the area. Thus, the species is threatened with extinction due to excessive exploitation through overcutting, overharvesting and overbrowsing. Similarly, Bally (1966) reported that yeheb is threatened with extinction due to excessive exploitation coupled with an almost entire lack of protection measures for the resource. It might also be due to the political instability in the region and people having no alternative source of subsistence. Drechsel and Zech (1988), Yahya and Durand (1993) and Johnson (1996) have reported similar findings. As a result, yeheb has now been declared as endangered species by the International Union for Conservation of Nature (IUCN, 1997). Local people are aware of this and claim that the population of *C.edulis* is seriously declining and will possibly disappear in the near future unless immediate protection measures are taken. They suggested that Government legislation, awareness raising and diversification of income source are required to save the species. Other wild fruit trees reported to be threatened with extinction elsewhere due to overexploitation include *Vitellaria paradox* (Shea Butter) and *Borassus aethiopum* (Teketay *et al.*, 2003; Maundu *et al*, 1999).

The present research revealed that although respondents did not apply them, they have indigenous knowledge about the characteristics of good quality fruit yielding tree/shrubs. Large size, many branches, smooth bark, matured and small leaves were some of the characteristics of yeheb mentioned by respondents in decreasing order of importance. The knowledge could not be applied during harvest due to the scarcity of the resource and thus local people collect anything they come across. However, there are no reports in the literature in this regard.

Regarding varietal differences in *C.edulis*, only one type of yeheb is found in the study area, although two different forms of yeheb have been described in the literature: 'Suuley' and 'Muqleey' (Booth and Wickens, 1988, FAO, 1988). The `Suuley´ form is smaller, usually less than 1.5 m in height with an open spreading habit and ovoid sweet tasting seed of 1.8 g in weight. The `Muqleey´ form is more common, taller and erect with less sweet seed of 1.3 g (Booth and Wickens, 1988, FAO, 1988). The variety found in the study area may probably be `Suuley` type as the shrubs found there were of open spreading habit with ovoid and sweet fruits.

The present research found that yeheb has never been domesticated in the study area. However, there are a few reports in the literature on attempts made elsewhere to domesticate the species. For example, Guinand & Lemessa (2002) stated that since the Somali people know well about the usefulness of *Cordeauxia edulis*, some have already started growing it by producing tree seedlings in Boh town. Bally (1966) also reported that seeds planted in 1954 at the Mwakik seed farm, Kenya, germinated and although several plants survived initially, by 1963 they could not be found. According to Kasmi (1979), some fifty shrubs were planted at the Central Agricultural Research station, Afgoye, Somalia and although they grew slowly, they flowered and produced fruit. Furthermore, it has been introduced on an experimental scale in to Sudan, Tanzania, Yemen, India, Israel, and United States (Brink, 2006; Bekele *et al.*, 1993; Nerd *et al.*, 1994).

Respondents reported that women played a vital role in almost all activities of *C.edulis* including harvesting, processing, storing, cooking and marketing of the fruit. This is in agreement with previous report in which women have been reported as playing a central role in income generation by being involving in the activities of collecting and marketing wild foods (Kipuri and Ridgewell, 2008). Usually, men look after livestock and move in the dry season elsewhere in search of pasture and water. This finding is also in close agreement with the report of Yahya (2004) who mentioned that among the Somali speaking nomads, men are usually in continuous movement with the camels while the women and children remain settled. It is generally women who benefit from the consumption of fruits of *C. edulis*; however, if there is a surplus, the women sell yeheb seeds in the market as a source of cash income (Yahya, 2004).

CHAPTER-IV

THE ECOLOGY AND BIOLOGY OF *CORDEAUXIA EDULIS* (YEHEB) AND THE NUTRITIONAL COMPOSITION OF ITS FRUITS

4.1 Introduction

To researches, *Cordeauxia edulis* (Yeheb) is an agronomically new species. Much remains to be learned about the environmental requirement, floral biology and ecology of this important multipurpose plant and the nutritional properties of its fruits (Liew, 2003; Booth and Wickens, 1988). Initiation of viable local conservation strategies of *C.edulis* is required before its ecological integrity is lost. To develop a viable conservation strategy for *C.edulis*, formal studies of the reproductive process, phenological patterns and ecological characteristic are vital.

C. edulis grows naturally in semi-arid bush or scrub land, on deep salt-free sandy to loamy-sandy soils with low lime and gypsum contents (Polhill & Thulin, 1989). The requirements for soil fertility are low; a good and deep infiltration of rain water is, however, very favourable (Drechsel and Zech, 1988). Furthermore, Seegeler (1983) described the soil as fine to coarse deep red sands locally called '*Haud*' which are poor in nutrient content, extremely low in nitrogen, usually slightly alkaline (pH 6.7-8.4). According to Seegeler (1983) the distribution of *C. edulis* may be limited by its soil requirement, however, much remains to be learned about the ecology of the species in terms of the soil physical and chemical properties.

Phenological studies are essential to understand how *C. edulis* functions in arid and semi-arid ecosystems, and they are also needed in conservation and rational

management schemes (Aronson *et al.,* 1994). Vegetative and reproductive cycles display the adaptation of the species to its environment (Akpo, 1997).

It has been reported that flowering of yeheb commences in early rainy season (Ismail, 1975). Floral parts fall soon after pollination, leaving the fertilised ovary (Wickens & Storey, 1984). Fruit takes 10-14 days to mature depending on amount of rainfall (Brilli & Mulas, 1939). If rain fails, fertilised ovaries can remain undeveloped up to 4-5 months, and with next rains they may ripen in 5-6 days. The species can fruit twice annually if there is abundant rain, or not at all if rains fail (Ismail, 1975). It yields up to 5 kg of fruit plant^{-1}, but nil in drought years (Baumer, 1983). Duration of flowering as well as the patterns of flowering intensity varies continuously between the two extremes (Gentry, 1974; Janzen, 1967). Information on pollinating insects as well as on vegetative phases of the species is, however, scanty.

Previous research has shown that the fruit from *Cordeauxia edulis* make an unusually nourishing and balanced food, containing substantial amounts of starch (37%), sugar (25%), protein (13%), fat (11%) and various minerals (Vietmeyer, 1985; Kazmi, 1979; El Zeany and Gutale, 1982; Brilli and Mulas, 1939). However, Booth and Wickens (1988) and Miege & Miege, (1979) recommended that further study is needed in order to estimate properly the nutritional values of fruit.

The present research was, therefore, undertaken to study the ecology and biology of *C. edulis* in its natural habitat and analyse the nutritional composition of its fruit.

4.2 Specific Objectives:

1. To characterise the soil physical and chemical properties of the study site,
2. To record the climate including rainfall and temperature of the study site,
3. To study the phenological cycles and events of *Cordeauxia edulis,* and
4. To analyse the nutritional composition of fruit of *Cordeauxia edulis*

Hypothesis of the study

a. Soil properties of the study site do not vary in depth and position (under and away from the shrub).

b. There is no relationship between reproductive (flowering and fruiting) and vegetative (leaf flush and shedding) characteristics of *Cordeauxia edulis* and environmental cues.

c. Fruit of *Cordeauxia edulis* is rich in carbohydrate, protein, fat and minerals

4.3 Materials and Methods

4.3.1. The study site

The study was conducted in ten villages (Maned, Godir wayis, Gambare, Mirafadle, Afardod, Damerjog, Dalhamur, Dudun, Foye ade and Dabhabalan) of Boh district, Ogaden where C. *edulis* is currently found in Ethiopia. Each village or locality represented one population of *C. edulis*.

4.3.2. Characterisation of soil of the study site

The soil in each village or stand was characterised using selected soil chemical and physical properties including soil texture, soil pH, electrical conductivity (EC), sodium (Na), Potassium (K), Calcium (Ca), cation exchange capacity (CEC), total nitrogen (T.N), organic carbon (OC), carbon nitrogen ratio (C/N), available phosphorus (Av.P), and organic matter (OM). Based on method of James & Well (1990), a small enough equal volume of soil from each village was collected in August, 2008, from areas under (up to 0.5 m from the base of shrub) and away from the shrubs (at about 2 m from the base of shrub) and at depths of 0-15 and 15-30 cm. A total of 20 samples per village, 10 samples under shrub (5 samples from each depth) and 10 samples away from shrubs (5 x 2 sampling depths) were taken. Finally, composite sample for each depth (0-15 cm and 15-30 cm) and position (under shrub and away from shrub) were prepared for each

locality. The soil samples were then taken to the soil laboratory of Bureau of Agriculture, Jijiga for analysis.

Protocol for soil analysis

Soil pH and EC

Soil pH and electrical conductivity were determined using a PH meter and EC meter, respectively for suspension of 1:25 soil: water mixture (Rayment & Higginson, 1992).

Organic carbon

Soil organic carbon was determined by Walkley and Blacks's (1934) rapid titration method. Soil organic carbon was oxidized with potassium dichromate in sulphuric acid solution, 10 ml $K_2Cr_2O_7$, was used in excess of that needed to destroy the organic matter and the excess determined by back titration of $FeSO_4.7H_2O$ by using diphenylamine indicator (Barium diphenylamine sulphonate), (1 gm soil + 10 ml $K_2Cr_2O_7$ + 20ml con. H_2SO_4 + after 30 minute add 200ml distilled water + 10 ml Ortho phosphoric acid + indicator). Finally 0.5 normal $FeSO_4$ was titrated till the colour changed to green. Percentage (%) organic matter was calculated by multiplying the organic carbon by 1.724.

Particle size

A hydrometer method was used to measure soil particle size by weighing 50 g soil and adding 100 ml of dispersing agent (40 g of $NaPO_3$ + 10 g $NaCO_3$ in one litre distilled water) letting stand overnight the next day shake the soil and solution by mechanical stirrer for 5 minutes then first read with in 40 sec for sand and after 2 hours for clay together with the temperature correction.

Available phosphorus

The Olsen *et.al* (1954) method was used by extracting P with $NaHCO_3$ at pH 8.5. 5 g of soil with 100 ml of $NaHCO_3$ were shaken for 30 min then filtered by Whatman 42 then by taking 3 ml from the filtrate and adding slowly 3 ml of mixed reagent (50 ml 4M H_2SO_4 + 15 ml NH_4 molbydate + 30 ml ascorbic acid + 5 ml Potassium antimony titrate

solution + adding 200 ml distilled water). After 1 hour the blue colour developed then read by spectrometer with absorbance of 882 nm.

Exchangeable bases

Determination of Na & K by flame photometer

50% ethanol & 50% ammonium acetate solution was used to wash 5 g of the soil with 25 ml of the solution 8 times successively to a total of 200 ml then 50 ml ammonium acetate was added and homogenised and then read by flame photometer.

Determination of Ca & Mg by EDTA titration.

2 ml taken from exchangeable base filtrate that was already used for Na and K analysis was used. 10ml of distilled water, a drop of hydroxylamine hydrochloride solution & KCN.FeCN were used for removing interference of trace elements. 10 drops of buffer was used to bring the pH around 10 then titrated with EDTA by using Ericrom black T and HHSNN indicator for Ca and Mg respectively.

Determination of CEC by distillation method

Washing the sample previously washed for exchangeable bases 25ml ethanol 4 times again by Nacl to a total of 100ml to made a distillation and finally titrated with 0.1N NaHO using methyl red indicator till the colour changed from purple to yellow.

Micro Kjeldahl procedure for total nitrogen

Total nitrogen was determined using Micro Kjeldahl procedure, 1gm of soil titrated with H_2SO_4 in a digestion tube. It is digested for 3 hours with a temperature 300°c. then allowed to cool by adding 50ml of distilled water and transfer the digested quantitatively in to distillation apparatus then placed 20ml boric acid in to the receiver tube. 75ml of 40 % NaHO added in to the digestion, heat and receive gas in to receiver contains boric acid. Then 2 drops of phenolphthalein indicator added and titrated with 0.1N H_2SO_4 until a colour changed from green to pink.

4.3.3. Measurement of rainfall and temperature

Metrological instruments including wireless Rain Gauge (Oregon Scientific RGR682, USA) and digital indoor / outdoor Thermometer were installed in study site for recording rainfall and temperature in the natural habitat of *C. edulis,* respectively. The amount of monthly precipitation, maximum and minimum temperature was recorded in the 2008 and 2009 years of study.

4.3.4. Phenological studies

Phenological assessment of the species was carried out from January 2008 until December 2009 at each village or stand (*Cordeauxia* population); a total of ten reproductive clumps were randomly selected and tagged from each village for phenological monitoring over a 24 month's period. The respective individual stem basal diameter and height and clump crown diameter were measured and recorded. Both the onset and relative length of leafing, flowering and fruiting phenophases were determined on the selected clumps. This data were combined with the respective percentages or proportions of Phenological events (leaf, flowers, and fruits) over time and a record was maintained for each clump. The three phenological events were monitored and recorded every two weeks through the reproductive season. After fruit harvest, the interval between recording visits was increased to four weeks until the start of the second flowering season when the two week schedule was re-established.

Based on Dafni (1992) and Seghieri *et al* (1995), phenological code and sequence of phases for leafing, flowering and fruiting are summarised in the table below.

Table 4.1 Phenological codes and sequences of phenophases for individual clump of *Cordeauxia edulis*

Phenological codes/indices	Definition of phenophases		
	Leafing	**Flowering**	**Fruiting**
0	Green leaf	No buds- no inflorescence buds.	Fruitless
1	Bud break- (>10<50% of these organs in major branches of individual tree crown).	Opening buds-up 25% of the major branches of individual shrub crown with opening inflorescence buds.	Early fruit setting (at least one fruit observed developing)
2	Flushing-all leaves are green; most are expanded (>50%<75% of expanded leaves and >25%<50% of buds not fully opened in the major branches of each individual shrub crown)	Inflorescence buds + open flowers-flowers and opening inflorescence buds (>25-50%) in the major branches of individual's shrub crown with flowers.	Developing green fruit –presence of full size green fruit but no yellowish fruit.
3	New leaf- all leaves are green; most are expanded (>75% less than or equal to 100%) of leafs in major branches in each crown.	Peak flower->50% of major branches on each individual's shrub crown with open and fresh flowers.	Fully develop greenish yellow fruit-mature fruits present on the crown with fruits, which are greenish-yellow to yellowish brown.
4	Mature leaf – crown in full leaf (mixture of green leaves and greenish yellow leaves) with >10% <50% of the crown being normal green leaves.	Mixture of open flowers, withering& withering flowers-(<25% of an individual crown) with open and fresh flowers.	Peak maturation, ripening& onset of fruit harvesting (ripening and fruit harvesting.
5	Start of shading- over 50% of each shrub with dry and falling leaves.	Dried & withered floral parts and flowers- a majority of dry flowers and withering of floral parts (Dried and withered floral parts/flowers.	End of fruit harvesting (>75% of all fruits have been harvested; fruit left on shrub <25% of peak number).

4.3.5. Flower visitors

The study was conducted during two flowering periods (April and October, 2008). Based on method of Martins (2003), sampling was taken from all the ten villages,

focused for the main part of the study on direct, timed visual observation. Each area of observation was closely watched and limited to a given number of flowers. One day observation was made per village in each season. On each observation day, inflorescences were observed for 15 minutes of each hour, between 08:00 am and 12:00 noon when visitors were at peak stage. Weather variation was considered and all data taken at same environmental condition which was sunny day of flowering. It was difficult to collect insects from the flowers. Consequently, floral visitors and their frequency were carefully observed and recorded. Each visitor was identified using reference material.

4.3.6. Analysis of nutritional composition

The proximate and mineral composition of yeheb fruit were analysed in laboratory of Bangor University. Nutritional composition of the fruits of *C. edulis* (Yeheb) including protein, fat, carbohydrate, fibre, ash, moisture content and minerals including Phosphorus (P), potassium K, Magnesium (Mg), Calcium (Ca), Sodium (Na), Iron (Fe), Zink (Zn) and Manganese (Mn) were determined.

4.3.6.1. Mineral analysis

Ashing and Extraction

Based on method described in Andrews and Felt, C. (1983), 1g (dw) sample was combusted at 450 degrees for 18 hours. 5ml of concentrated HCl was added to the ash, and then 5ml of distilled H_2O added. This was shaken for 1 hour, centrifuged briefly, then filtered using Whatman 541 filter paper and funnel. Resulting solution is a 1 in 10 dilution from which further dilutions were made.

Phosphorus (P) Analysis

Based on method of AOAC (2000), phosphorus contents was read at 882nm using a spectrophotometer plate reader. HCl digested samples were diluted to 1/1000. Standard concentrations used were 500 µM, 200 µM, 100 µM, 50 µM, 25 µM and 0 µM, diluted

from a 1000 mM stock standard, and made up with the same solvent as the 1/100 sample dilutions. To each well, 200 µl of sample/standard was added with 45 µl of AMES reagent. AMES reagent is 7.5 ml of H_2SO4 reagent (1.05 ml of conc. H_2SO4 i.e. sulphuric acid, added to 6.5 ml of water), 2.5 ml of NH4-Mo reagent (0.075 g of ammonium molybdate in 2.5 ml water), 2.5 ml of ascorbic acid (0.135 g in 2.5 ml water) 1.25 ml of K-sb-tart reagent (0.0068 g of KSB.C4H4O7 in 10 ml water). A calibration curve obtained from the standards, plotting absorbance against concentration of P.

Sodium (Na), potassium (K) and Calcium (Ca)

A flame photometer was used to detect Na, K and Ca in HCl digested samples. Standard operating procedure of Jenway, U.K. was employed. Calibration curves were constructed using standards. 5 standards (each standard containing more than one element), including one blank was made up from stock solutions as described below:

Table 4.2 Different volume and concentration of elements used to create calibration curve

Conc. of standard (K and Ca) mg/l	Volume of 1000 mg/l standard (ml) K	Volume of 1000 mg/l standard (ml) Ca	Conc. of standard (Na) mg/l	Volume of 1000 mg/l standard (ml) Na	Volume of e-pure water (ml)
0	0	0	0	0	100
25	2.5	2.5	5	0.5	94.5
50	5	5	10	1	89
75	7.5	7.5	15	1.5	83.5
100	10	10	20	2	78

A calibration curve was obtained from the standards by plotting absorbance against concentration of Ca, Na, and K.

Heavy metals; Magnesium (Mg) Manganese (Mn) Zinc (Zn) and Iron (Fe)

The Varian AAS Duo system operated in air-acetylene flame mode, according to standard protocol. 6ml of each sample were used in the 12 ml tubes. Sample concentrations used were 1/100 for Mn, Fe and Zn and 1/10000 for Mg.

4.3.6.2. Proximate composition

Fat

The FOSS Soxtec 2050 Autofat extraction system was used to determine fat contents (FOSS, 1992). Approximately 3g of dried sample was weighed into cellulose thimble. An aluminium cup was weighed empty and 70ml petroleum ether was added to aluminium cup. Machine was run as in standard protocol with 40 minutes boiling, 40 minutes rinsing and 40 minutes recovery time. The aluminium cup and fat residue was weighed, this weight minus the weight of the aluminium cup empty is equal to the fat in the dried sample.

Fibre

The Sigma TDF100A total dietary fibre assay kit was used (AOAC, 1989). A water bath up to 90 degrees was used with an improvised lid to get up to boiling temperature. Quantities in the protocol were halved to save the kit. A ceramic funnel and filter papers were used for the final stage of filtering. The samples were dried in an air oven (in a petri dish) overnight before weighing.

0.5 g sample was weighed out into 50 ml plastic beakers. 25 ml of pH 6.0 phosphate buffer were added to each beaker, then 0.05 ml alpha-Amylase to each beaker added and mix well. Beakers were closed and placed in a boiling water bath. Beakers were agitated gently at 5 minute intervals. Incubate for 15 minutes after the internal temperature of the beakers reached 95°c. Solutions allowed to cool to room temperature. The pH of the solutions adjusted to 7.5 by adding 5 ml of 0.275 N NaOH to each beaker then pH checked, adjusted with either NaOH or HCl. Immediately before used, 50 mg/ml solution of Protease (Product Code P 3910) made in a phosphate buffer. Pipette 0.05 ml of this solution into each beaker. Beakers were closed and placed in 60c° water

bath. With continuous agitation incubated for 30 minutes after the internal temperature of the beakers reached 60c°. solutions were allowed to cool to room temperature. The pH of the solutions adjusted to between pH 4.0 and 4.6 by adding 5ml of 0.325 M HCl to each beaker. Then pH checked, adjusted with either NaOH or HCl. 0.05 ml of Amyloglucosidase added to each beaker. Lid on beakers closed and placed in 60c° water bath. With continuous agitation incubated for 30 minutes after the internal temperature of the beakers reached 60c°. 4 volumes of 95% ethanol added to each beaker. Solutions were set overnight at room temperature to allow complete precipitation. Small glass fibre filter paper weighed and placed in a ceramic flat bottomed funnel, set on top of a conical flask with a rubber stopper. A vacuum accessory was used to draw out the liquid from fibre on the paper. Filter papers and fibre residues were dried overnight in a 60c° air oven. All crucibles in desiccators cooled and weighed. This weight minus the weight of the filter paper alone was the weight of fibre in the dried sample.

Protein

The protein content of fruit samples was obtained by measuring N content of the samples by the Kjeldahl method using a Kjeltec 2300 analyser unit described AOAC (2000). 200 mg of each sample were digested by adding 4 ml of sulphuric acid (98%) and 2 digestive tablets and warmed at 30°C for 4 hours. During the digestion, the nitrogen in the samples was converted into ammonia in the form of ammonium ions $NH4^{+}$ which binded to the $SO4^{2-}$ ions of the acid. After the digestion, sample solutions were placed in the Kjeltec analyser unit which determined their N content. The N content was multiplied by 6.25 to obtain protein content in samples.

Carbohydrate

Carbohydrate was determined by the following formula;

Carbohydrate content (g g-1) = 1 – (Ash content + Dietary fibre content + Fat content + Protein content).

4.3.7. Data analysis

Soil characterisation

In order to make a sound comparison of soils, the sampling was stratified into under shrub and away from shrub with two different depths each (0–15 cm and 15-30 cm). Mean were computed for each character and an analysis of variance (ANOVA) was used to identify soil variability in depth and position. Pairwise t-test used for comparison between the means.

Phenological pattern

Results were first combined at the station scale by phenological period separately. The relationship in phenological pattern over the two monitoring seasons (2008 and 2009) was expressed in terms of identical phenological expression over the two seasons on the chronologically equivalent dates /months. A table was created showing whether each code of each shrub was leafing, flowering or fruiting at each sampling date. Line chart, bar chart and class combination charts were used to process and present the results of each phase. Pearson's correlation was used to examine and show the relationship between phenological events (phenophases) and the climatic variables assessed.

Data on nutritional composition were processed in Ms *excel*, descriptive statistics (mean and percentage) were used to analysis result of nutrient composition. All analysis carried out with Statistical Package for Social Science (SPSS) version 12.

4.4 Results

4.4.1. Characterisation of soil of the study site

4.4.1.1 Soil properties of study localities

C.*edulis* was generally found on deep red sandy soil (Plate 4.1).

Plate 4.1 Soil in Boh district, Ogaden, Ethiopia (Photo by: M.Yusuf)

Table 4.3a summarises the results of soil analyses, under shrub and at depth of 0 – 15 cm for all localities. The results indicated a high degree of homogeneity of soil properties among villages. However, Damerjog and Foye ade villages showed relatively lower values in EC, Na, Ca, TN, Av.P, OC & OM and higher soil pH. Soil at all villages was sandy loam except in Damerjog which was Loamy sand (Table4.3a).

Table 4.3a Soil properties under *C.edulis* canopy of 0-15 cm depth in Boh, district, Ogaden, Ethiopia

soil property	Maned	Godir wayis	Gambare	Mirafadle	Afardod	Damerjog	Dalhamur	Dudun	Foye ade	Dabh abalan
pH H_20	7.7	7.9	7.7	7.9	7.9	8	7.8	7.7	8	7.9
EC(ds/m)	0.14	0.14	0.15	0.13	0.14	0.11	0.13	0.14	0.12	0.13
Sand (%)	76	75	76	75	76	80	75	76	75	76
Silt (%)	13	13	14	12	14	14	12	14	12	14
Clay (%)	11	12	10	13	10	16	13	10	13	10
Texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Loamy sand	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Na	1.46	1.47	1.46	1.47	1.42	0.98	1.23	1.43	0.99	1.43
K	0.43	0.33	0.42	0.23	0.41	0.30	0.11	0.31	0.33	0.41
Ca	8	8	8	7	7	5	7	6	5	7
Mg	0.59	0.48	1.19	0.42	0.51	0.49	0.59	0.44	0.42	0.55
Sum	10.37	10.28	11.06	9.12	9.34	6.77	8.93	8.17	6.84	9.39
CEC	8.57	7.97	8.37	7.97	7.73	7.53	8.51	7.51	7.46	8.53
TN (%)	0.067	0.066	0.067	0.066	0.067	0.049	0.062	0.061	0.044	0.066
OC (%)	0.663	0.663	0.662	0.652	0.642	0.462	0.661	0.660	0.471	0.682
C/N	11.6	10	9.9	9.8	9.6	9.4	10.7	10.7	10.7	10.3
Av.P(ppm)	3	3	3	2	3	2	3	3	2	3
OM (%)	1.14	1.14	1.15	1.11	1.12	0.99	1.04	1.12	1.00	1.116

(pH H_20 1:2.5, EC-electrical conductivity, Na-sodium, K-potassium, Ca-calcium, Mg-magnesium, Sum-sum of Na, K, Ca & Mg, TN-total nitrogen, OC-organic carbon, C/N-carbon nitrogen ratio, AP-available phosphorus, OM-is organic matter)

Table 4.3b presents the result of analysis of soil taken from under shrub at depth of 15 – 30 cm. All soil properties among villages were the same except organic carbon (OC), which was lower at Damerjog and Foye ade (Table 4.3b).

Table 4.3b. Soil properties under *C.edulis* canopy 15 – 30 cm depth in Boh, district, Ogaden, Ethiopia

soil property	Maned	Godir wayis	Gambare	Miraf adle	Afardod	Damerjog	Dalhamur	Dudun	Foye ade	Dabh abalan
pH H_20	8.2	8.1	8.1	8.2	8.1	8.1	8.1	8.1	8.1	8.1
EC(ds/m)	0.04	0.06	0.04	0.05	0.04	0.03	0.04	0.03	0.03	0.03
Sand (%)	82	82	83	82	83	81	82	82	81	82
Silt (%)	5	7	5	7	5	6	6	7	6	7
Clay (%)	13	11	12	11	12	13	12	11	13	11
Texture	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand
Na	2.15	2.08	2.17	2.06	2.13	1.09	1.96	1.81	1.10	2.03
K	0.41	0.30	0.51	0.20	0.41	0.21	0.01	0.20	0.11	0.39
Ca	7	7	7	6	6	6	6	6	6	6
Mg	1.13	1.03	2.11	0.63	0.3	0.28	1.33	1.31	0.53	0.33
Sum	10.68	10.42	11.79	8.90	8.84	7.58	9.30	9.33	7.74	8.75
CEC	10.8	8.9	11.2	8.3	10.12	9.12	8.23	9.23	9.92	10.02
TN (%)	0.045	0.043	0.045	0.042	0.042	0.039	0.04	0.045	0.041	0.04
OC (%)	0.527	0.519	0.524	0.508	0.514	0.374	0.511	0.501	0.382	0.574
C/N	11.6	12.1	11.7	12	12.2	9.6	12.7	11.1	9.3	14.4
Av.P(ppm)	2	2	2	2	2	2	2	2	2	2
OM (%)	0.91	0.90	0.92	0.88	0.91	0.81	0.90	0.80	0.92	0.91

(pH H_20 1:2.5, EC-electrical conductivity, Na-sodium, K-potassium, Ca-calcium, Mg-magnesium, Sum-sum of Na, K, Ca & Mg, TN-total nitrogen, OC-organic carbon, C/N-carbon nitrogen ratio, AP-available phosphorus, OM-is organic matter)

Table 4.3c presents soil analysis taken away from shrub, at depth 0 – 15 cm. The result indicated similar soil properties between villages except OC, C/N and OM which were relatively lower at Damerjog and Foye ade (Table 4.3c). Moreover, higher value of available phosphorus (AP) was recorded at Gambare village and soil textural class of all localities was loamy sand except sandy loam of Dalhamur village (Table 4.3c).

Table 4.3c. Soil properties away from *C.edulis* canopy 0-15 cm depth in Boh, Ogaden, Ethiopia

soil property	Maned	Godir wayis	Gambare	Mira fadle	Afardod	Damerjog	Dalhamur	Dudun	Foye ade	Dabh abalan
pH H_20	8.1	8	8	8.1	8.2	8.2	8.1	8	8.1	8.1
EC(ds/m)	0.02	0.03	0.02	0.03	0.03	0.02	0.03	0.03	0.02	0.03
Sand (%)	82	83	82	83	83	83	78	83	82	82
Silt (%)	5	5	5	6	6	6	10	6	12	5
Clay (%)	13	12	13	11	11	11	12	11	6	13
Texture	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Sandy loam	Loamy sand	Loamy sand	Loamy sand
Na	1.45	1.47	1.45	1.43	1.44	0.59	1.42	1.33	0.59	1.67
K	0.22	0.21	0.23	0.20	0.22	0.19	0.16	0.24	0.20	0.25
Ca	5	5	5	5	5	5	5	5	5	6
Mg	0.54	0.46	0.53	0.47	0.51	0.62	0.41	0.52	0.49	0.64
Sum	7.21	7.14	7.21	7.10	7.17	6.40	6.99	7.09	6.29	8.56
CEC	8.72	6.62	8.8	6.72	8.5	3.72	7.66	6.66	4.48	7.7
TN (%)	0.05	0.05	0.05	0.049	0.046	0.047	0.047	0.049	0.048	0.044
OC (%)	0.546	0.542	0.549	0.5319	0.549	0.429	0.5219	0.549	0.418	0.533
C/N	10.9	10.9	10.9	10.8	11.9	9.2	11.1	11.2	8.7	12.1
Av.P(ppm)	3	3	4	3	3	2	2	3	2	2
OM (%)	0.94	0.94	0.94	0.91	0.93	0.74	0.92	0.90	0.77	0.93

(pH H_20 1:2.5, EC-electrical conductivity, Na-sodium, K-potassium, Ca-calcium, Mg-magnesium, Sum-sum of Na, K, Ca & Mg, TN-total nitrogen, OC-organic carbon, C/N-carbon nitrogen ratio, AP-available phosphorus, OM-is organic matter)

Based on the result presented in table 4.3d, soil taken away from shrub at depth of 15 – 30 cm showed that CEC and available phosphorus were relatively lower at Damerjog while organic carbon, organic matter and C/N were lower at both Damerjog and Foye ade (Table 4.3d). Soil textural class was sandy loam except at Damerjog and Foye ade of loamy sand (Table 4.3d).

Table 4.3d. Soil properties away from shrub at depth 15-30 cm in Boh, Ogaden, Ethiopia

soil property	Maned	Godir wayis	Gambare	Mira fadle	Afardod	Damerjog	Dalhamur	Dudun	Foye ade	Dabh abalan
pH H_20	8.1	8.1	8	8.2	8.2	8.2	8.2	8.1	8.2	8.2
EC(ds/m)	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.02
Sand (%)	78	78	77	78	77	78	78	77	84	78
Silt (%)	7	6	8	7	8	8	7	8	12	7
Clay (%)	15	16	15	15	15	14	15	15	4	15
Texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Loamy sand	Sandy loam	Sandy loam	loamy sand	Sandy loam
Na	1.87	1.76	1.85	1.66	1.80	0.80	1.55	1.45	0.82	1.91
K	0.26	0.25	0.28	0.13	0.18	0.25	0.14	0.12	0.26	0.19
Ca	6	5	5	4	5	5	5	6	6	5
Mg	1.06	0.34	1.26	0.38	1.01	1.15	0.31	0.56	0.39	0.46
Sum	8.6	7.4	8.82	7.1	7.22	5.22	7.21	7.91	7.02	7.92
CEC	8.6	7.4	8.82	7.1	7.22	5.22	7.21	7.91	7.02	7.92
TN (%)	0.042	0.041	0.043	0.039	0.043	0.035	0.036	0.039	0.038	0.042
OC (%)	0.488	0.486	0.488	0.466	0.477	0.293	0.455	0.465	0.302	0.462
C/N	11.6	11.8	11.3	11.9	11.1	8.3	12.6	11.9	7.9	11.0
Av.P(ppm)	2	2	2	2	2	1	2	2	2	2
OM (%)	0.84	0.84	0.82	0.82	0.80	0.51	0.83	0.85	0.49	0.80

(pH H_20 1:2.5, EC-electrical conductivity, Na-sodium, K-potassium, Ca-calcium, Mg-magnesium, Sum-sum of Na, K, Ca & Mg, TN-total nitrogen, OC-organic carbon, C/N-carbon nitrogen ratio, AP-available phosphorus, OM-is organic matter)

4.4.1.2 Comparison of soil properties at different position and depth

Table 4.4 summarises mean soil properties at different positions and depths. The percentage of sand and silt varied ($P<0.05$) significantly with depth in under shrub soils, and indicated soil textural class from sandy loam to loamy sand (Table 4.4). Furthermore, the percentage of sand varied ($P<0.05$) significantly with depth in away from shrub soils, whereas there was no significance variation ($P>0.05$) in silt. However, no significance difference ($P > 0.05$) was found in percentage of clay at depth and

position. Soils under shrubs at depth 0 - 15cm contains higher percentage of silt, while percentage of sand is higher at depth 15 - 30cm and 0 - 15cm of under shrub and away from shrub soil respectively (Table 4.4). Except for K, Mg and Ca content variation of all soil properties were significant ($P<0.05$) between the two depths of under shrub soil, while variation of EC, T.N, Av.P, OM and C/N were significant ($P<0.05$) between the two depths of soil away from shrub (Table 4.4). Variation of pH, EC, Ca, T.N, OM and OC were significant ($P<0.05$) between the two positions (under shrub and away from shrub) at depth of 0-15 cm, whereas EC, Ca, CEC, OM and C/N showed also significant variation ($P<0.05$) between the two positions at depth of 15-30cm (Table 4.4).

Table 4.4 Mean value of soil properties at different depth and position in Boh, Ogaden, Ethiopia

	Under shrub		Away from shrub	
Soil property	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Texture (%)				
Sand	77±0.47^{a}	82±0.21^{b}	82.1±0.48^{b}	78.3±0.65^{a}
Silt	10.2±0.29^{a}	6.1±0.28^{b}	6.6±0.76^{b}	7.8±0.51^{b}
Clay	12.8±0.43^{a}	11.9±0.28^{a}	11.3±0.65^{a}	13.9±0.61^{a}
PH	7.85±0.04^{a}	8.12 ±0.01^{b}	8.09±0.02^{cb}	8.15±0.02^{db}
EC (Ds/m)	0.13±0.004^{a}	0.04±0.003^{b}	0.03±0.002^{c}	0.02±0.002^{d}
Na (meq/100gsoil)	1.33±0.06^{ad}	1.86±0.13^{b}	1.28±0.12^{cd}	1.55±0.13^{db}
K(meq/100gsoil)	0.33±0.03^{a}	0.28±0.05^{ab}	0.21±0.008^{ac}	0.21±0.02^{bc}
Ca(meq/100gsoil)	6.80±0.36^{a}	6.30±0.15^{a}	5.10±0.10^{b}	5.20±0.20^{b}
Mg(meq/100gsoil)	0.57±0.07^{a}	0.90±0.19^{a}	0.52±0.02^{a}	0.69±0.12^{a}
CEC(meq/100gsoil)	8.02±0.14^{a}	9.58±0.32^{b}	6.96±0.55^{a}	7.44±0.32^{a}
T.N (%)	0.06±0.003^{a}	0.04±0.001^{b}	0.05±0.001^{c}	0.04±0.001^{db}
OC (%)	0.62±0.03^{a}	0.49±0.02^{b}	0.52±0.02^{bc}	0.44±0.02^{bd}
Av.P (ppm)	2.70±0.15^{a}	2.00±0.00^{b}	2.70±0.21^{a}	1.90±0.10^{b}
OM (%)	1.09(±0.02)^{a}	0.89±0.01^{b}	0.89±0.02^{b}	0.76±0.04^{d}
C/N	10.27±0.21^{a}	11.67±0.46^{b}	10.77±0.34^{ab}	7.44±0.32^{c}

Values are mean and standard error of mean (SEM), different letters in same row show significance difference at 0.05 level

4.4.2. Environmental cues

Temperature and rainfall amounts recorded in the period (2008 and 2009) are presented in Table 4.5. The climatic result indicated that the rainfall in the natural habitat of yeheb is bimodal, with two rainy seasons of March to June and September to December. In the

first rainfall season (March-June) a total precipitation of 146 mm in 2008 and 126 mm in 2009 was recorded while in the second rainfall season (September-December) 83 mm in 2008 and 112 mm in 2009 were obtained. A total annual rainfall of 229 mm and 238 mm was registered in the 2008 and 2009 study periods respectively (Table 4.5). The result also showed mean maximum temperature of year 1 (2008) was 30°C while mean minimum temperature was 19°C. Mean maximum temperature of 31°C and mean minimum temperature of 20°C was recorded in year 2 (2009) (Table 4.5).

Table 4.5 Climatic data of two years (2008/09) in Boh district, Ogaden, Ethiopia

	Year1(2008)			**Year2 (2009)**		
Months	Precipitation (mm)	Maximum temp. (°C)	Minimum temp. (°C)	Precipitation (mm)	Maximum temp. (°C)	Minimum temp. (°C)
January	0	29	16	0	29	14
February	0	30	20	0	31	20
March	36	35	21	32	36	22
April	67	32	20	55	32	20
May	34	28	20	32	29	20
Jun	9	28	19	7	29	21
July	0	29	23	0	29	22
August	2	28	21	0	29	21
September	8	30	23	10	30	22
October	43	31	19	44	32	19
November	28	30	18	50	31	21
December	2	27	13	8	29	16
	Tot. 229mm	Av.30°C	Av. 19°C	Tot. 238mm	Av.31°C	Av. 20°C

4.4.3. Phenological study

4.4.3.1 Size class distribution of reproductive *Cordeauxia edulis*

Table 4.6 presents basal diameter class distribution of reproductive *C.edulis* shrubs that were categorized in classes of <1cm, 1-2.5cm, 2.51-4 cm, 4.01-5.5 cm, 5.51-7 cm and >7 cm. The majority of stem basal diameter of reproductive *C.edulis* was in a class 2.51- 4 cm and followed by class 1-2.5cm

Table 4.6 Basal diameter class distribution of reproductive *Cordeauxia edulis* in Boh, Ogaden, Ethiopia

	Basal diameter class (cm)					
Village	<1	1 - 2.5	2.51 - 4	4.01 - 5.5	5.51 - 7	>7
Maned	1	41	135	25	3	3
Godir wayis	5	85	70	14	0	0
Gambare	2	40	122	22	2	3
Mirafadle	4	66	84	12	1	0
Afardod	3	53	105	12	1	0
Damerjog	5	70	67	8	0	0
Dalhamur	4	51	100	9	2	0
Dudun	3	31	112	13	3	1
Foye ade	8	74	66	6	1	0
Dabhabalan	5	39	103	7	4	1
Total	**40**	**550**	**964**	**128**	**17**	**8**

Table 4.7 indicates that majority of reproductive *C.edulis* was found in the height class 1.51-2 m followed by class 2.01-2.5 m (Table 4.7).

Table 4.7 Height class distribution of reproductive *Cordeauxia edulis* in Boh, Ogaden, Ethiopia

	Height class (m)				
Village	0.5 - 1	1.01 - 1.5	1.51 - 2	2.01 - 2.5	>2.5
Maned	0	8	97	104	0
Godir wayis	4	40	90	40	0
Gambare	0	14	72	103	2
Mirafadle	2	25	90	50	0
Afardod	2	16	103	53	0
Damerjog	2	24	102	22	0
Dalhamur	1	23	100	42	0
Dudun	0	9	97	57	0
Foye ade	2	34	105	14	0
Dabhabalan	0	11	102	47	0
Total	**13**	**204**	**958**	**532**	**2**

4.4.1.2 Leafing and leaf fall events

Leaf flushing started in March for the first season of rainfall, and at end of September for next season (Figure 4.1a). New leaves appeared in the end of March and onset of October and leaves were matured by April and October of the two seasons (Figure 4.1a; Plate 4.2).

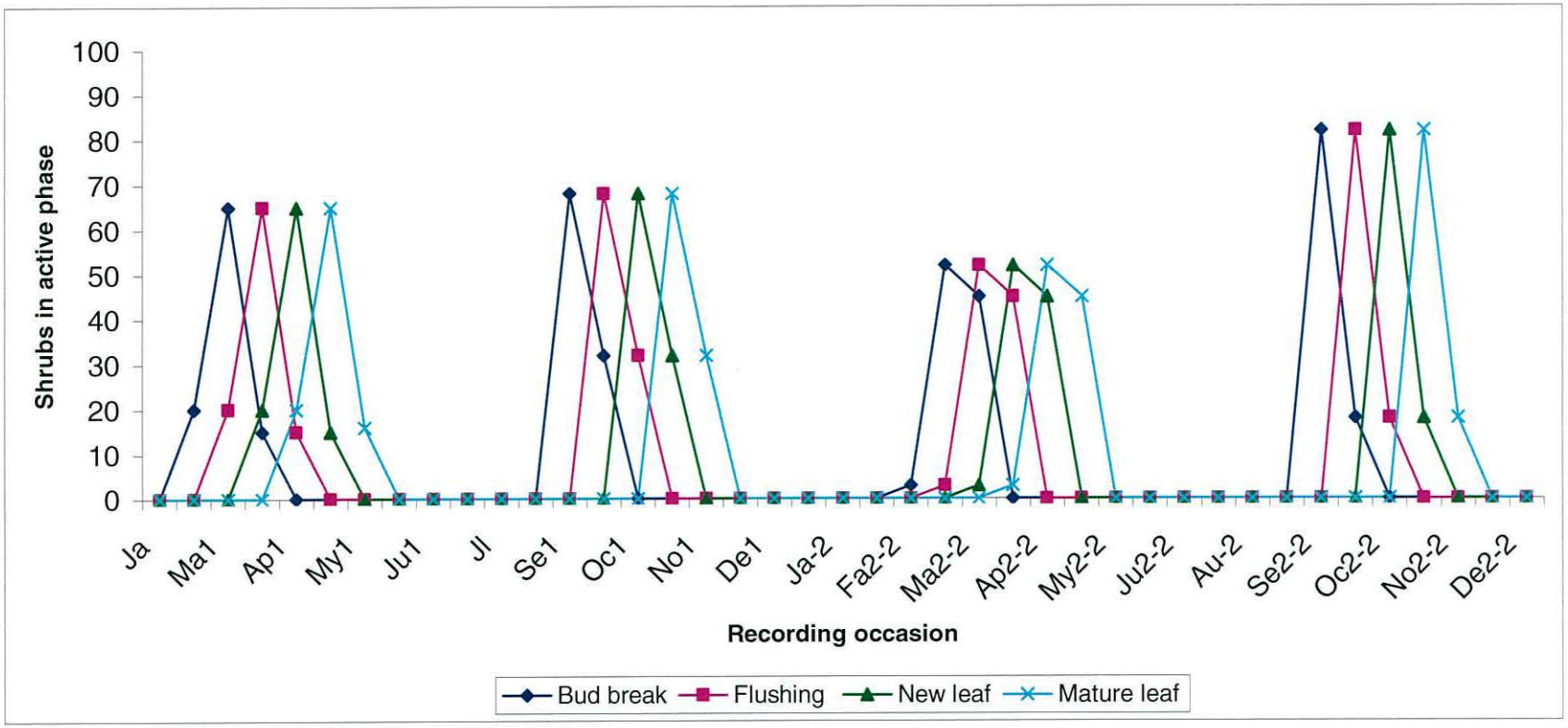

Figure 4.1a Leafing phenophases; Bud break, flushing, new leaf and mature leaf of *Cordeauxia edulis* in Boh district, Ogaden, Ethiopia

For instance Ma1, indicates first 15 days of March, 2008 and Ma2-2 indicates second 15 days of March, 2009

The majority of leaves dropped in February and September before the early seasonal rainfall, and the plants produce a new leaves for the subsequent vegetative and reproductive phase (Figure 4.1b).

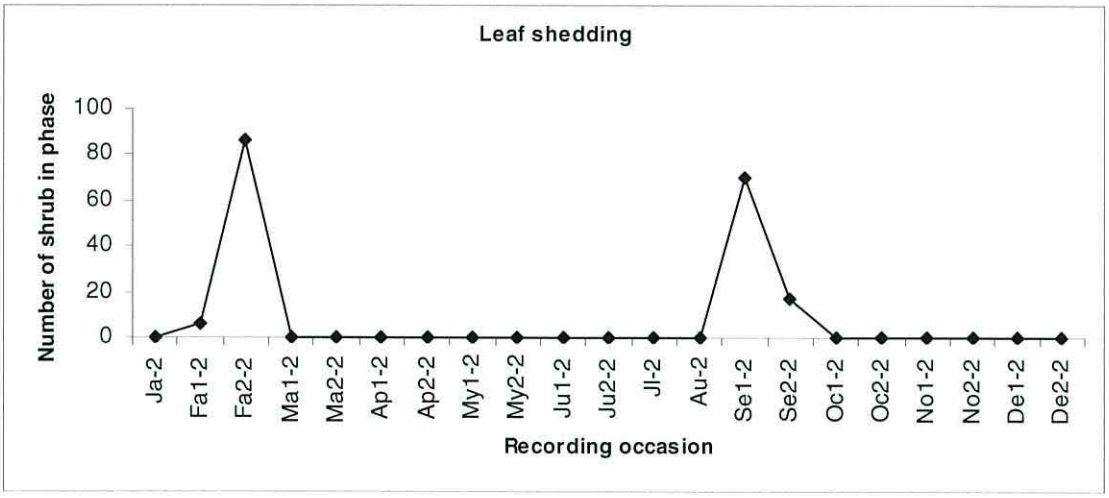

Figure 4.1b. Leaf shedding phase of *Cordeauxia edulis* in Boh, Ogaden, Ethiopia

Plate 4.2 Mature leaf of *Cordeauxia edulis* in Boh, Ogaden, Ethiopia

(Photo by: M.M. Yusuf)

The relationship between leafing phenophases and corresponding monthly precipitation indicated that *C.edulis* started flushing in the early rainfall of the season and continued its development with rising of precipitation (Figure 4.2).

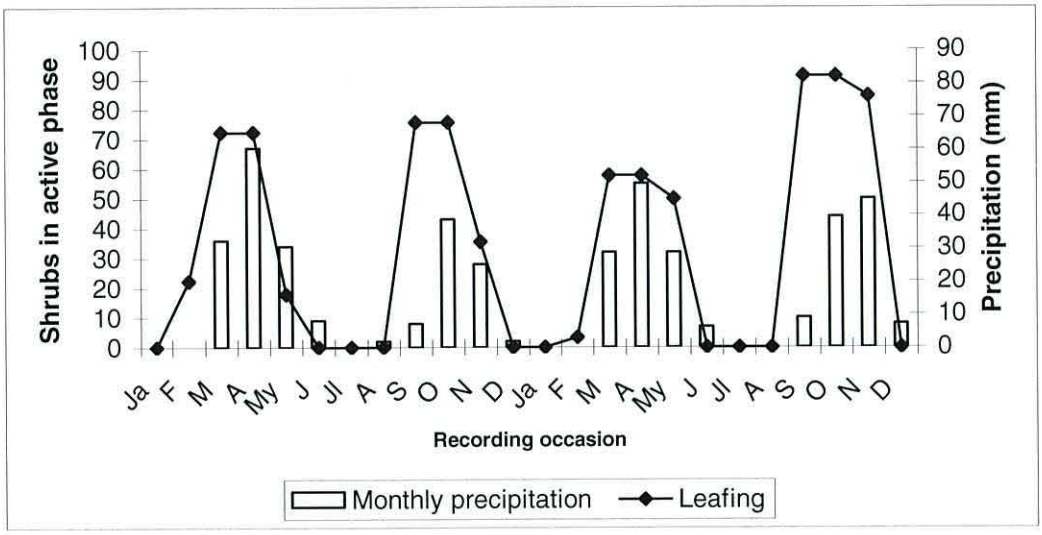

Figure 4.2 Relationship between leafing patterns of *Cordeauxia edulis* and the corresponding monthly rainfall in Boh, Ogaden, Ethiopia

Figure 4.3 presents the relationship between leafing phases and the corresponding monthly temperature and shows that temperature raised its maximum stage in the leafing period of C.*edulis* (Figure 4.3).

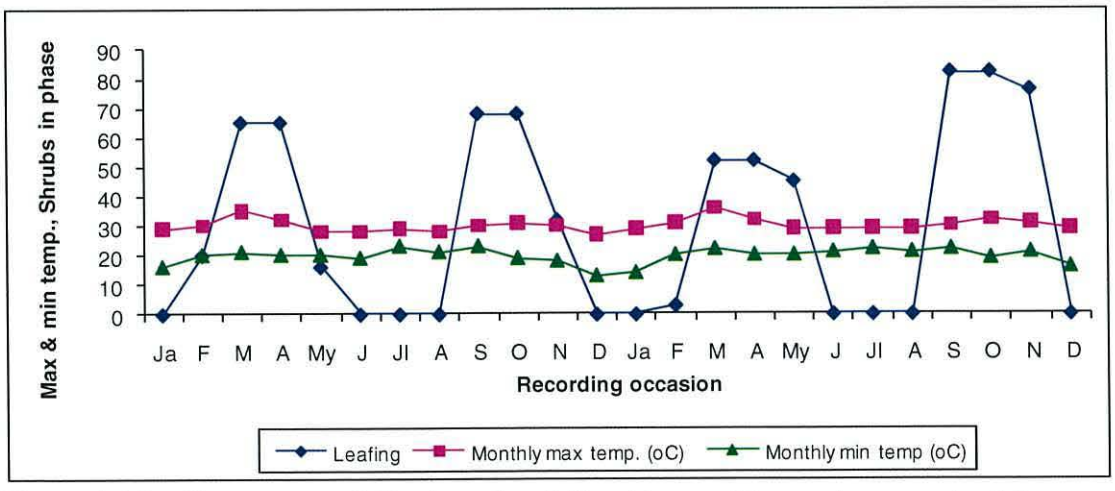

Figure 4.3 Leafing pattern of *Cordeauxia edulis* with monthly maximum and minimum temperature in Boh, Ogaden, Ethiopia

Table 4.8 summarises the correlation between monthly precipitations, maximum and minimum temperature and leaf shedding, flushing, flowering and fruiting. Flushing, flowering and fruiting were significantly correlated ($P<0.01$) with precipitation. Flushing ($P<0.01$) and flowering ($P<0.05$) also showed significant correlation with maximum temperature (Table 4.8).

Table 4.8 Pearson's correlation (coefficient) of leaf shedding, leaf flushing, flowering and fruiting with monthly precipitation, maximum and minimum temperature in Boh, Ogaden, Ethiopia

Environmental variables	Leaf shedding	Flushing	Flowering	Fruiting
Monthly total precipitation (mm)	-0.23	0.66(**)	0.80(**)	0.65(**)
Monthly max.temp (C^o)	0.18	0.73(**)	0.35(*)	-0.07
Monthly min.temp (C^o)	0.02	0.25	0.02	-0.19

(**=correlation is significant at $P\leq 0.01$, *=correlation is significant at $P\leq 0.05$ level)

Temp- temperature, Max-maximum, Min-minimum

4.4.1.3 Flowering activity

Flowering of *Cordeauxia edulis* were observed in both wet seasons of the year (Figure 4.4). Inflorescence buds and open flowers began to appear at the end of March and beginning of April in the first rainfall season and in October for the second season. Flower dried withered in April and beginning of November (Figure 4.4).

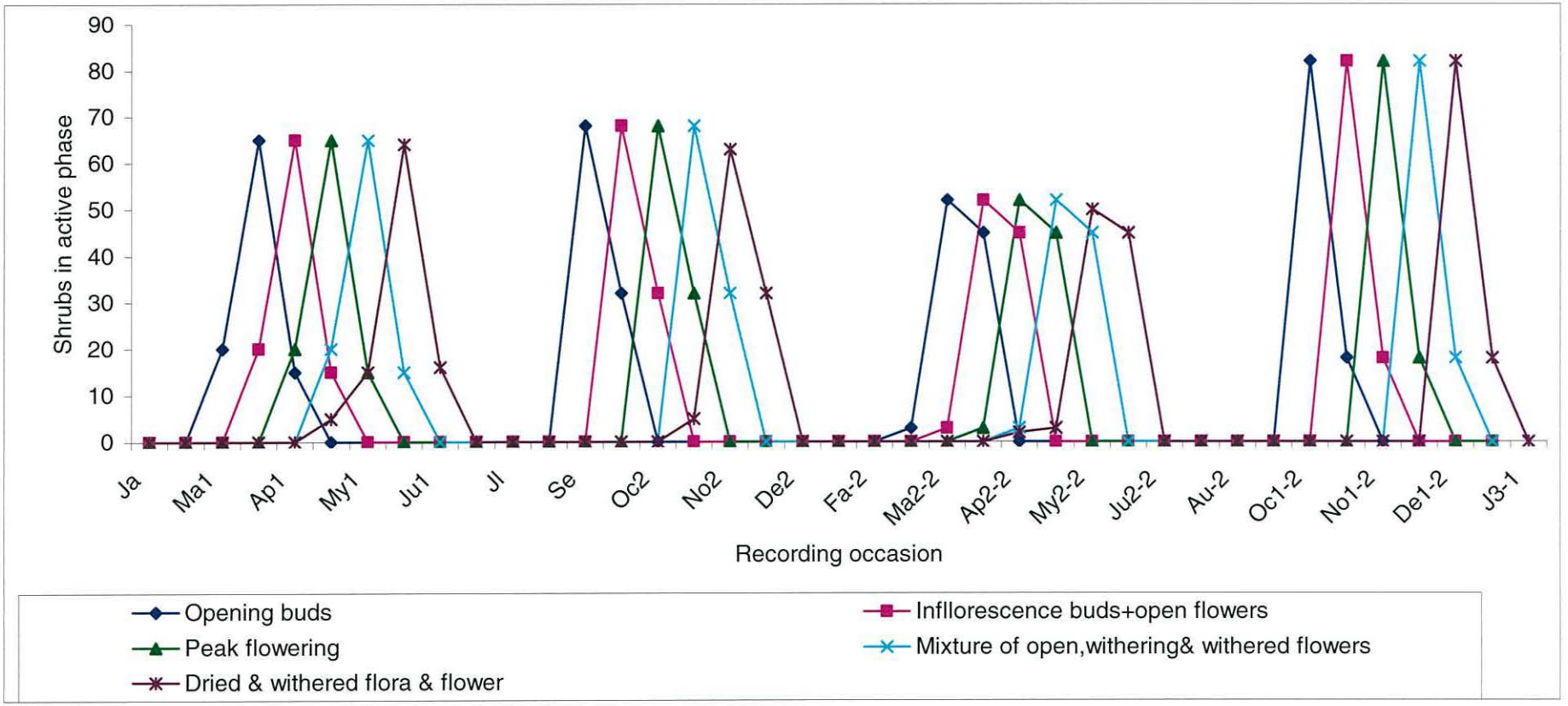

Figure 4. 4 Intensity of flowering phases; opening buds, inflorescence buds + open flower, peak flowering, mixture of open withering, and withered flowers, and dried and withered flower of *Cordeauxia edulis* in two years of study 2008 & 2009 in Boh district, Ogaden, Ethiopia.

For instance Ma1, indicates first 15 days of March, 2008 and Ma2-2 indicates second 15 days of March, 2009

The result of analysis of flowering pattern with monthly rainfall indicated that higher flowering intensity was observed to occur with higher precipitation (Figure4.5).

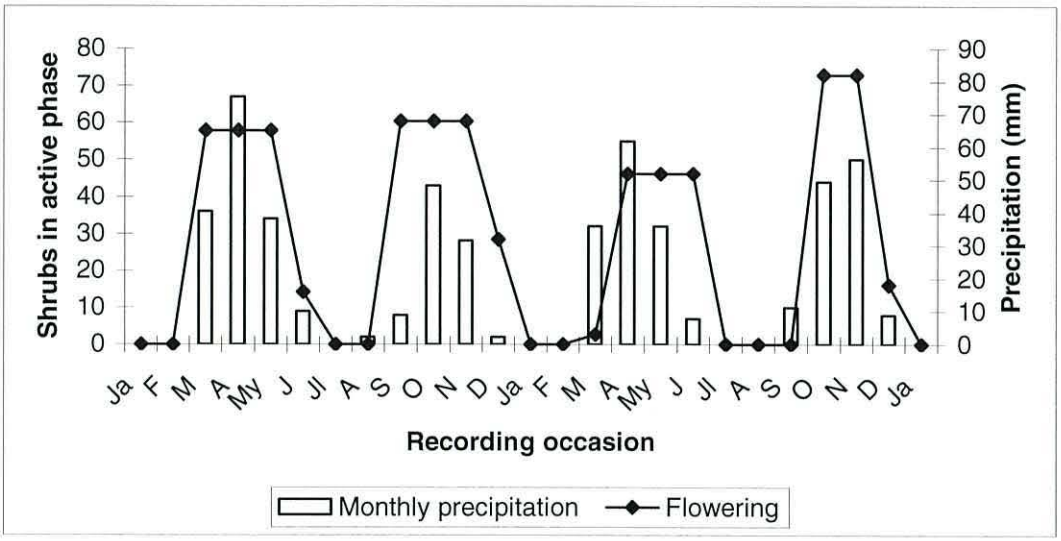

Figure 4.5 Flowering patterns of *Cordeauxia edulis* with monthly precipitation in 2008 &2009 at Boh, Ogaden, Ethiopia

The highest maximum mean monthly temperature was recorded in the flowering period (Figure 4.6). Similarly, the lowest mean minimum temperature was recorded when flowers dried and withered (Figure 4.6).

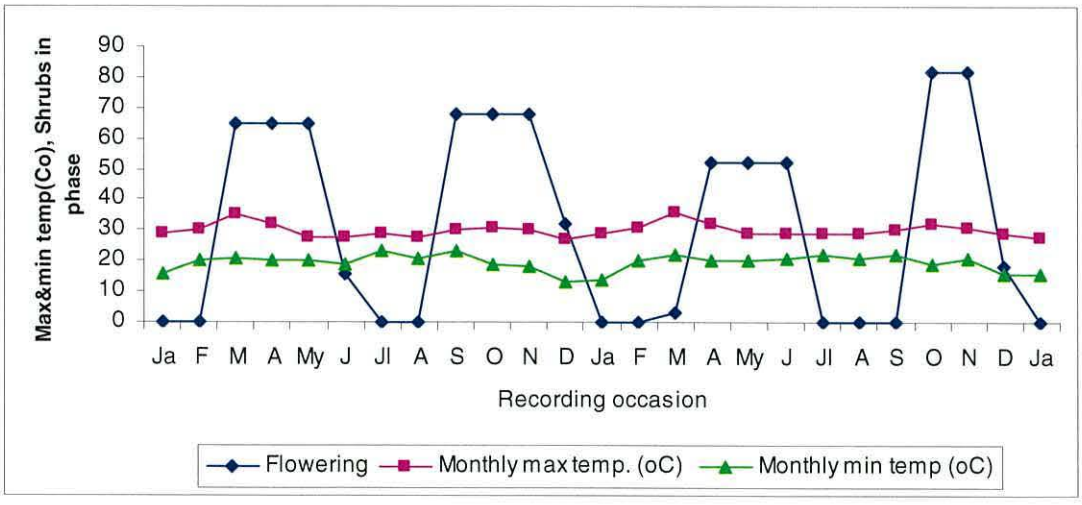

Figure 4. 6 Flowering patterns of *Cordeauxia edulis* with monthly maximum and minimum temperature in Boh, Ogaden, Ethiopia

Plate 4.3 *Cordeauxia edulis* in flowering at Boh, Ogaden, Ethiopia (Photo by: Mussa M. Yusuf)

4.4.1.4 Flower visitors

A wide range of insect species were observed visiting *C.edulis* (Figure 4.7). Floral visitors were species of bees (*Apis spp.*), ants (*Camponotus spp.*), butterflies (*Cephonodes spp.*), sunbirds (Hedydipna *spp.*) and beetles (*Pachnoda spp.*). Among them native bees were the most frequent visitors (51%), followed by honeybee (*Apis mallifera*) (22%) (Figure 4.7).

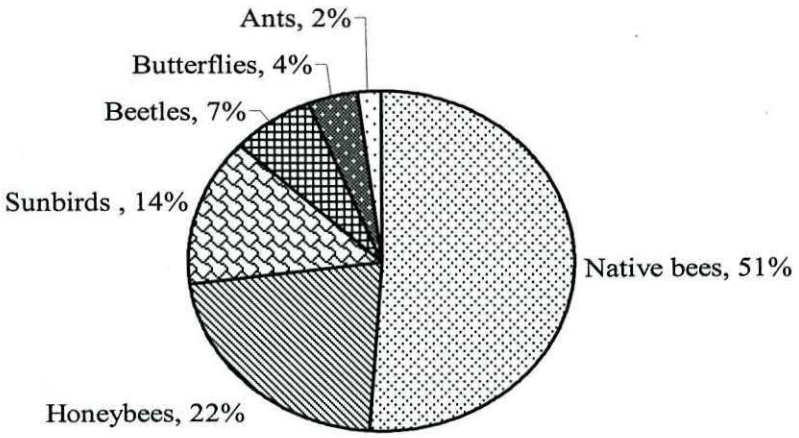

Figure 4.7 Floral visitors of *Cordeauxia edulis* in Boh, Ogaden, Ethiopia

4.4.1.5 Fruiting episode

Analysis of fruiting phenophases of *Cordeauxia* showed that early fruit setting started at the end of April and the beginning of November. May, early June, November and December were the periods of peak maturation, ripening and onset of fruit harvesting (Figure 4.8). The fertilized ovaries of some flowers stopped development after early fruit settings and went in to a diapauses stage due to lack of precipitation. These continued development and ripened early in the next rainfall.

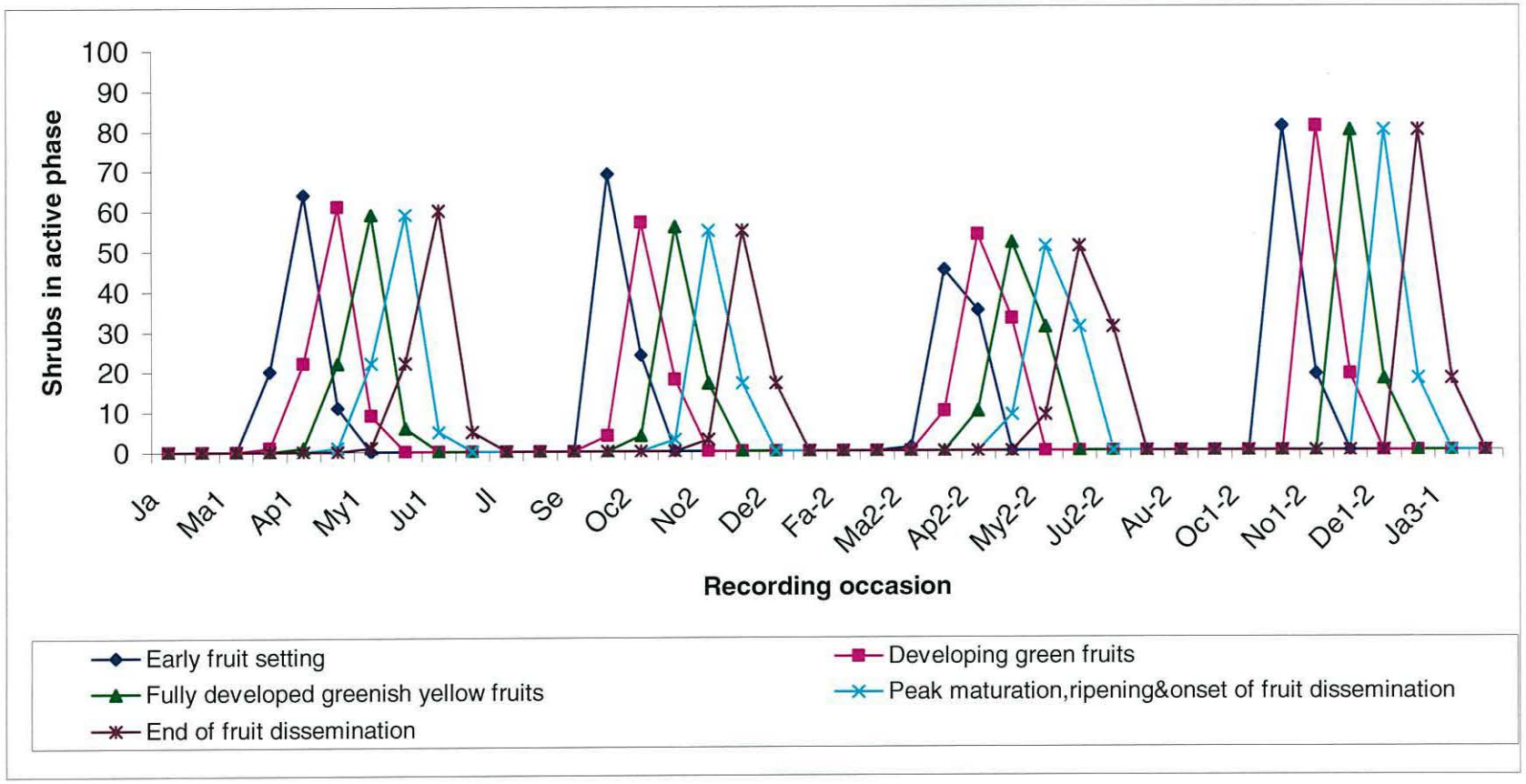

Figure 4.8 Fruiting phases; Early fruit setting , developing green fruit, fully develop greenish yellow fruit, peak maturation, ripening and onset of fruit harvesting and end of fruit harvesting of *Cordeauxia edulis* in Boh, Ogaden, Ethiopia

For instance Ma1, indicates first 15 days of March, 2008 and Ma2-2 indicates second 15 days of March, 2009

Rainfall was at a peak during early fruit setting and developing green fruit and declined as the fruit become fully developed (Figure 4.9).

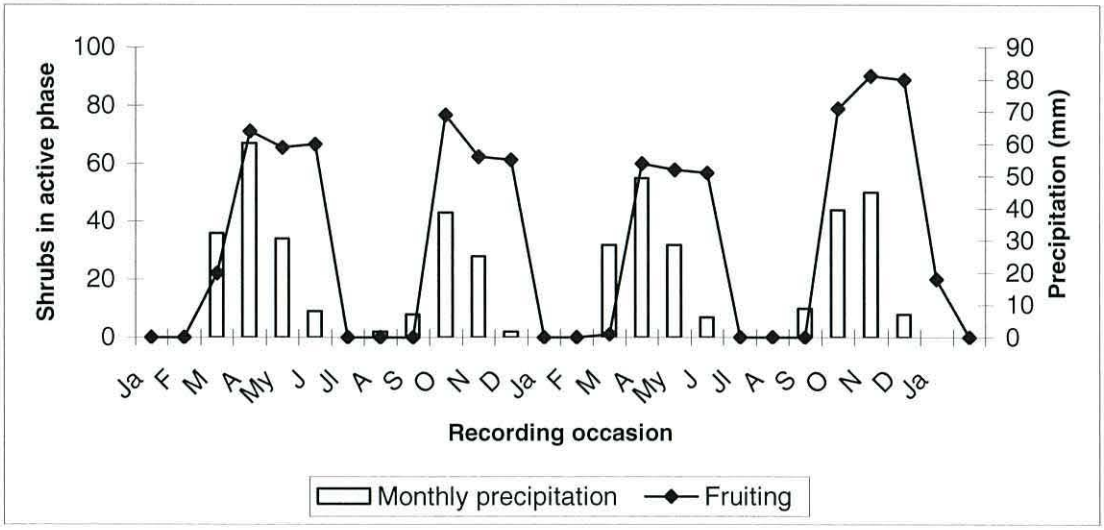

Figure 4.9 Fruiting pattern of *Cordeauxia edulis* with monthly precipitation in Boh, Ogaden, Ethiopia

Monthly maximum temperature declined and reached its lowest level during fruiting phases (Figure 4.10). Similarly, monthly minimum temperature declined during peak maturation, ripening & onset of fruit harvesting and end of fruit harvesting (Figure 4.10).

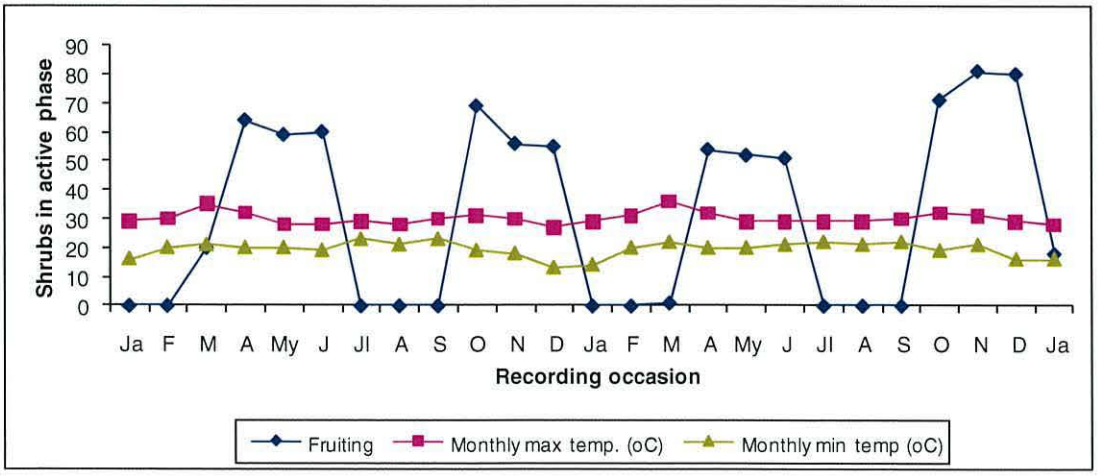

Figure 4.10 Fruiting pattern of *Cordeauxia edulis* with monthly maximum and minimum temperature in Boh, Ogaden, Ethiopia

Plate 4.4 *Cordeauxia edulis* in fruiting at Boh, Ogaden, Ethiopia (Photo by: M.M.Yusuf)

Fruit harvested

Figure 4.11 shows the mean weight of fruit harvested per *C.edulis* shrub at the end of each rainy season. The highest mean weight of fruits per clump was 2.02 kg obtained at Maned village, whereas the lowest mean weight was 0.10 kg recorded from Demerjog locality (Figure 4.11).

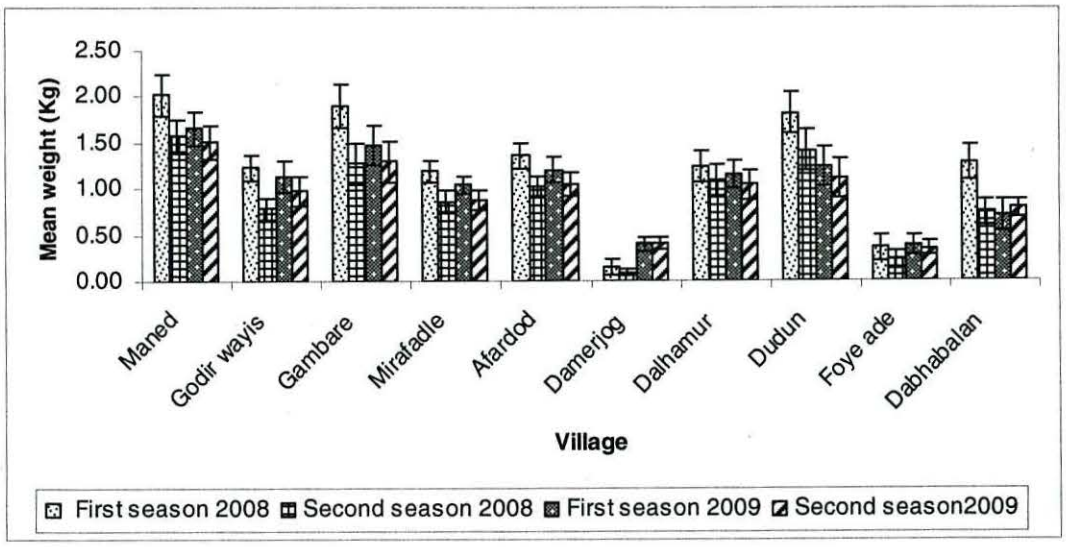

Figure 4.11 Mean weight of fruit harvested per clump of *Cordeauxia edulis* at Boh, Ogaden, Ethiopia

Maximum of 458 fruits kg^{-1} and a minimum of 290 fruits kg^{-1} were counted, the average number of fruit being 388 fruits kg^{-1}.

Figure 4.12 presents comparison of total fruit harvested at the end of each season from 100 sampled *C.edulis* with respective total precipitation (mm). The result revealed that the highest fruit weight of 123 kg was recorded in first season of 2008, during which the highest amount of total precipitation of 146 mm was also recorded. The lowest amount of harvest was 89 kg in second season of 2008 when the minimum total precipitation of 83 mm was recorded (Figure 4.12).

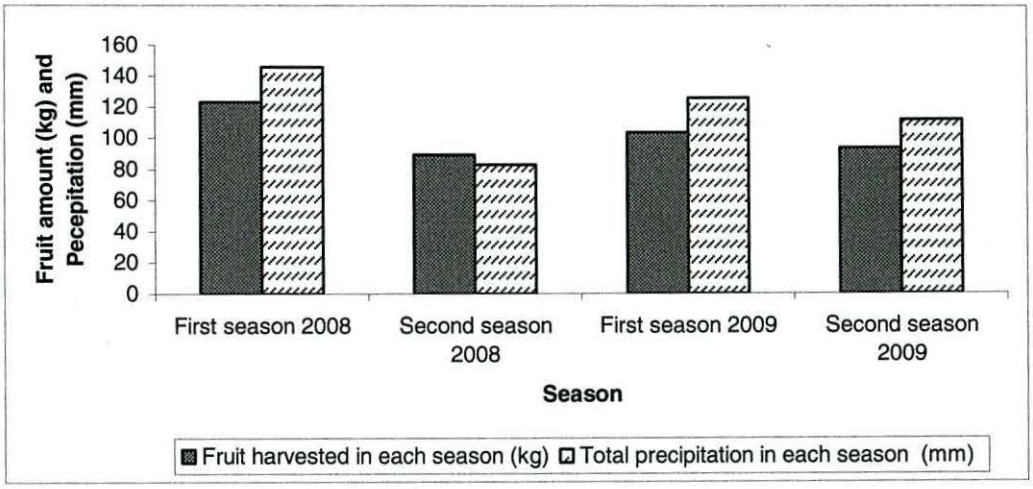

Figure 4.12 Comparison of harvested fruit per 100 clumps with total precipitation in Boh, Ogaden, Ethiopia

4.4.4. Nutritional composition of fruits of *Cordeauxia edulis*

Table 8.7 presents nutritional composition of *Cordeauxia* fruit, the results indicated that 1 g of dry weight of fruit contained 0.36 g (36%) of carbohydrate, 165.47 mg (16.54%) protein, 125.80 mg (12.58%) fat, 0.25g (25%) fibre, 48.07mg (4.81%) ash and 0.07g (7%) water.).

Table 4.9 Nutrient composition of fruit of *Cordeauxia edulis* in Boh, Ogaden, Ethiopia

Nutrient	per 1g dried weight	Percentage
Carbohydrate	0.36 ± 0.04 g	36
Protein	165.47 ± 4.69 mg	16.54
Fat	125.8 ± 0.98 mg	12.58
Fiber	0.25 ± 0.04 g	25
Ash	48.07 ± 5.56 mg	4.81
Water	0.07 ± 0.01 g	7

The mineral composition of *Cordeauxia* fruit is summarised in Table 4.10. The results showed that 1g of dry weight of fruit contained 13.14 mg of Potassium, 3.18 mg of Calcium, 3.09 mg of Magnesium, 1.62 mg of Phosphorous and 0.02 mg of Sodium 71.40 µg of Zinc, 42.63 µg of Iron and 18.70 µg of Manganese.

Table 4.10 Mineral composition of fruit of *Cordeauxia edulis* in Boh, Ogaden, Ethiopia

Mineral	Composition
	(in mg g-1 dry weight)
Phosphorus (P)	1.62 (0.10)
Sodium (Na)	0.02 (0.00)
Potassium (K)	13.14 (0.87)
Calcium (Ca)	3.18 (0.12)
Magnesium (Mg)	3.09(0.94)
	(in µg g-1 dry weight)
Iron (Fe)	42.63 (2.44)
Manganese (Mn)	18.70 (1.72)
Zinc (Zn)	71.40(24.29)

Values in bracket are SEM

4.5 Discussion

4.5.1. Soil of the study site

Based on Marx *et al.,* (1999) soil nutrient test and interpretation guide, soil in the study area may be categorized as poor, low organic matter and essential nutrients such as, available phosphorus, potassium and total nitrogen. According to Bally (1966) and FAO (1988), the soil of the area to which *C.edulis* (Yeheb) is limited (locally called *'Haud'*), is poor in fertility and usually slightly alkaline (pH 6.7 - 8.4). Drechsel and Zech (1988) also reported that *C.edulis* seems to prefer deep soil with low lime and gypsum contents, and has a low requirement for soil fertility.

Despite the fact that the soil of the study area largely homogenous, the textural class of soil seems to vary from sandy loam to loamy sand with position (under and away from shrub) and depth. This finding is consistent with findings of Drechsel and Zech (1988) who described that, besides the homogeneous deep red sands, non-homogenous reddish sandy soils also occur in the eastern *Haud* and Ogaden of Ethiopia; the soils vary in texture from sand to loam and in depth.

Essential nutrients such as available phosphorus, organic matter and total nitrogen were relatively low in Damerjog and Foye ade villages. This is most probably associated with lack of soil cover; population of C.*edulis* was disappearing from these two villages (See next chapter 5). Vegetation cover has been reported to prevent soil and nutrient loss (Benkobi *et al.*, 1994; Biesemans *et al.*, 2000). Thus, as a result of reduced vegetation cover, the soil of these two localities was exposed to erosion, both sheet and wind erosion, which has led to the loss of essential nutrients.

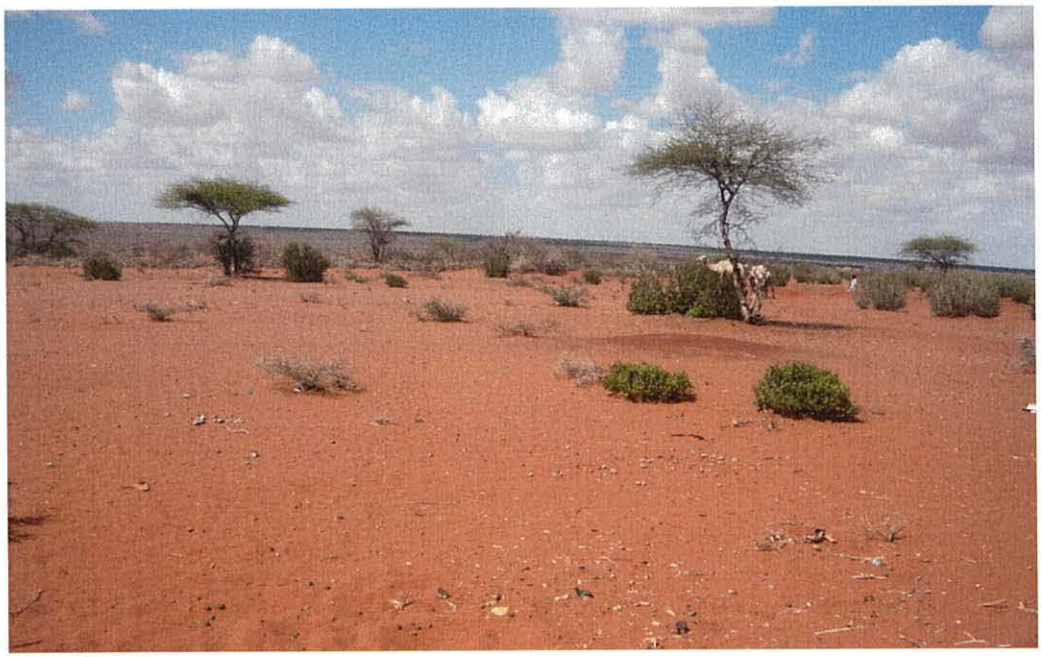

Plate 4.5 Soil exposed to wind and sheet erosion due to removal of *Cordeauxia edulis* at Damerjog Boh district, Ogaden, Ethiopia (Photo by: Mussa.M.Yusuf)

The results of the present study showed that Ca, total N, organic C and organic matter were higher under shrubs than further away. Soils under tree/shrub canopies having higher concentrations of organic matter and increased nutrient availability compared with neighbouring bare lands have also been reported in the literature (Garcia-Miragaya *et al.*, 1994; Tiedemann and Klemmedson, 1973). This is most probably due to released nutrients from decomposition of litters under tree/shrub (Swift *et al.*, 1979).

It is well known that the chemical characteristics of a soil, as much as its physical attributes, can vary with depth down the soil profile. A number of analytes (e.g. phosphorus, organic matter, total nitrogen, organic carbon) are normally concentrated at the soil surface (Bolland *et.al*, 1996; Sharma *et al.*, 2009). Similarly, the present study also found that the content of soil nutrients such as total N, Organic C, available P and OM varied in depth; higher in the surface soil than at the subsoil. But, Na and CEC however were higher in deeper than at the surface soil. Cations may be subjected to leaching by rain and could accumulate at lower depths in the soil profile (Lipsett & William 1971; Taylor *et.al*, 1988).

4.5.2. Climate of the study area

The native region of yeheb is the semi-desert region in the Horn of Africa, where rainfall is only 150-200 mm a year (Vietmeyer, 1985). But, Kazmi (1979) reported typical annual rainfall of 250 – 400 mm, but often reported that rainfall is below 250 mm. Yeheb can survive on as little as 150 mm rainfall (Zimsky, 1990). The rainfall in the natural habitat of yeheb is bimodal, in which there are two main rainy seasons, of varying reliability in April-June and October-November, and two pronounced dry seasons, daily average temperature is exceeding 25°C (Yahya and Durand, 1993), mean annual temperatures of 27-30 °C (Seegeler, 1983). The present study also showed that, the rainfall in the natural habitat of yeheb is bimodal, with two rainy seasons of varying in intensity from March to June (the main rainy season, locally called '*Guh*'), and from September to December called '*deyr*'. A total annual rainfall of 229 mm and 238 mm were registered in 2008 and 2009, respectively. The mean maximum temperature of the study site was 30°C while mean minimum temperature was 19°C.

4.5.3. Phenology of *Cordeauxia edulis*

Plants may time their leaf flushing, flowering and fruiting activity to coincide with conducive weather conditions for optimal performance (Khan, 1999). In the semi-desert area where annual rainfall is low, moisture is a limiting factor for production. Leaf flushing, flowering and fruiting showed an extremely strong positive relation with seasonal precipitation. Leaf flushing and flowering of C.*edulis* also showed a significant positive relation with maximum temperature. However, fruiting time exhibited negative relation with maximum temperature. This is most probably in order to minimise evapotranspiration, since fruit of C.*edulis* mature when the plant is at its highest water content (Ali, 1988).

According to Ali (1988), C.*edulis* is one of few ever green dry land plants; leaves not shaded rather start to curl as soil moisture content drops, at the onset of first rain they regain their turgidity and uncurl. It might be one of several adaptive responses allowing C.*edulis* to survive under stressful environments. Changing leaf size and shape may reduce the amount of solar energy absorbed through self imposed shading and thereby reduce water loss (Mooney *et al.,* 1978). The present study found that most of leaves of C.*edulis* were shed and fresh leaf flushing occurred at the onset of first rainfall in March. This finding was confirmed by pastoralists (Chapter 3) who reported that *C. edulis* sheds several leaves at the end of dry period. Curtis *et al*, (1996) and Ali (988) reported that the leaves of *C. edulis* exist for more than one season, but the lifespan of individual leaflets are not known.

If abundant water/rain is available, yeheb can flower twice but usually only once annually (Booth and Wickens, 1988). However, Miège and Miège (1978) and Gaertner *et. al.*, (1983) reported that flowering occurs throughout the year, but is more profuse during the rainy season. The present study also revealed that C.*edulis* flowers twice a year. Pastoralists (Chapter 3) also claimed that the main determining factor for flowering of *C.edulis* is precipitation; it can flower more than two times a year if water is available.

Several previous authors reported it is not known which insects pollinate *C. edulis* that floral parts fall soon after pollination leaving only the fertilized ovary (Booth and Wickens, 1988; Ali 1988; Wickens and Storey, 1984). The present study found that native bees (51%), honey bees (22%) and sunbirds (4%), were the most frequent visitors of *C. edulis* flowers, indicating that these are most probably the pollinators (pollinating agents) of *Cordeauxia* flower. This finding is in close agreement with the report of Bekele *et al.*, (1993) who revealed that bees are consumers of the flora and that *C.edulis* could be used for bee forage.

Early fruit setting in *C. edulis* started at the end of April and the beginning of November. Peak maturation, ripening and onset of fruit dissemination were observed in May-June of first rainy season and November - December of the second rainy season. But, in few shrubs however, development stopped after fruit set. This may be due to lack of moisture for continued development. These fruit did not die, but a rather went to a diapause stage and continued their development and matured early in next rainy season. This pattern of development is well adapted to an environment where setting seed carries a risk of failure due to the variability and uncertainty of the length of the available moisture period (Brilli and Mulas, 1939).

It has been reported that a shrub of *C. edulis* can yield up to 5 - 8 kg of fruits per year in normal years, or none in drought years (Brink, 2006). The result of the present study showed that the highest mean fruit yield /shrub per year were 3.6 kg, which is lower than the value reported in the literature. Fruit yield depends on the amount of seasonal rainfall.

4.5.4 Nutritional composition of fruits of *Cordeauxia edulis*

The nuts of C.*edulis* are of high nutritional value (Polhill & Thulin, 1989; Bekele *et al.*, 1993; Guinand & Lemessa, 2002). N.A.S (1979) reported that the main characteristics of the seeds are their high sugar and fat contents compared to other seeds of species in

the Fabaceae family. The present study also confirmed the results of the previous workers. The fruit of *C.edulis* is high in carbohydrate (36%), fat (12.58%) and also fiber (25%) contents. Fruit also contains protein (16.54%), water (7%) and ash (4.81%). These values closely agree with values reported by Booth and Wickens (1988) (carbohydrate (31-41%), protein (11-16%), fats (10- 13%), ash (2.2-3.8%) and water (7.8-16.9%)).

The present study also found that the fruit of C.*edulis* contains 165.47 mg g-1 of dry weight (16.54%) of protein which is less compared to other species of the Papilionaceae family (Miege and Miege, 1979). However, since the daily protein requirement is 56 g for adult male and 46 g for adult female consuming 340 g and 279 g of yeheb fruit daily can satisfy the protein demand of adult male and female respectively (Roizen, 1997; McAnarney *et. al,* 1992) (Table 8.12). Considering the arid condition of the region, the fruit of *C.edulis* alone can be source of considerable protein. Bally (1966) also suggested that for a region with very low rainfall, which can carry only a nomadic population and where agriculture is to all practical purposes non-existent, the protein content of yeheb might be essential.

Table 4.11 Daily dietary intake requirement of food nutrients (g) for humans

Nutrient	**Adult male**	**Adult female**	**Both**
Protein	56 g	46 g	
Fibre	30 - 38 g	21 - 25 g	
Calcium (Ca)	1.8 - 2.2 g	1.0 - 1.6 g	
Potassium (K)	4.8 - 5 g	4.5 - 4.7 g	
Magnesium (Mg)	0.40 g	0.32 g	
Phosphorus (P)			3 - 4 g
Sodium (Na)			2.3 g
Iron (Fe)			0.01 g
Manganese (Mn)			0.01 g
Zinc (Zn)			0.01 g

Sources: Roizen (1997), McAnarney *et. al* (1992)

The protein content of *Cordeauxia* fruit is high when compared with some other wild fruits such as Baobab *Adansonia digitata* (3.1%), *Vitellaria paradoxa* (8.4 - 8.8%), *Tamarindus indica* (4.1%) and *Ziziphus Mauritania* (4.1%) (Saka and Msonthi, 1994; Teketay *et al.*, 2003). Moreover, comparison of nutritional content with some cultivated fruit shows that C. *edulis* is also superior in protein and fat contents to banana (1.2% and 0.3% respectively), guava (0.9% and 0.3% respectively), mango (0.6% and 0.4% respectively) and Papaya (0.6% & 0.1% respectively) (Srivastava and Kumar, 1998).

In common with other high fiber legume seeds such as Peas and Soybeans (Vidal-valverde and Frias, 1991), the present study also revealed that fruit of Yeheb is rich in fiber (25%), much higher than the value of 14% reported by Leung *et.al* (1986). As reported in chapter 3, local people use fruit of yeheb medicinally to relieve stomach constipation, since consumption of food with high fiber has been reported to help prevention and treatment of stomach constipation (Weickert and Pfeiffer, 2008).

Among the macronutrients, potassium (K) content seems close to the value reported by Bally (1966), while phosphorus (P) was close with the result of El Zeany and Gutale (1982). Calcium (Ca) and Magnesium (Mg) however were higher compared to the results of these authors, but Sodium (Na) content was lower. Fruit of *C.edulis* is higher in P, Ca and Mg compared with other wild fruits such as Baobab *Adansonia digitata* (1g of dried weight contains 0.450mg of P, 1.16 mg of Ca & 2.09 mg of Mg), *Annona senegalenis* (1g of dried weight contains 1.51 g of P, 0.95 mg of Ca, 1.76 mg of Mg) and *Tamarindus indica* (1gm of dry weight has 1.08 mg of P, 0.17 mg Ca & 1.28 mg) (Saka and Msonthi, 1994).

According to the daily requirement of macronutrients described by Roizen (1997) and McAnarney *et. al* (1992) in table 8.12, daily consumption of 566 – 692 g of yeheb fruit by adult male and 314 – 503 g by adult female is enough to get daily amount of calcium needed whereas 365 - 380 g and 342- 357g of fruit for adult male and female respectively can provide daily requirement of potassium. However, relatively large quantity (1852 - 2469 g) of fruit would be needed for adult to get daily requirement of

phosphorus, while eating only 129g yeheb fruit is enough to get the amount of Mg needed daily. Hence, with the exception of phosphorus, fruit of yeheb can provide the required amount of nutrients alone for local people who rely on and consider it as a major daily diet.

The results of the present study also showed that the fruit of yeheb is very rich in iron (4.3mg/100g) which is higher than some cereals such as rice (1.8mg/100g), wheat (3.5mg/100g), maize (2.7mg/100gm) (Léder, 2004). Local people claimed (see Chapter 3) that the fruit can be used to cure anaemia problems strengthening the finding of the present study because iron is essential to enhance red blood cell in human body (Andrews, 1999).

CHAPTER-V

POPULATION STATUS AND ASSOCIATED TREE/SHRUB SPECIES OF *CORDEAUXIA EDULIS* (YEHEB)

5.1 Introduction

Cordeauxia edulis, wherever it occurs, forms scattered, isolated clumps, with multi-branched ascending stems forming a tightly bunched crown. Branches close to the ground are foliated where they are not denuded by browsing livestock (Bally, 1966). *C. edulis* has been reported to grow in association with shrub species such as *Acacia spp, Commiphora* spp, *Grewia spp*, *Cordia spp* and *Cordyla somalensis* and some taller trees such as *Acacia tortilis*, *Delonix elata* and *Albizia anthelmintica* (Bally, 1966; Hemming, 1966; Watson *et al.*, 1982).

At present the populations of *C. edulis* in regions, which were formerly dominated by *C.edulis*, have shrunk to small, scattered patches, primarily due to lack of regeneration as a result of decades of intensive and destructive harvesting of seeds, which are a popular food for the local people in the regions. Moreover, once the seed harvest is over, the herdsmen let the herds of goats and camels browse the shrubs at will, claiming that the meat of animals fed on the leaves is particularly tasty (Bally, 1966). Thus, there are only few populations of *C. edulis* left. It is not just the scientific community that has misinterpreted the decline of yeheb; the pastoralists themselves appear unaware of the real reason for its decline and they are even reluctant to admit it. For example, according to Kucher (1987), when pastoralists were asked to explain the reasons for the decline of *C. edulis*, they blamed it on weather (drought) and disease. They were less likely to relate decline to fruit collecting, and none blamed their livestock (Kucher 1987). An IUCN (1997) report, however, underlines that drought, overgrazing, cutting and war have all contributed to decimate yeheb from its nature regions. The extinction an important resource so well adapted to arid zones would be an irreplaceable loss for

the long-term survival not just of the East African populations concerned but possibly also for others living in semi- arid areas of Africa (Miege & Miege, 1979).

Some yeheb populations in central Somalia have been studied but no information of even the most basic kind has come out of the Ogaden region in Ethiopia. Thus, there is an urgent need to gather some basic data on extent and status of yeheb in the Ogaden or Somali Regional State of Ethiopia (Kucher 1987). The present study was undertaken in Boh district of the Ogaden region to assess the population status of *C. edulis* and associated tree/shrub species growing with it.

5.2 Specific Objectives:

1. To assess size class distribution, density and regeneration status of populations of *Cordeauxia edulis* in the study area.
2. To assess the associated plant species growing with *Cordeauxia edulis* in the study area.

Hypothesis and research question of the study

a. There is no variation in height, basal diameter, crown diameter of *Cordeauxia edulis* between populations in the study area
b. There is no variation in density of *Cordeauxia edulis* between populations in the study area
c. There is no variation in regeneration of *Cordeauxia edulis* between populations in the study area
d. What are associated tree/shrub species growing with *Cordeauxia edulis*?

5.3. Materials and Methods

Size class distribution and stocking density were determined to assess the population status of *C. edulis*. The study was conducted in 10 villages (localities) in Boh district,

Ogaden the only region where *C. edulis* is found in Ethiopia. The study was conducted in 2008. Each village represented one population of *C. edulis*. Methods consisted of field inventory of *C.edulis* and associated tree/shrub species growing with it.

In each village, a point was randomly selected inside the population of *C.edulis* and 1 km long transect was laid out. Along each transect, 10 m x 10 m plots were established at 100 m intervals. This gave a total of ten 10 x 10 m plots per village. Since *C. edulis* is multi-stemmed, within each plot all clumps of *C. edulis* with more than 1 stem per clump (adult clumps) were counted. The number of stems in each clump was recorded and height and basal diameter of each stem within each clump were also measured. The crown diameter was measured for each clump. Crown diameter was derived by measuring the north-south & east-west crown diameters through the crown vertical projection. The mean of the two crown measurements were used as a single crown diameter value for each clump

To assess the natural regeneration, all seedlings (single stemmed shrubs) were counted in each 10 x 10 m plot. Seedlings were categorised as either arising from seed or root sucker. In each plot the number of associated species of trees/shrub were also identified and counted.

Plate 5.1 Assessment of *Cordeauxia edulis* population by the field survey team in Boh district, Ogaden, Ethiopia

5.3.1. Data analysis

Data were entered, processed and frequencies by height, basal diameter, and crown diameter classes as well as the densities of *C.edulis* were computed using Ms *excel* spread sheets. Analysis of variance (ANOVA) was applied to the data Using Minitab software to reveal the overall variation between populations. Tukey's-test was used to make pairwise comparison between the means. Pearson's correlation was also used to find allometric relationships between morphological characteristics of *C. edulis*.

5.4 Results

5.4.1 Population status of *Cordeauxia edulis*

5.4.1.1 Size class distribution

a) Basal diameter class distribution

A total of 1059 stems in 67 clumps were enumerated in the 10 populations at Boh district, Ogaden, Ethiopia.

As shown in Figure 5.1 and Table 5.1, the majority (632) of C.*edulis* stems was in size class 2.01-3.5 cm (Table 5.2).

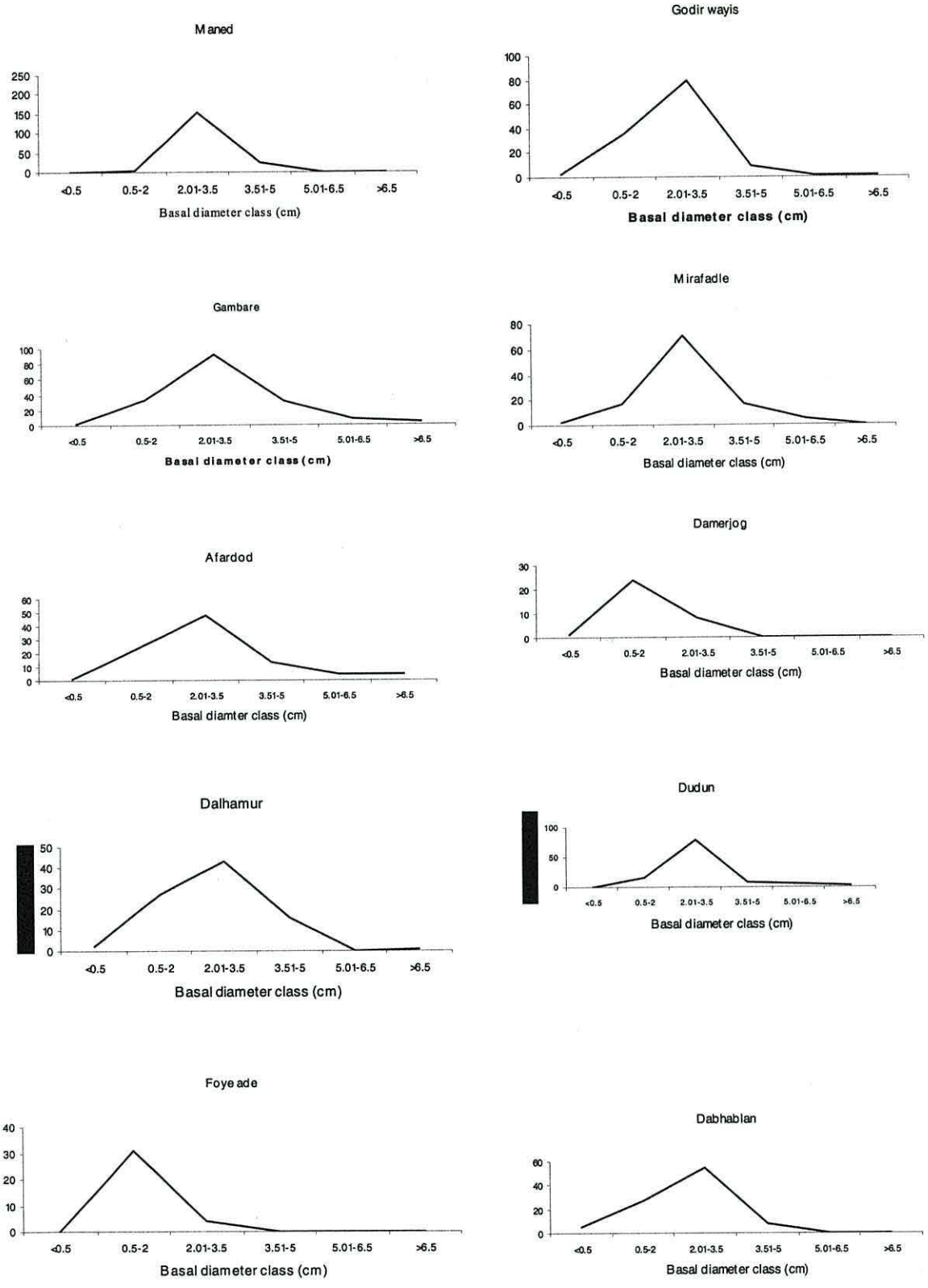

Figure 5.1 Frequency of basal diameter of *Cordeauxia edulis* in each village

Table 5.1 Frequency distribution of individual stems of *Cordeauxia edulis* by basal diameter classes at Boh, Ogaden, Ethiopia.

	Basal diameter class (cm)					
Population	<0.5	0.5-2	2.01-3.5	3.51-5	5.01-6.5	>6.5
Maned	0	5	155	25	1	1
Godir wayis	3	36	79	9	1	1
Gambare	1	34	92	31	8	4
Mirafadle	2	17	70	17	5	0
Afardod	1	25	48	13	5	5
Damerjog	1	24	8	0	0	0
Dalhamur	2	27	43	16	0	1
Dudun	1	17	78	7	6	3
Foye ade	0	31	4	0	0	0
Dabhablan	5	28	55	8	0	0
All populations combined	**16**	**244**	**632**	**126**	**26**	**15**

b) Height class distribution

Figure 5.2 and Table 5.2 indicates that the majority of individuals of *C.edulis* was in height class of 1.5-2 m. Very few stems had height less than 0.5 m (3 stems).

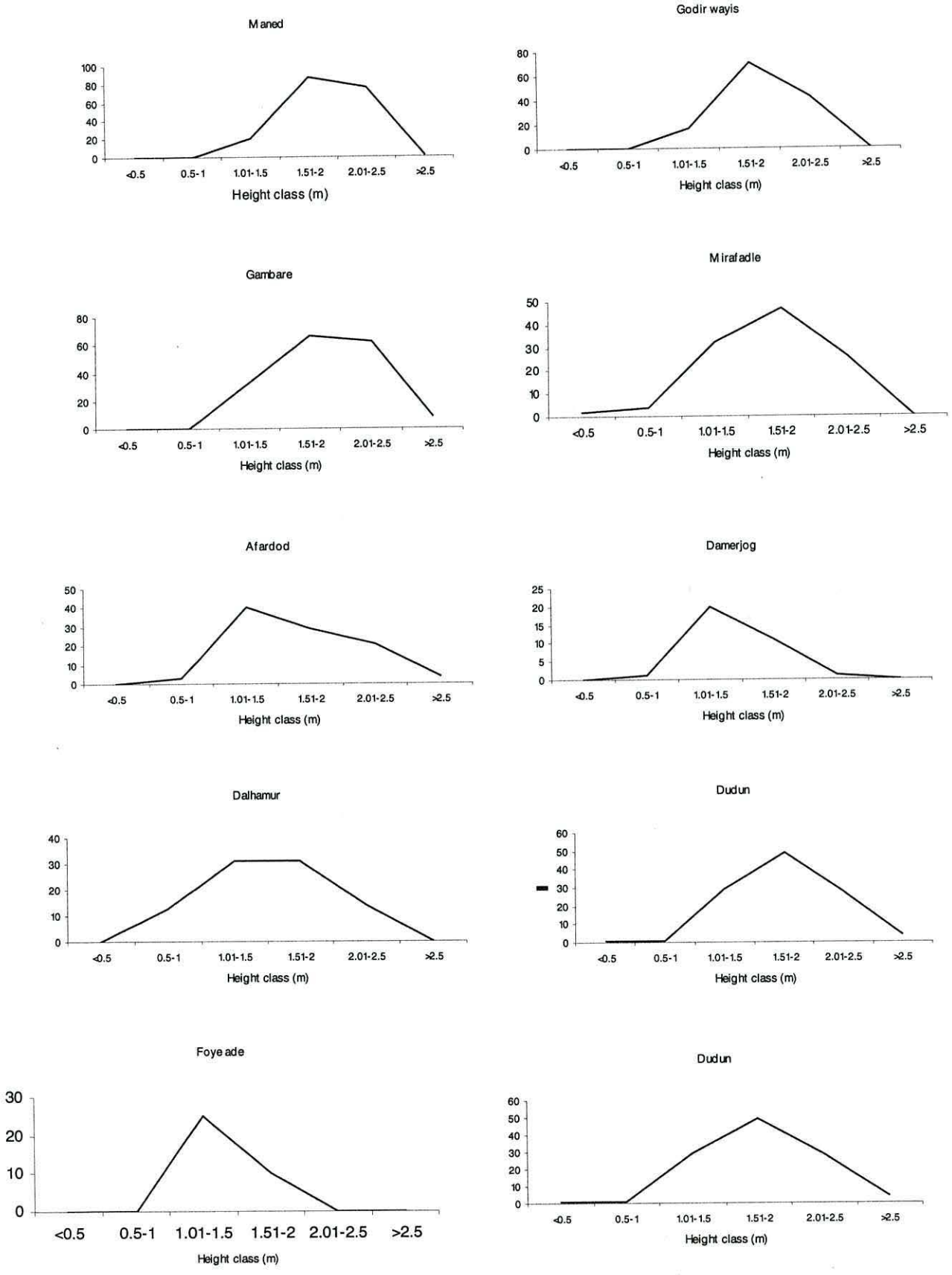

Figure 5.2 Frequency distribution of stem height of *C.edulis*

Table 5.2 Frequency distribution of individual stems of *Cordeauxia edulis* by height classes at Boh district of Ogaden, Ethiopia

	Height class (m)					
Populations	<0.5	0.5-1	1.01-1.5	1.51-2	2.01-2.5	>2.5
Maned	0	0	20	88	77	2
Godir wayis	0	0	16	71	42	0
Gambare	0	0	33	67	62	8
Mirafadle	2	4	32	47	26	0
Afardod	0	3	40	29	21	4
Damerjog	0	1	20	11	1	0
Dalhamur	0	13	31	31	14	0
Dudun	1	1	29	49	28	4
Foye ade	0	0	25	10	0	0
Dabhablan	0	4	38	34	20	0
All pop. combined	**3**	**26**	**284**	**437**	**291**	**18**

5.4.1.2. Mean height and mean basal diameter variations between populations

The result of ANOVA indicated that populations significantly varied in the mean height ($P<0.001$) and mean basal diameter ($P<0.001$) of individual stems as shown in Table 5.3. The highest mean basal diameter and mean height was found in Maned population (3.03±0.05 cm and 1.94±0.02 m, respectively) and the least in Damerjog population (1.55±0.08 cm and 1.42±0.05 m, respectively).

Table 5.3 Analysis of variance of mean basal diameter and mean height of individual stems of *Cordeauxia edulis* between populations at Boh, Ogaden, Ethiopia

Population	Height (m)	Basal diameter (cm)	N
Maned	1.94 ± 0.02^{a}	3.03 ± 0.05^{a}	187
Godirwayis	1.87 ± 0.02^{ad}	2.66 ± 0.09^{ab}	129
Gambare	1.90 ± 0.03^{ad}	2.99 ± 0.10^{ad}	170
Mirafadle	1.68 ± 0.04^{b}	2.84 ± 0.10^{ad}	111
Afardod	1.65 ± 0.05^{bc}	2.87 ± 0.16^{ad}	97
Damerjog	1.42 ± 0.05^{ce}	1.55 ± 0.08^{c}	33
Dalhamur	1.51 ± 0.05^{ce}	2.56 ± 0.13^{bd}	89
Dudun	1.78 ± 0.04^{bd}	2.88 ± 0.12^{ad}	112
Foyeade	1.42 ± 0.03^{ef}	1.57 ± 0.06^{ce}	35
Dabhablan	1.62 ± 0.04^{bcf}	2.25 ± 0.10^{bce}	96
	$P<0.001$	$P<0.001$	

Results are mean ± SEM; different letters in the same column indicates significance difference between populations at 0.001 level according to Tukey's test. N is number of individual stems.

5.4.1.3 Crown diameter and canopy cover

Based on the result presented in Figure 5.3 and Table 5.4 the majority of individual clumps of *C.edulis* were in crown diameter class of 2.01-2.5 m, while few were in class less than 1 m and above 3 m.

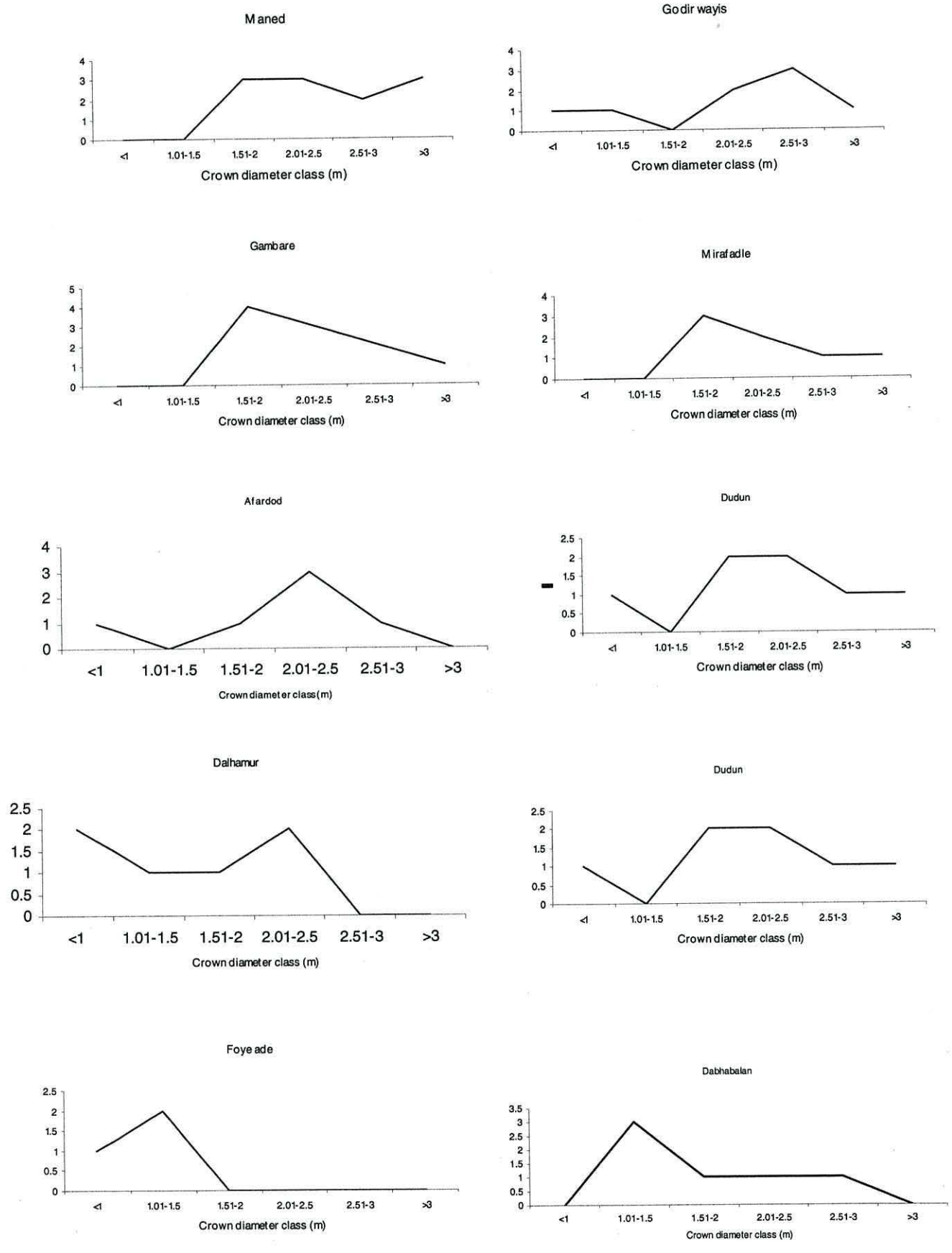

Figure 5.3 Frequency of crown diameter of *C.edulis* in each village

Table 5.4 Frequency distribution of individual clumps of *Cordeauxia edulis* by crown diameter classes at Boh district of Ogaden, Ethiopia

Population	Crown Diameter classes (m)					
	<1	1.01-1.5	1.51-2	2.01-2.5	2.51-3	>3
Maned	0	0	3	3	2	3
Godir wayis	1	1	0	2	3	1
Gambare	0	0	4	3	2	1
Mirafadle	0	0	3	2	1	1
Afardod	1	0	1	3	1	0
Damerjog	1	1	1	0	0	0
Dalhamur	2	1	1	2	0	0
Dudun	1	0	2	2	1	1
Foye ade	1	2	0	0	0	0
Dabhabalan	0	3	1	1	1	0
All pop. combined	**7**	**8**	**16**	**18**	**11**	**7**

Table 5.5 summarises mean crown area per clump and population canopy cover per hectare. The highest mean crown area per clump of 4.58 m^2 was recorded at Maned and the lowest (0.89 m^2) at Damerjog population (Table 5.8). Similarly, the highest population canopy cover per hectare of 503 m^2 was recorded at Maned. The lowest population canopy cover per hectare of 27 m^2 was found in Damerjog.

Table 5.5 Mean crown area per clump and population canopy cover per hectare of *Cordeauxia edulis* in Boh, Ogaden

Population	Mean crown area (m^2)	Population canopy cover ha^{-1} (m^2)
Maned	4.58	503
Godir wayis	4.03	322
Gambare	4.09	409
Mirafadle	4.09	287
Afardod	3.21	193
Damerjog	0.89	27
Dalhamur	1.84	110
Dudun	3.49	244
Foye ade	0.98	29
Dabhablan	2.19	131

5.4.1.4 Number of stems per clump of *Cordeauxia edulis*

Figure 5.4 and Table 5.6 shows frequency for number of stem per clump of *C.edulis* and the result indicates majority clumps of *C.edulis* contains number of stem ranged from 13 to 16 and closely followed by 17 to 20 while only one clump with number of stem in class greater than 24 was recorded.

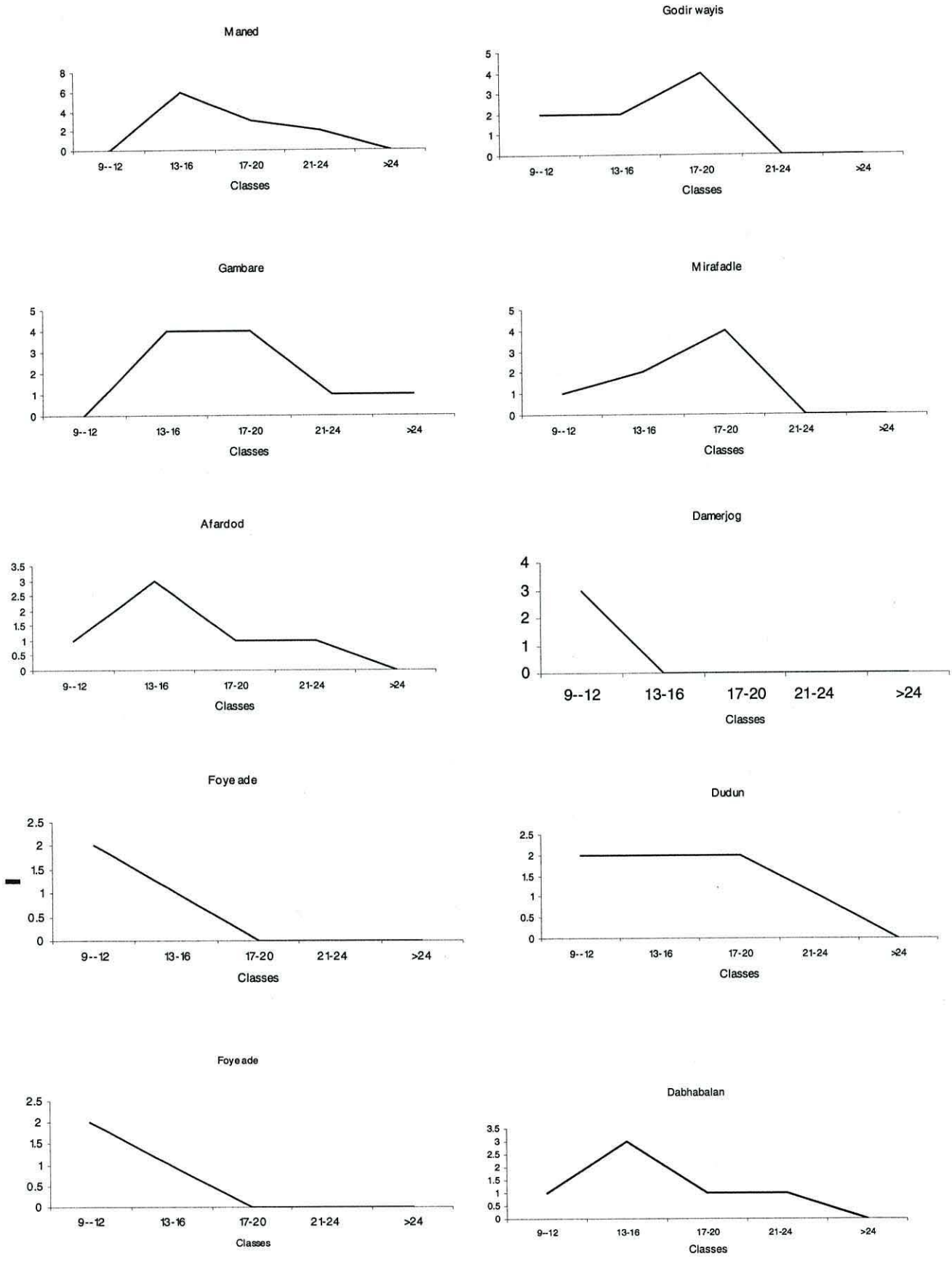

Figure 5.4 Frequency of number of stem per clump of *C.edulis* in each village

Table 5.6 Frequency distribution of number of stems per clump of *Cordeauxia edulis* in Boh, Ogaden, Ethiopia

	Classes for number of stem per clump				
Population	9-12	13-16	17-20	21-24	>24
Maned	0	6	3	2	0
Godir wayis	2	2	4	0	0
Gambare	0	4	4	1	1
Mirafadle	1	2	4	0	0
Afardod	1	3	1	1	0
Damerjog	3	0	0	0	0
Dalhamur	2	2	2	0	0
Dudun	2	2	2	1	0
Foye ade	2	1	0	0	0
Dabhabalan	1	3	1	1	0
All population combined	**14**	**25**	**21**	**6**	**1**

5.4.1.5. Mean crown diameter and mean number of stems variations between populations

The result of ANOVA revealed that mean crown diameter of *C.edulis* varied significantly ($P<0.01$) between populations (Table 5.7). The highest mean crown diameter was found in Maned population (2.42 ± 0.16 m) and the least in Damerjog population (1.06 ± 0.27 m). However, no significance difference ($P>0.05$) in mean number of stems per clump was found between populations of *C.edulis* (Table 5.7).

Table 5.7 Analysis of variance of mean crown diameter and mean number of stems per clump of *Cordeauxia edulis* between populations at Boh, Ogaden, Ethiopia

Population	**Crown diameter (m)**	**No of stems per clump**	**No of clumps**
Maned	2.42 ± 0.16a	17.00 ± 1.18	11
Godirwayis	2.27 ± 0.26ab	16.13 ± 1.23	8
Gambare	2.28 ± 0.15ab	17.00 ± 1.25	10
Mirafadle	2.28 ± 0.18ab	15.86 ± 1.32	7
Afardod	2.02 ± 0.30ab	16.17 ± 1.90	6
Damerjog	1.06 ± 0.27cb	11.00 ± 1.00	3
Dalhamur	1.53 ± 0.30ab	14.83 ± 1.62	6
Dudun	2.11 ± 0.29ab	16.14 ± 1.62	7
Foyeade	1.12 ± 0.12ab	11.67 ± 1.20	3
Dabhablan	1.67 ± 0.25ab	16.00 ± 1.46	6
	P<0.01	NS	

Results are mean ± SEM; different letters in the same column indicates significance difference between populations at 0.001 level according to Tukey's test. NS is non significance

5.4.1.6. Allometric relationships between morphological characteristics

Table 5.8 shows correlation between morphological characteristics of *C.edulis* and based on the results there was strong positive correlation between height and basal diameter and also between number of stems per clump and crown diameter.

Table 5.8 Pearson's correlation (Coefficients) between height, basal diameter, crown diameter and number of stems/clump of *Cordeauxia edulis* in Boh, Ogaden, Ethiopia

	Height	Basal diameter	Crown Diameter
Basal diameter	0.79 (**)		
Crown diameter	0.17 (ns)	0.09 (ns)	
No of stems/clump	0.15 (ns)	0.10 (ns)	0.85 (**)

**=correlation is significant at P≤ 0.01 level and ns indicates non significance

5.4.1.7. Population density

Figure 5.5 shows number of clumps of C.*edulis* (Yeheb) per hectare per population. The result of ANOVA indicated that there was no significant variation in population density between populations. The overall mean population density was 67 clumps ha^{-1}. The highest population density of 110 clumps ha^{-1} was recorded at Maned while the lowest was at Damerjog and Foye ade populations (each 30 clumps ha^{-1}).

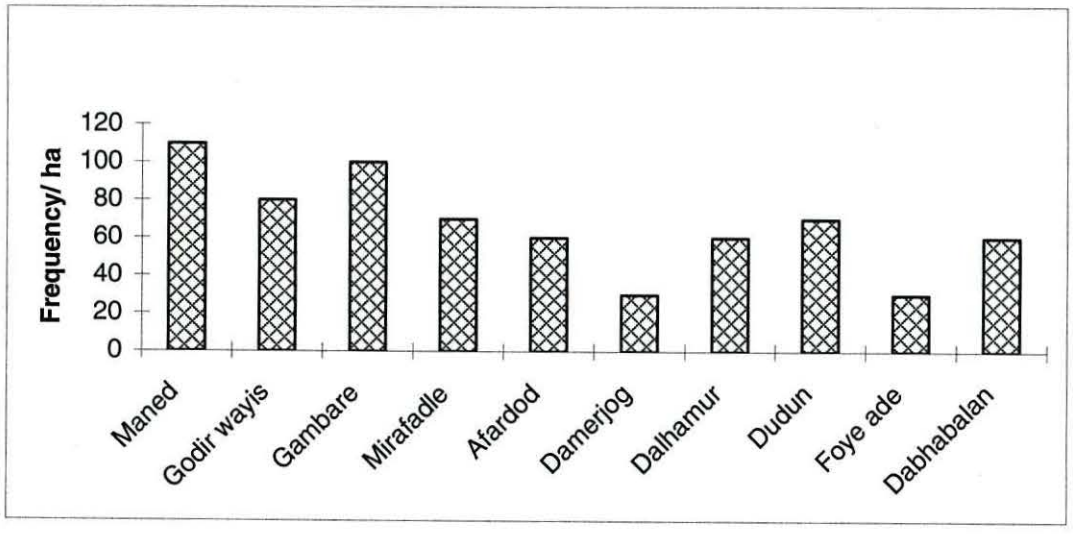

Figure 5.5 Density of *Cordeauxia edulis* (clumps ha^{-1}) in Boh district of Ogaden, Ethiopia

5.4.1.8 Natural Regeneration Status

The result on natural regeneration status indicated that there was almost no natural regeneration of C.*edulis*. A single seedling was found in each of four populations (Maned, Gamabere, Mirafadle and Dudun). No seedlings were found in other six populations hence, it was not possible to test the hypothesis whether or not there was variation between populations. The origin of the seedlings recorded was mainly from seed (75%) where as the remaining 25% was from root sucker.

Table 5.9 Mean seedling/plot and number of seedling ha^{-1} of *Cordeauxia edulis* in Boh, Ogaden, Ethiopia

	Man	Godw	Gam	Mir	Afa	Dam	Dal	Dud	Foy	Dab
Mean No of seedlings $plot^{-1}$	0.1	0	0.1	0.1	0	0	0	0.1	0	0
No of seedlings ha^{-1}	10	0	10	10	0	0	0	10	0	0

Ma-Maned, Godw-Godirwayis, Gam-Gambare, Mir-Mirafadle, Afa-Afardod, Dam-Damerjog, Dal-Dalhamur, Dud-Dudun, Foy-Foye ade and Dab-Dabhabalan

5.4.2 Associated tree/shrub species growing with *Cordeauxia edulis* (Yeheb)

Table 5.10 shows that there were a total of 16 different tree or shrub species closely associated with *C.edulis,* with a majority (6 species) belonging to the family *Burseraceae.*

Table 5.10 Associated tree species growing with *Cordeauxia edulis* in Boh district, Ogaden, Ethiopia

S/N	Scientific name	Family	Somali name	Growth form
1	*Commiphora erytherae*	*Burseraceae*	Hagar	Tree
2	*Commiphora candidula*	*Burseraceae*	Rahanreeb	Tree
3	*Acacia tortilis*	*Mimosaceae*	Qudhac	Tree
4	*Sesamothamnus rivae*	*Pedaliaceae*	Salaamako	Tree/shrub
5	*Terminalia orbicularis*	*Combretaceae*	Bisiq	Shrub
6	*Balanites scillin*	*Balaniteceae*	Shillin	Tree
7	*Commiphora spp.*	*Burseraceae*	Qadhoon	Tree/shrub
8	*Acacia horrida*	*Mimosaceae*	Sarmaan	Tree
9	*Fagonia lahovari*	*Zygophyllaceae*	Baskalax	Tree
10	*Cordia africana*	*Boraginaceae*	Madheedh	Tree
11	*Indigofera ruspoli*	*Papilionaceae*	Jillab	Tree
12	*Boswellia neglecta*	*Burseraceae*	Murchen	Tree
13	*Euphorbia cuneata*	*Euphorbiaceae*	Dhirindhir	woody herb
14	*Cassia obovata*	*Caesalpiniaceae*	Jallelo	Shrub
15	*Commiphora horrida*	*Burseraceae*	Qadhoon madow	Tree
16	*Boswellia microphylla*	*Burseraceae*	Jewdheer	Tree

Figure 5.6 shows percentage of individual associated tree/shrub species and the result indicated that *Acacia tortilis* and *Boswellia neglecta* were the dominant (13.64% each) associated species.

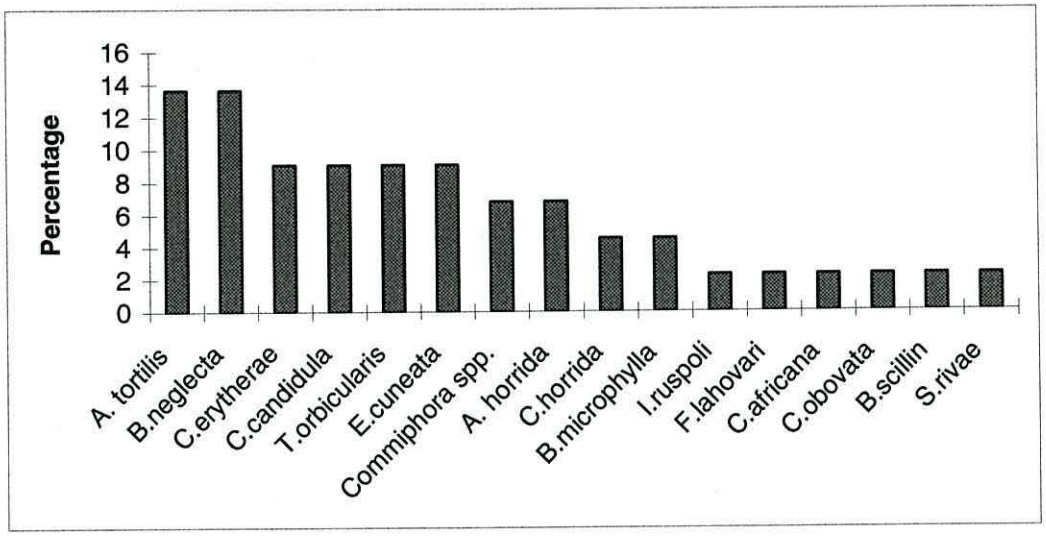

Figure 5.6 Percentage of individual associated tree species growing with *Cordeauxia edulis* in Boh, Ogaden, Ethiopia

Comparison of density of associated tree/shrub species in relation to density of C.*edulis* revealed that the density of associated species was low where the density of C.*edulis* was high (Figure 5.7). The lowest density of associated species (30 trees/shrubs ha^{-1}) was found in Maned population where the density of *C. edulis* was the highest (110 clumps ha^{-1}). The highest density of associated species (70 trees/shrub ha^{-1}) was recorded at Damrejog where the lowest density of C. *edulis* was recorded (30 clumps ha^{-1}) (Figure 5.7).

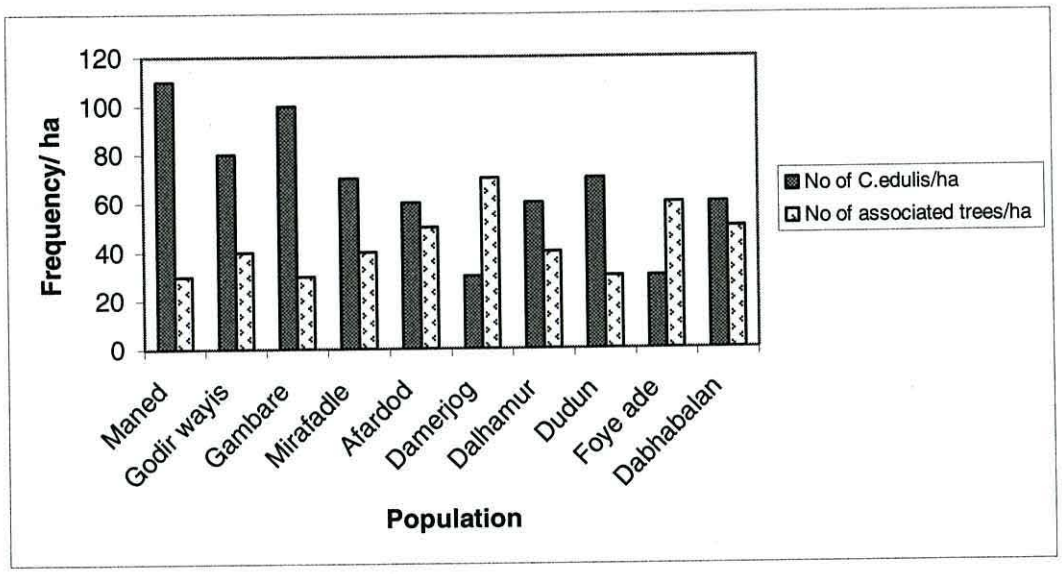

Figure 5.7 Comparison of density of *Cordeauxia edulis* with density of associated tree/shrub species in Boh district, Ogaden, Ethiopia

5.5 Discussion

The present study showed that the mean population density of *C.edulis* was 67 clumps ha^{-1}. This was extremely low compared to 162 plants ha^{-1} in poor sites and 319 plants ha^{-1} on sites in excellent condition reported by Ali (1988). Brink (2006) also reported that under natural conditions in Somalia there were up to 320 plants ha^{-1}, depending on growing conditions and distances from villages and water points. Hence, the result of the present study indicates that *C. edulis* may be considered to be in a critical stage of extinction in the Ogaden region especially at Damerjog and Foye ade where only 30 clumps ha^{-1} were recorded. As these two populations are close to the border with neighboring Somalia, the low density may be attributed to over-exploitation by the local people as well as by people crossing over the border from neighboring Somalia.

Comparison of morphological characteristics (height, basal diameter, crown diameter) of C.*edulis* showed significant variations between populations. Height and basal

diameters were higher in relatively higher density populations. The majority of stems had basal diameter between 2.01 cm and 3.5 cm and height between 1.5 m and 2 m. Majority of clumps had crown diameter between 2.01m and 2.5 m and between 13 and 16 stems per clump. There are no data on basal diameter and crown diameter in the literature to compare with the results of the present study. The result of stem height of the present study was, however, in agreement with results reported in the literature. It was reported by previous workers that mature plants of *Cordeauxia edulis* (Yeheb) may reach a height of 1.6 m while a few grew to 2.5 m in favourable locations and in places where it has not been grazed it reached a height of 3 to 4 m but was usually dwarf and no taller than 1.6 m because of browsing of its tender shoots and leaves by livestock (Kasmi, 1979; Thulin, 1983; Bally, 1966). The present study also confirmed the finding of the previous workers that the dwarf nature of species may be due to over-browsing by livestock, cutting for construction and firewood as well as for sale as source of income as reported in Chapter 3.

As like in other plant species, such as *Acacia etbaica* and *Carissa edulis* (Legesse and Eddy, 1990) there were strong positive relationships between height ($P<0.01$) and basal diameter and also between number of stems per clump and crown diameter per clump ($P<0.01$) of *C.edulis*.

The study on natural regeneration of *C.edulis* indicated that there were no seedlings observed in most of the populations studies (6 populations) while only one seedling and only in one plot per population was found in the remaining four populations. Hence, natural regeneration status of *Cordeauxia* was considered almost negligible according to the results of the present study. This may be due to excessive harvesting of seed by humans for food and sale. Whatever seed remains, they are also consumed by wild animals especially rodents. Similar findings were reported by many previous authors on regeneration status of *C.edulis*. Kazmi (1979) and Nerd *et al.* (1994) mentioned that local people harvest almost all the seeds for their own consumption and for sale, this leads to poor or no natural regeneration of *C.edulis*. Bally (1966) also mentioned that

the total absence of seedlings and young plants suggests that regeneration had been inhibited for years.

The origin of almost all seedlings (75%) observed was from seed. According to the local people, earth squirrels (Plate 5.2) may play role in the seed germination of *C.edulis*. The rodents collect the seeds, consume some and bury the remaining as a food reserve for later consumption. Some of the buried seeds germinate if the squirrels forget to consume them. The local people claimed that the seedlings which arose from seed were usually the result of such activity of the squirrels. This finding is in agreement with the finding of Yahya (2004) who also reported that earth squirrel may facilitate the establishment of new plants by burying seeds as a food reserve, thus giving forgotten seeds better germination conditions. Pastoralists mentioned however that this only takes place in years of high seed production. It is well known in other tropical plants such as Apricot (*Prunus armeniaca*) and Hickory (*Carya ovata*) that rodents bury seeds for reserve and that undamaged seeds eventually germinate (Jansen *et al.*, 2004; Ivan and Swihart, 2000). The food reserve of rodents also allows seeds to escape other predators and successfully establish. However, the rate of germination may decrease with decreasing seed abundance (Crawley and Long, 1995).

Plate 5.2 Earth squirrel associated with *Cordeauxia edulis*, in Boh district, Ogaden, Ethiopia (Photo by: Mussa.M.Yusuf)

The results of the present study indicated that the most common associated species with *C. edulis* included *Acacia* spp and *Commiphora* spp. and *Boswellia neglecta.* This finding is in close agreement with reports in the literature that *Cordeauxia edulis* is an evergreen shrub growing in a rangeland dominated by deciduous plant species mainly thorn bushes of *Acacia* and *Commiphora* (Kucher 1987; Ali, 1988). It was also found that the density of associated tree species was low in areas where C.*edulis* was relatively abundant. The finding confirms the report by Bally (1966) who reported that *C.edulis* is locally dominant and apart from a few scattered trees of *Acacia tortilis*, the yeheb bush is the tallest of the woody plants with which it grows in association. However, associated tree/shrub species are substituting and become abundant in areas where *C.edulis* is eradicating like Damerjog and Foye ade villages. This is happened as local peoples are selecting to cut *C.edulis* among all plants in the area due to its highest quality of construction and fuel wood.

In conclusion, the present study on population status of C.*edulis* indicated that the species is highly endangered, due to over-utilisation by pastoralists as a result of frequent drought in the region. Similarly, several previous authors also reported that the population of *C. edulis* is in great danger of extinction and today remaining stands are progressively being destroyed (Bally, 1966; Hemming, 1966). This is due to over-exploitation including long term heavy grazing pressure, over-harvesting of seeds for food and sale, and over-cutting for fire wood and construction (Booth and Wickens, 1988; FAO, 1988). Bally (1966) suggested that unless no steps are taken to protect the areas from overgrazing, to limit the harvesting and to set aside some of the crops for seeding purposes, the yeheb bush will disappear from the Boh region within a matter of few years.

CHAPTER-VI

PROPAGATION OF *CORDEAUXIA EDULIS* (YEHEB)

6.1 Introduction

Cordeauxia edulis (Yeheb) is a wild plant and although recently there have been attempts to domesticate it, these have not been with success (Kazmi, 1979). Some efforts have also been made to introduce *C. edulis* outside its natural habitat, again without much success. Attempts to grow the species have been made in Kenya, Tanzania, and Israel, Sudan, Yemen, India, and United States (Bekele *et al.*, 1993; Nerd *et al.*, 1994). The seeds seem to germinate well (up to 80% germinability) but establishing the seedlings in the field has been less successful. Seedlings were planted at four sites in the Negev Desert (Israel), but plants established and grew at only one of the sites (Nerd *et al.* 1994). The reason for failure is not known but Nerd *et al.* (1994) suggested that climate and/or biological factors may be responsible. Moreover, Ismail (1975) reported that seeds germinated in two weeks and germination of 65-80% was achieved, but plantation establishment was poor as the seedlings quickly developed a massive tap root and death occurred when broken. This is occurring as the plants develop access to soil moisture and increase the chances of survival (Kazmi, 1979).

To grow the plant from seeds, Wickens and Storey (1984) pointed out that they should be sown immediately after collection because they retain their viability for only few months (Kazmi, 1979). Viable seeds are not readily available and the one sold in market are rendered unviable by roasting (Von Carlowitz, 1986).

C. edulis is a most interesting plant for agrosilvopastoral land use. As a typical multi-purpose tree it should be more cultivated under favourable site conditions in the arid to semiarid tropics (Drechsel and Zech, 1988). However, lack of knowledge on suitable

agronomic techniques, poor seed supply for planting, short duration of seed viability, water necessary for establishment, slow aerial growth and fast tap root growth (Booth and Wickens, 1988) are the main hindrances to its survival. Furthermore, Brink (2006) also reported that inadequate knowledge on yeheb, especially on its propagation, agronomic practices, and selection and breeding aspects are some of the constraints curtailing its domestication (Brink, 2006). It may be possible to overcome some of these limitations by testing various propagation techniques and different seed and nursery treatments (Booth and Wickens, 1988). Hence, the present study was carried out to develop efficient and low technology propagation methods as well as produce improved planting materials for domestication of *C. edulis.*

6.2 Specific Objectives:

1. To develop efficient and low technology propagation methods to improve tree growth and fruit production of *Cordeauxia edulis.*
2. To produce improved planting materials for domestication of the species using propagation method developed.

Hypothesis of the study

a. *Cordeauxia edulis* can be propagated both sexually and asexually.

b. Growing media, seed pretreatments and watering regimes (watering at intervals) have no effect on seed germination and survival and growth of seedlings of *Cordeaxia edulis.*

6.3 Materials and Methods

6.3.1 Vegetative propagation

For vegetative propagation of *C. edulis*, soft and hard (terminal and basal, respectively) stem cuttings were used. These were taken from superior fruit bearing *C. edulis* shrubs that were selected using local people's selection criteria. The criteria included large

sized shrubs in height and crown diameter, matured shrubs, shrubs bearing several branches and shrubs with smooth bark. According to the local people, *C. edulis* with the above characteristics produced superior fruits. Based on these criteria 10 superior shrubs in each village or a total of 100 superior shrubs from 10 villages were selected with the help of local communities. The cutting trials were conducted in three phases: nursery, lath house and non-mist propagator phases. The trials were carried out both in the study site (Boh) as well as in Jijiga (the capital city of the region located about 600 km away from the study site at the Agricultural Research Centre). The trials in Boh involved only the nursery and non-mist propagator phases, whereas in Jijiga all the three phases were conducted.

i) Nursery phase trial

In the nursery phase trial, which was a preliminary phase of the stem cutting trial, in Boh as well as in Jijiga, four growing media were used: (i) local soil, (ii) local soil plus sand, (iii) local soil plus compost, and (iv) local soil plus sand plus compost. The soil mixtures were prepared based on the method described by Palzer (2002). All soils were sieved to remove gravel and debris. To prepare the mixture of local soil plus sand, three parts of sieved local soil was thoroughly mixed with one part of sand. To make the local soil and compost mixture, three parts of sieved local soil was mixed with one part of compost (cattle dung). For the mixture of local soil plus sand and plus compost, three parts of sieved soil was mixed with one part of sand and one part of compost. These mixtures were filled in polyethylene bags which were 10 cm in diameter and 15 cm in height (Plate 6.1).

Plate 6.1 Soil filling in poly bag and preparing for experiment in nursery at Jijiga, Ogaden, Ethiopia

For each site nursery phase trial, three cuttings from each of the basal and terminal branches of each selected superior shrub or a total of 120 basal and 120 terminal cuttings were taken from randomly chosen 40 of the 100 selected superior shrubs. Randomised complete block design (RCBD) was applied and 10 cuttings of each of basal and terminal cuttings were planted in each of the above four growing media (treatments) and replicated three times. The cuttings were watered daily. Rooting was assessed at fortnightly intervals starting from four weeks after planting. Observation was carried out over a period of four months. However, none of the cuttings rooted.

ii) Non-mist propagator trial

A non-mist propagator (Plate 6.2) was constructed at Boh as well as in Jijiga using wooden frame, polyethylene sheeting and rooting medium following the design of Leakey *et al.* (1990). Three growing media were tested: (i) sand, (ii) sawdust, (iii) mixture of sand and sawdust. For each site trial, three cuttings from each of basal and terminal branches were taken from each selected superior shrub or a total of 360 cuttings from 60 of the 100 selected superior shrubs were used for each site (Boh and Jijiga). Randomised complete block design (RCBD) was adapted and 20 cuttings of each of basal and terminal were planted in each of the above three growing media in which half of the cuttings in all media were treated with rooting hormone NAA (Alpha-Naphthalene Acetic acid) and the remaining without hormone treatment (control). Each treatment combination was replicated three times. The cuttings were watered or sprayed daily. Rooting was assessed at fortnightly intervals starting from four weeks after planting. Observation was carried out over a period of four months. However, none of the cuttings rooted.

Plate 6.2 a) and b) are non-mist propagator c) stem cuttings planted on non-mist propagator of sand substrate d) NAA hormone

iii) Lath house trial

The lath house trial was only conducted in Jijiga (Plate 6.3). Five growing media were tested: (i) study site soil (from Boh transported over 600 km distance), (ii) local soil (from Jijiga), (iii) local soil plus sand, (iv) local soil plus compost and (v) local soil plus sand plus compost. Six cuttings from each of basal and terminal branches from each selected superior shrub or a total of 600 cuttings from 50 of the 100 selected superior shrubs were used in this trial. Randomised complete block design (RCBD) was applied and 20 cuttings of each of basal and terminal cuttings were planted in each of the above five growing media in which half of the cuttings in all media were treated with rooting hormone NAA (Alpha-Naphthalene Acetic acid) and the remaining received no hormone treatment (control). Each treatment combination was replicated three times. The cuttings were watered daily. Rooting was assessed at fortnightly intervals starting from four weeks after planting. Observation was carried out over a period of four months. However, none of the cuttings rooted.

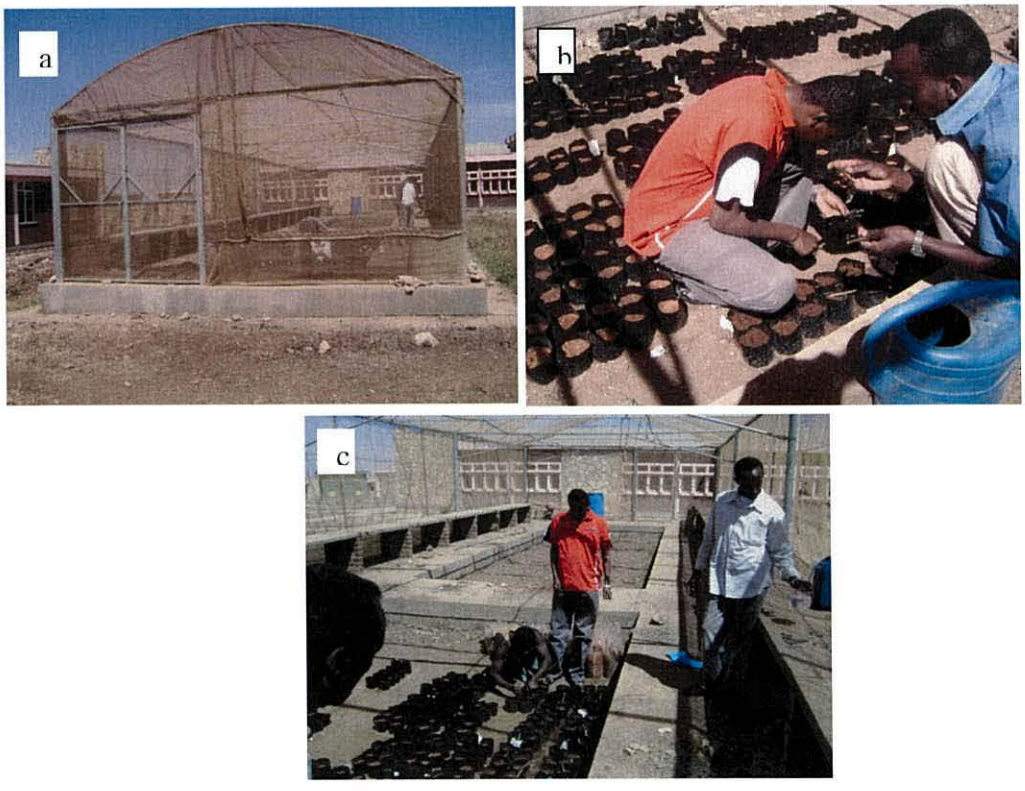

Plate 6.3 a) Lath house b) and c) planting stem cuttings in lath house

6.3.2 Propagation from seed

A study on the propagation of *C. edulis* from seed was conducted in the nursery in Jijiga. The altitude of Jijiga ranged from 600 - 1600 m.a.s.l., mean maximum and minimum temperatures are 28°C and 15°C, respectively and annual rainfall of 300 - 600 mm (Bekele, 2001).

Six experiments were conducted on seed propagation.

Experiment I:

In the first experiment, cooked seeds of *C. edulis* were used (seeds that were buried in hot ash by local users to prevent insect pest attack) (Plate 6.3). The objective of this experiment was to test the effect of different soil growing media on seed germination and performance of seedlings. Five growing media were tested (i) study site soil (from Boh), (ii) local soil (from Jijiga), (iii) local soil plus sand, (iv) local soil plus compost and (v) local soil plus sand plus compost. Completely randomised design (CRD) was used in this experiment. For each growing media 80 pots were used and replicated three times. A total of 1200 poly bags were used in the whole experiment. Watering was applied daily. Germination assessed on a daily bases immediately after sowing. Seedling survival and growth parameters including seedling height, root collar diameter and number of leaves and leaflets were assessed eight weeks after germination.

Plate 6.4 Seeds cooked by local users to prevent insect pest attack

Experiment II:

In the second experiment, uncooked seeds of *C. edulis* were used. The objective was to test the effect of different soil growing media on seed germination and performance of seedlings. The experiment involved five growing media as described in Experiment I. A completely randomised design (CRD) was adapted. For each growing media 80 pots were used and replicated four times. A total of 1600 poly bags were used in the whole experiment. Watering was applied daily. Germination assessed on a daily bases immediately after sowing. Seedling survival and growth parameters including seedling height, root collar diameter and number of leaves and leaflets were assessed eight weeks after germination. The seedlings that survived were then transplanted to larger poly pots. Survival and seedling growth were assessed at two monthly intervals up to 16 months of age.

Experiment III:

In the third experiment uncooked seeds were also used and the objective was to study the effect of alcohol as a pretreatment for breaking the seed dormancy of *C. edulis*. The

pretreatment was conducted by soaking seeds in alcohol for ½ an hour followed by washing in distilled water following the method described by Roshetko (1995). The experiment was carried out on five growing media as described in Experiment I. Completely randomised design (CRD) was used. For each growing media 80 pots were used and replicated three times. A total of 1200 poly bags were used in the whole experiment. Watering was applied daily. Germination was assessed on a daily bases immediately after sowing. Seedling survival and growth parameters including seedling height, root collar diameter and number of leaves and leaflets were assessed eight weeks after germination.

Experiment IV:

In this experiment uncooked seeds were also used. The objective was to test the effect of four other seed pretreatment methods: cold water, sulphuric acid, boiling water and untreated seeds as control. Seed pretreatments were conducted based on the method of Roshetko (1995) (Plate 6.4). For cold water treatment, seeds were soaked in cold water with volume five times the volume of seeds for 48 hours at room temperature. For sulphuric acid treatment, seeds were completely soaked in 98% sulphuric acid for 10 minutes (until waxy gloss of the seed coat was replaced by a dull appearance), and later removed from acid, rinsed with water for 10 minutes and soaked in cool water for 12 hours. Boiling water was poured over the seeds at a volume of five times the volume of seeds used in the treatment of boiling water. Seeds were soaked in and stirred gently for 3 minutes and then soaked in cool water for 12 hours. The pretreated seeds were then sown in five growing media as described in Experiment I. The design was split plot design involving four seed pretreatments and five growing media with pretreatment as main plot and growing media as subplot. For each growing media and seed pretreatment 80 pots were used and replicated three times. A total of 4800 poly pots were used in the whole experiment. Watering was applied daily. Germination was assessed on a daily bases immediately after sowing. Seedling survival and growth parameters including seedling height, root collar diameter and number of leaves and leaflets were assessed eight weeks after germination.

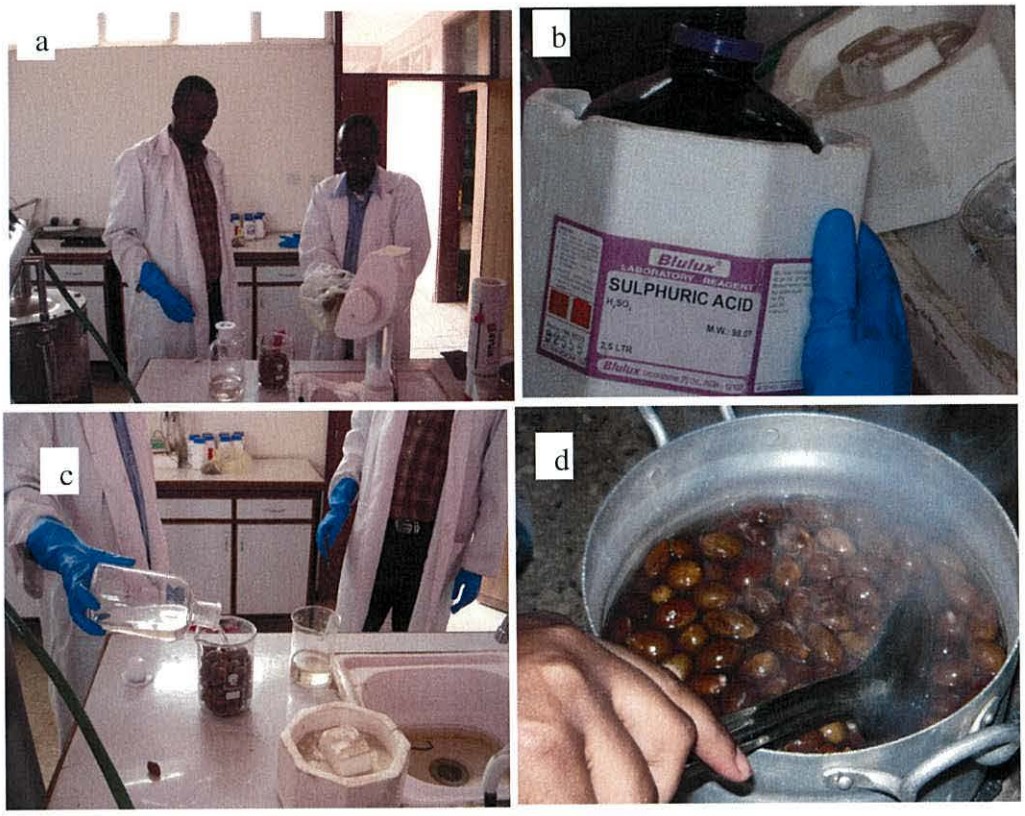

Plate 6.5 a) seed preparing for treatment of sulphuric acid b) 98% sulphuric acid and c) seed treating by sulphuric acid d) seed treating by boiling water

Experiment V:

The aim of this experiment was to test the effect of watering regimes on seed germination and seedling performance. Uncooked seeds treated with boiling water were also used in this experiment. The boiling water treatment was chosen because of high success in Experiment IV above. The watering regimes included i) watering twice a day, ii) once a day, iii) one day interval, iv) two days interval and v) three days interval. The plants were grown in five growing media as described in Experiment I. The design was split plot design involving five watering regimes and five growing media, with watering regime as main plot and growing media as subplot. For each growing media and watering regime 40 pots were used and replicated four times. A total of 4000 poly pots for the whole experiment. Germination was assessed on a daily bases immediately

after sowing. Seedling survival and growth parameters including seedling height, root collar diameter and number of leaves and leaflets were assessed eight weeks after germination.

Experiment VI:

The aim of this experiment was to test the effect of nursery shade on seed germination and seedling performance. The shade treatments were: i) full shade (100%), ii) intermediate shade (50%), and iii) without shade as control. The shade was made from palm leaves and to make full shade several layers of the palm leaves were used so that no light reached the nursery seed bed. Whereas in the case of the intermediate shade the leaves were arranged with gaps in between so that they only covered the nursery seed bed partially. Uncooked seeds pretreated with boiling water were used. The design was split plot design involving three nursery shade types and five growing media, with nursery shade as main plot and growing media as subplot. For each growing media and shade type 40 pots were used and replicated four times. A total of 2400 poly pots for the whole experiment. Germination was assessed on a daily bases immediately after sowing. Seedling survival and growth parameters including seedling height, root collar diameter and number of leaves and leaflets were assessed eight weeks after germination.

6.3.4 Data analysis

Data were first processed using Ms *Excel* to determine the mean and standard error of mean of each treatment. Analysis of variance (ANOVA) was used to compare variation between treatments. Pair wise t-tests were also carried out to compare treatments. Pearson's correlation was used to examine allometric relations between seedling parameters. All statistical analyses were performed using SPSS version12.

6.4 Results

6.4.1 Propagation from seed

Experiment I:

Table 6.1 presents the results of Experiment I. Seed germination varied significantly ($P<0.01$) between growing media. However, the overall seed germination (17%) was considered to be very low. The highest (24 ± 2.56%) mean germination was recorded in SS soil followed by P+S soil (17 ± 2.4%), while 11.5 ± 1.34% was the lowest mean germination obtained in P+C soil. Similarly, there was a significant difference ($P<0.01$) in mean seedling survival between growing media. The highest mean seedling survival was 53 ± 2.60% found in SS soil whereas 11 ± 4.53% was the lowest recorded in P+C soil. Mean height of seedlings also differed significantly ($P<0.05$) and the highest was 2.53 ± 0.26 cm in SS soil followed by P+S soil (2.02 ± 0.15 cm) whereas 1.12 ± 0.07 cm was the lowest mean seedling height obtained in P+C soil. Furthermore, root collar diameter ($P<0.05$) and number of leaflets ($P<0.05$) differed significantly among growing media, and the highest mean value (1.39 ± 0.05 mm and 8.93 ± 0.53 respectively) was recorded in SS while the lowest value (1.01 mm and 4.00 ± 0.58 respectively) was in P+C soil. No significance variation ($P>0.05$) in mean seedling number of leaves was found between growing media (Table 6.1).

Table 6.1 Result of seed germination and seedling parameters of *Cordeauxia edulis* germinated from cooked seed in different growing media

Characters	SS	P + S	P + S + C	P	P + C	F	P
Germination (%)	24±2.56a	17±2.4ab	16±1.65ab	16±1.93ab	11.5±1.34bc	4.75	<0.01
Survival (%)	53±2.60a	29±5.88b	33±3.33b	27±5.60b	11±4.53b	10.23	<0.01
Height (cm)	2.53±0.26a	2.02±0.15a	1.61±0.07b	1.64±0.07b	1.12±0.07c	2.96	<0.05
Root collar Diameter (mm)	1.39±0.05a	1.06±0.01b	1.06±0.002b	1.04±0.002b	1.01±0.002b	3.78	<0.05
No of leaflets	8.93±0.53a	7.08±0.38ab	5.54±0.24bc	4.92±0.29bc	4±0.58c	9.61	<0.01
No of leaves	1.81±0.15	1±0.1	1±0.00	1±0.00	1±0.00	2.19	>0.05

Data are mean ± SE; different letter in the same row indicates significant difference at $P < 0.05$
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

As shown in Table 6.2, there was significant (P<0.05) positive allometric relationships between seedling morphological parameters (height, root collar diameter, number of leaves and leaflets) in Experiment I, the highest being between number of leaves and number of leaflets and between seedling height and number of leaflets (r=0.85 and 0.75, respectively).

Table 6.2 Pearson's correlation (Coefficient) of seedling morphological parameters of cooked seed

	Root Collar Diameter	No of leaves	No of leaflets
Height	0.30(**)	0.69(**)	0.75(**)
Root collar Diameter		0.14(*)	0.18(*)
No of leaves			0.85(**)

**= Correlation is significant at the 0.01 level, *= Correlation is significant at 0.05 level

Experiment II:

Despite the fact that uncooked seeds were used in this experiment, the overall mean seed germination of 23% was still very low. However, mean seed germination differed (P<0.05) significantly between growing media. The highest mean germination value was 36.87% obtained in SS soil followed by P+S soil (24.69%) while the lowest was 13.10% obtained in P+C soils (Figure 6.1).

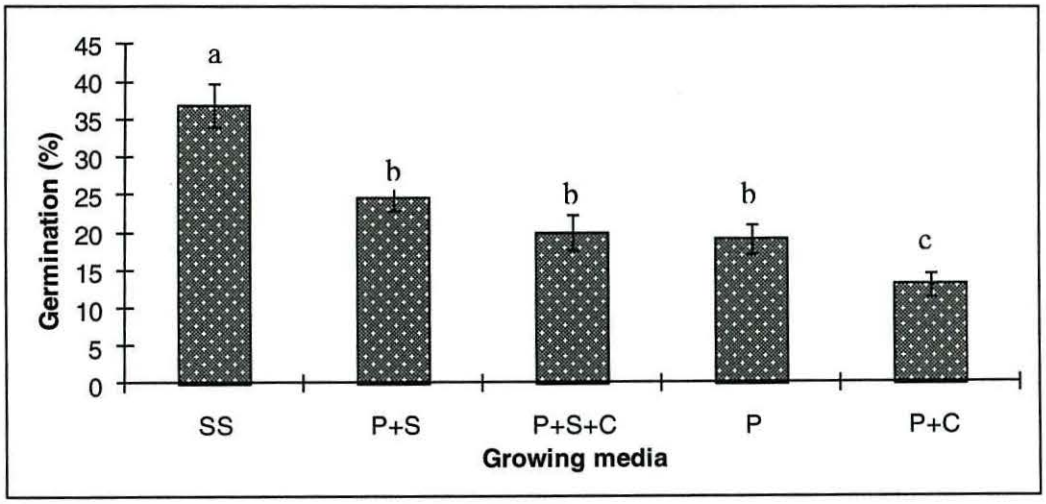

Figure 6.1 Mean seed germination (%) of *Cordeauxia edulis* from untreated seed in different growing media

Different letter on bar chart indicates significance difference at the level of 0.05.

Similarly, there were significance ($P<0.05$) differences in mean seedling survival (%) between growing media in all the eight ages of seedling growth (Table 6.3). The highest mean seedling survival in all ages was found in the study site soil (SS) followed by P+S soil whereas the lowest was in P+C soils. None of seedlings survived in P+C, P+S+C, and P growing media after the ages of 6, 10 and 12 months, respectively. In SS soil, mean seedling survival declined from 60% at the age 2 months to 18.97% at the age of 12 months but remained constant thereafter (Table 6.3).

Table 6.3 Mean seedling survival (%) of *Cordeauxia edulis* at different age of growth and under various growing media

Duration	**SS**	**P+S**	**P+S+C**	**P**	**P+C**
Surv in month 2	60.5±1.89a	41±4.25b	32.25±4.11b	31.38±7.8b	7.37±3.93c
Surv in month 4	36±2.33a	15.45±3.86b	4.87±2.56c	7.08±4.61c	1.79±1.79c
Surv in month 6	31.9±2.91a	12.82±3.17b	3.74±1.87c	5.51±3.18c	Dead
Surv in month 8	24.46±2.87a	9.29±2.17b	2.18±1.43c	3.39±2.56c	Dead
Surv in month 10	20.9±2.59a	6.99±2.12b	Dead	2.65±1.42b	Dead
Surv in month 12	18.97±3.16a	4.21±2.13b	Dead	Dead	Dead
Surv in month 14	18.76±3.54a	3.6±2.19b	Dead	Dead	Dead
Surv in month 16	18.76±3.54a	3.22±2.13b	Dead	Dead	Dead

Data are mean ± SE; different letter in the same row indicates significant difference at $P < 0.05$
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

The result presented in Figure 6.2 and 6.3 revealed that mean seedling height varied significantly ($P<0.05$) between growing media in all ages of seedling growth, the highest value recorded being in SS soil followed by P+S soil and the lowest in P+C medium. At the age of 16 months, seedlings in SS soil were 13.46 cm in height which was considered a very slow growth rate (Figure 6.2 and 6.3). There was also significance difference ($P<0.05$) in mean seedling root collar diameter (mm) between growing media in all ages of growth. The highest mean seedling root collar diameter (mm) in all ages was recorded in SS soil and at the age of 16 months the highest mean value of seedlings root collar diameter was 6.56 mm which was also very small (Table 6.4).

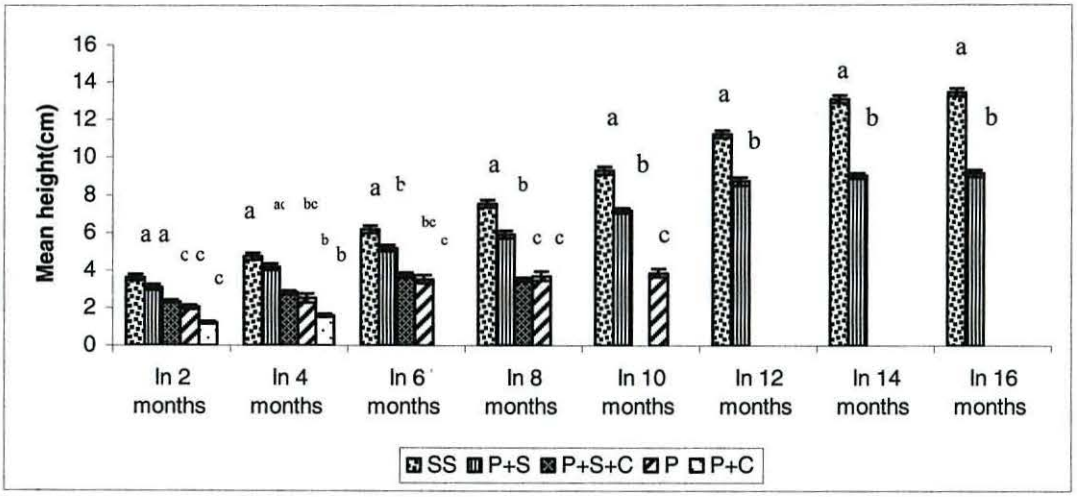

Figure 6.2 Mean seedling height (cm) of *Cordeauxia edulis* at different ages and growing media. Different letter on bar chart indicates significance difference at the level of 0.05.

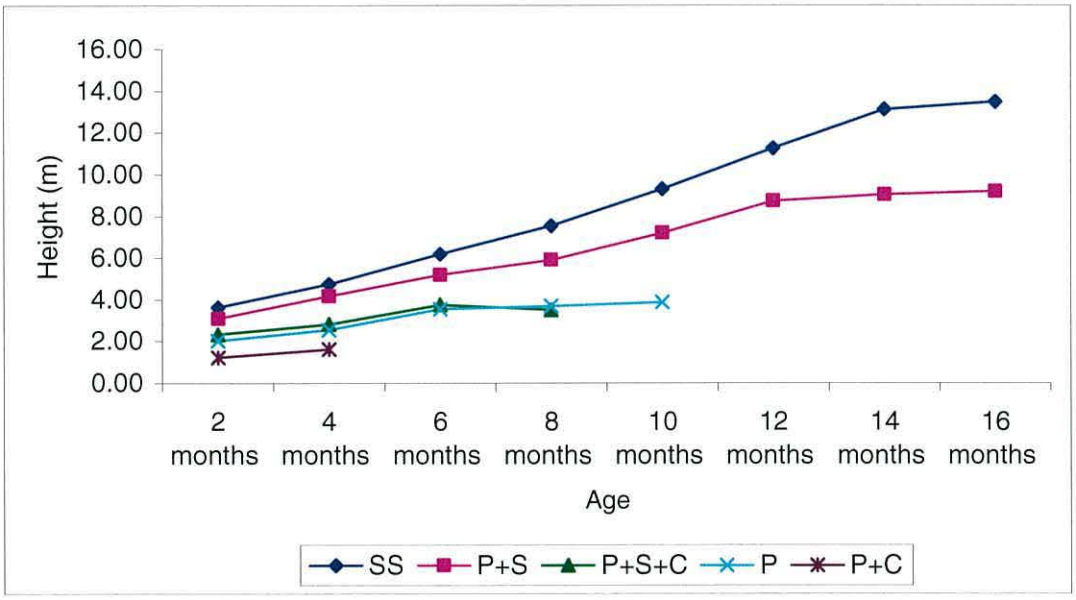

Figure 6.3 Growth of seedling height of *Cordeauxia edulis* in different age

SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C- local soil +compost

Table 6.4 Mean seedling root collar diameter (mm) of *Cordeauxia edulis* in difference ages and growing media

Duration	SS	P+S	P+S+C	P	P+C
Month2	1.60±0.04a	1.16±0.01b	1.1±0.003b	1.06±0.003b	1.04±0.001b
Month4	2.04±0.04a	1.47±0.01b	1.08±0.003c	1.07±0.01c	1.05±0.00c
Month6	2.97±0.05a	1.57±0.01b	1.10±0.01b	1.15±0.01c	
Month8	3.06±0.05a	1.60±0.01b	1.11±0.003c	1.10±0.01c	
Month10	3.46±0.05a	2.11±0.01b		1.18±0.02c	
Month12	4.35±0.06a	2.25±0.03b			
Month14	6.41±0.06a	2.47±0.01b			
Month16	6.56±0.06a	2.48±0.01b			

Data are mean ± SE; different letter in the same row indicates significant difference at $P < 0.05$
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

Regarding number of leaves, there was no significance variation ($P > 0.05$) in mean number of leaves between growing media at the age of 2 months. However, number of leaves began to differ ($P<0.05$) significantly between growing media after the age of 4 months, and the highest was recorded in SS growing media (Figure 6.4 and 6.5). Mean

number of leaflets, however, differed significantly (P<0.05) between growing media in all ages of growth and the highest number was recorded in SS soil followed by P+S soil. Mean number of leaflets at the age 16 months in SS soil was 25.58 (Figure 6.6 and 6.7).

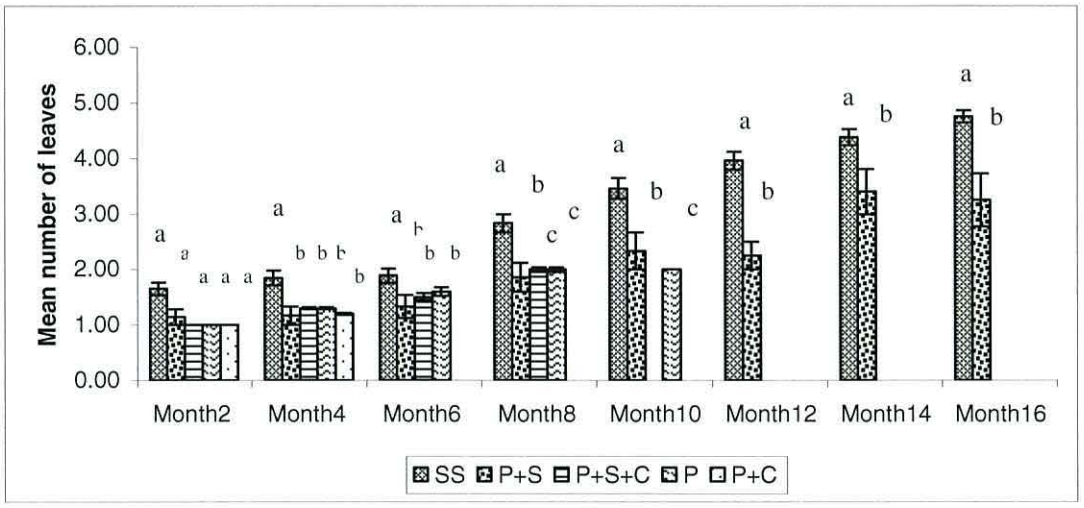

Figure 6.4 Mean seedling number of leaves of *Cordeauxia edulis* in different age and growing soil

Different letter on bar chart indicates significance difference at the level of 0.05.

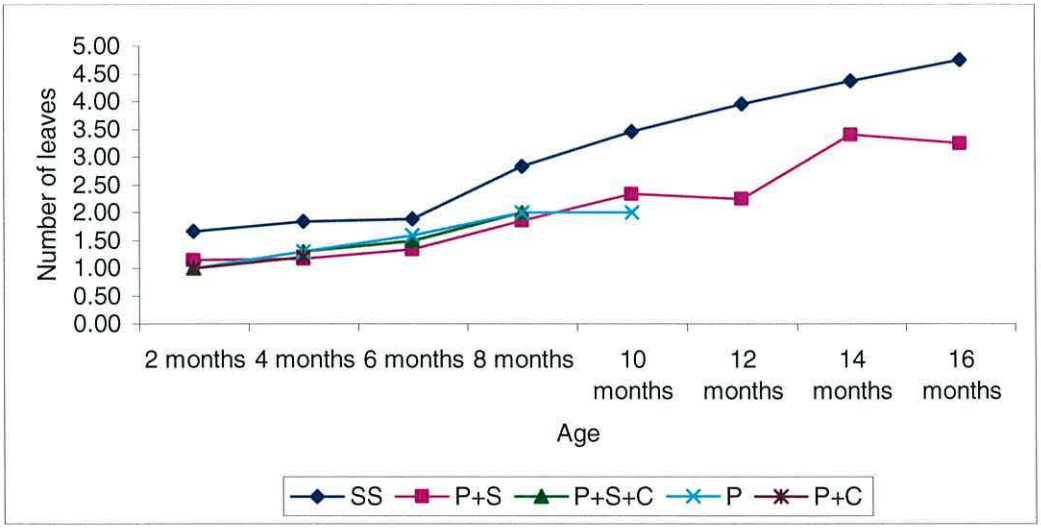

Figure 6.5 Number of leaves of seedlings in different age of growth

SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

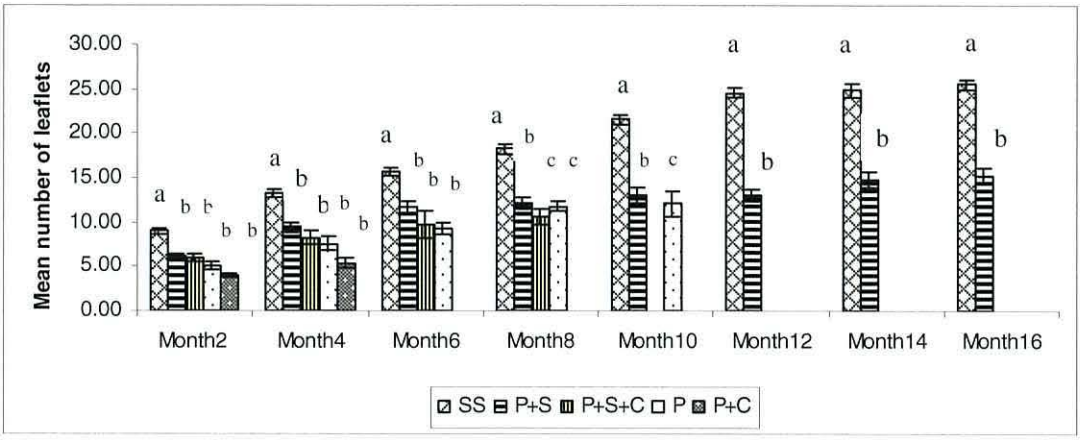

Figure 6.6 Mean number of leaflet per seedling of *Cordeauxia edulis* in different ages and soil media

Different letter on bar chart indicates significance difference at the level of 0.05.
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

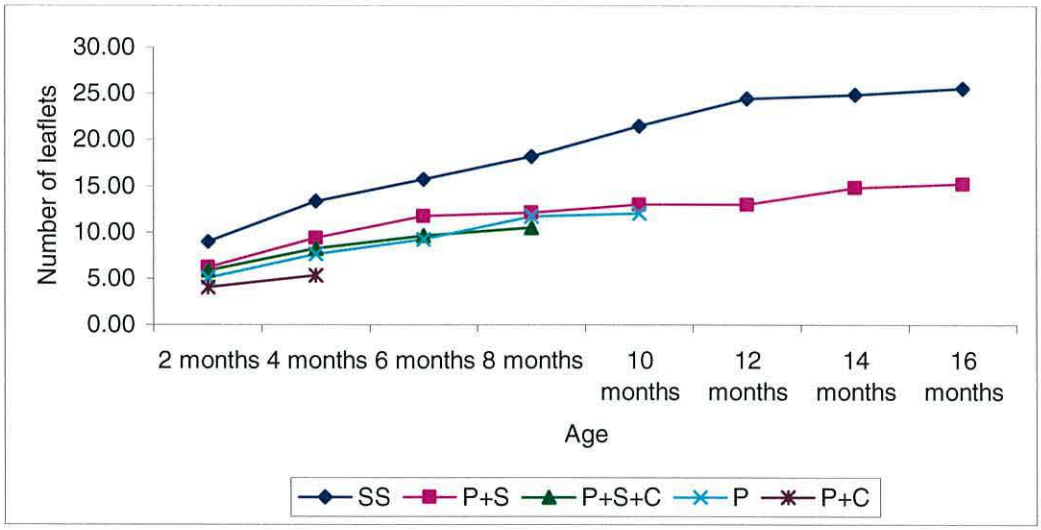

Figure 6.7 Number of leaflet of seedlings in different age of growth

SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

The results of the allometric relationships presented in Table 6.5 showed that there were significant positive relations between seedling parameters, the highest being between number of leaves and leaflets and between seedling height and number of leaflets (r=0.90 and 0.84, respectively).

Table 6.5 Pearson's correlation (Coefficient) of *Cordeauxia edulis* seedling morphological parameters of uncooked seed

	Root collar diameter	No of leaves	No of leaflets
Height	0.66(**)	0.81(**)	0.84(**)
Root collar diameter		0.41(**)	0.48(**)
No of leaves			0.90(**)

** Correlation is significant at the 0.01 level

Experiment III:

In this experiment seeds were pretreated with alcohol. According to the results shown in Table 6.6, all measured parameters differed ($P<0.05$) significantly between growing media. Soil from study site (SS) gave the highest values followed by P+S soil (seed germination = 56 ± 4.00%, seedling survival = 78 ± 4.33%, seedling height = 3.80 ± 0.18cm, root collar diameter = 1.65 ± 0.04 mm, number of leaves = 2.1 ± 0.12, and number of leaflets = 9.46 ± 0.39) (Table 6.4). The lowest values were obtained in P+C soil. Similarly, there was significant ($P<0.05$) positive allometric relationships between height, root collar diameter, number of leaves and leaflets of seedlings in Experiment III (Table 6.7).

Table 6.6 The result of mean seedling parameters in the age of eight weeks, germinated from seed treated with alcohol under different growing media

Characters	SS	P + S	P + S + C	P	P + C	F	P
Germination (%)	56±4.00a	29±2.94b	24±2.62bc	23±1.97bc	16±1.86c	15.54	<0.01
Survival (%)	78±4.33a	62±3.79b	57±4.65bc	53±6.73bc	37±4.61c	13.06	<0.01
Height(cm)	3.80±0.18a	3.70 ±0.17a	2.67± 0.08b	2.42±0.11b	1.68±0.05c	12.06	<0.05
Root collar diameter (mm)	1.65±0.04a	1.16 ±0.01b	1.09±0.002b	1.10±0.003b	1.04±0.001b	22.06	<0.01
No of leaves	2.1±0.12a	1.41 ± 0.6b	1.2±0.20b	1.25±0.20b	1±0.00c	4.06	<0.05
No of leaflets	9.46±0.39a	7.09±0.32b	6.29±0.25bc	5.20±0.29c	4.93±0.28c	11.25	<0.05

Data are mean ± SE; different letter in the same row indicates significant difference at $P < 0.05$
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

Table 6.7 Pearson's correlation (Coefficient) of seedling morphological parameters of seed treated with alcohol

	Root collar diameter	No of leaves	No of leaflets
Height	0.47(**)	0.79(**)	0.89(**)
Root collar diameter		0.16(*)	0.21(*)
No of leaves			0.84(**)

**= Correlation is significant at the 0.01 level, *= Correlation is significant at 0.05 level

Experiment IV:

In this experiment, seeds were pretreated with cold water, sulphuric acid, boiling water and a control with pretreatment. The results shown in Table 6.8 revealed that mean seed germination differed ($P<0.05$) significantly between seed treatments in the same growing media. Seeds treated with boiling water and grown in the study site soil (SS) gave the highest germination rate of 65 ± 2.91% (Table 6.8). The lowest mean germination in all growing media was recorded in the control untreated seed (Table 6.8).

Table 6.8 Mean germination (%) of pretreated seeds of *Cordeauxia edulis* under different growing media

Treatment	SS	P + S	P + S + C	P	P + C
No pretreatment	41±2.50a	24±3.06a	21±2.02a	21±1.15a	14±1.48a
Cold water	44±3.08a	28±2.63ab	24±2.38ab	23±2.79ab	16±2.46ab
Sulphuric acid	64±2.56b	37±3.46b	30±3.93b	29±3.09b	22±2.8b
Boiling water	65±2.91b	41±3.93b	32±4.20b	33±3.00b	24±3.70b
F	10.99	9.16	7.09	3.07	5.139
P	<0.05	<0.05	<0.05	<0.05	<0.05

Data are mean ± SE (%); different letter in the same column indicates significant difference at P < 0.05
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

Pairwise comparison of mean germination (%) between growing media (soil) also showed that there were significance differences (P<0.05) between soil from study site (SS) and other soils (P+S, P+S+C, P and P+C), whereas no significance (P>0.05) variation was observed among P+S, P+S+C, P and P+C growing media (Table 6.9).

Table 6.9 Pairwise comparison of seed germination (%) in different growing media

	SS	P+S	P+S+C	P	P+C
SS		*	**	**	**
P+S			*ns*	*ns*	*ns*
P+S+C				*ns*	*ns*
P					*ns*

* = significant at the 0.05 level, ** = significance at the 0.01 level, *ns* indicates non significance
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

The results presented in Table 6.10 showed that seed pretreatment had significant effect (P<0.05) on seedling survival (%). Seeds treated with boiling water exhibited the highest seedling survival (%) in all growing media. The highest seedling survival of 98±1.3% was recorded in seeds pretreated with boiling water and grown in SS soil. The least survival of 19 ± 4.77% was recorded in the untreated seeds (control) grown in P+C soil (Table 6.10).

Table 6.10 Mean survival (%) of seedlings of *Cordeauxia edulis* grown from pretreated seeds under different growing media

Treatment	SS	P + S	P + S + C	P	P + C
No pretreatment	77±4.35a	50±4.12a	50±3.90a	43±6.66a	19±4.77a
Cold water	79±1.20a	56±3.57a	47±6.65a	48±6.14ac	22±4.60ac
Sulphuric acid	97±0.72b	85±2.80b	85±2.96b	81±2.73b	51±5.44b
Boiling water	98±1.31b	82±1.85b	73±7.04ab	72±2.45bc	50±5.67bc
F	16.574	8.686	9.191	7.108	6.663
P	<0.05	<0.05	<0.05	<0.05	<0.05

Data are mean ± SE (%); different letter in the same column indicates significant difference at $P < 0.05$
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

Seed pretreatment had also significant effect ($P<0.05$) on seedling height (Table 6.11). Highest mean seedling height was recorded in seed treated with boiling water and grown in the soil of study site (SS) (4.91 ± 0.12 cm). The shortest mean seedling height was 1.32 ± 0.07cm which was recorded in P+C soil of seed treated with cold water (Table 6.11) (Plate 6.6).

Table 6.11 Mean height (cm) of seedlings of *Cordeauxia edulis* grown from pretreated seeds under different growing media

Treatment	SS	P+S	P+S+C	P	P+C
Untreated	3.65 ± 0.16^{a}	2.71 ± 0.16^{a}	2.37 ± 0.10^{a}	2.09 ± 0.12^{a}	1.52 ± 0.14^{ac}
Cold water	3.75 ± 0.16^{a}	2.64 ± 0.17^{a}	2.12 ± 0.08^{a}	1.95 ± 0.11^{a}	1.32 ± 0.07^{a}
Sulphuric acid	4.75 ± 0.12^{b}	3.73 ± 0.12^{b}	3.15 ± 0.07^{b}	2.59 ± 0.07^{b}	2.03 ± 0.10^{b}
Boiling water	4.91 ± 0.12^{b}	4.13 ± 0.11^{b}	3.13 ± 0.08^{b}	2.75 ± 0.07^{b}	1.92 ± 0.04^{bc}
F	12.74	13.09	22.12	10.38	5.55
P	<0.05	<0.05	<0.05	<0.05	<0.05

Data are mean ± SE; different letter in the same column indicates significant difference at $P < 0.05$
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

Mean seedling root collar diameter (mm) of C.*edulis* in different seed pretreatments and growing media are presented in Table 6.12. The results revealed that there was significance difference ($P<0.05$) between treatments in each growing media, and the highest value of root collar diameter of 2.21 ± 0.03 mm was recorded from seeds pretreated with boiling water in SS growing media (Table 6.12).

Seed pretreatment had also significant effect on number of leaves (P<0.05) (Table 6.13) and number of leaflets (P<0.05) (Table 6.14). Seeds that were treated with boiling water in SS growing media had the highest (2.67 ± 0.09) mean number of leaves (Table 6.13) and mean number of leaflets (17.19 ± 0.29) (Table 6.14).

Table 6.12 Mean root collar diameter (mm) of seedlings of *Cordeauxia edulis* grown from pretreated seeds under different growing media

Treatment	SS	P+S	P+S+C	P	P+C
Untreated	1.56 ± 0.04^{a}	1.14 ± 0.01^{ab}	1.08 ± 0.005^{a}	1.08 ± 0.021^{a}	1.03 ± 0.003^{a}
Cold water	1.49 ± 0.04^{a}	1.12 ± 0.01^{a}	1.09 ± 0.004^{a}	1.09 ± 0.003^{a}	1.03 ± 0.002^{a}
Sulphuric acid	2.04 ± 0.04^{b}	1.20 ± 0.01^{b}	1.17 ± 0.003^{b}	1.10 ± 0.002^{a}	1.05 ± 0.002^{b}
Boiling water	2.21 ± 0.03^{b}	1.38 ± 0.02^{c}	1.19 ± 0.003^{c}	1.16 ± 0.015^{b}	1.07 ± 0.002^{c}
F	50.87	43.01	65.47	6.62	16.48
P	<0.05	<0.05	<0.05	<0.05	<0.05

Data are mean ± SE; different letter in the same column indicates significant difference at P < 0.05
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

Table 6.13 Mean number of leaves of seedlings of *Cordeauxia edulis* grown from pretreated seeds under different growing media

Treatment	SS	P+S	P+S+C	P	P+C
Untreated	2.1 ± 0.11^{a}	1.31 ± 0.5^{a}	1±0.09	1±0.00	1±0.00
Cold water	2.25 ± 0.11^{a}	1.37 ± 0.5^{b}	1.25±0.10	1.27±0.12	1±0.00
Sulphuric acid	2.34 ± 0.09^{ab}	1.54 ± 0.7^{c}	1.35±0.09	1.39±0.08	1.25±0.13
Boiling water	2.67 ± 0.09^{b}	1.61 ± 0.7^{d}	1.62±0.11	1.27±0.08	1.14±0.10
F	6.34	1.15	0.82	0.71	0.43
P	<0.05	<0.05	>0.05	>0.05	>0.05

Data are mean ± SE; different letter in the same column indicates significant difference at P < 0.05
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

Table 6.14 Mean number of leaflets of seedlings of *Cordeauxia edulis* grown from pretreated seeds under different growing media

Treatment	SS	P+S	P+S+C	P	P+C
Untreated	9.66 ± 0.39[a]	7.73±0.58[a]	6.38±0.51[a]	5.15±0.44[a]	4.83±0.48[a]
Cold water	9.26 ± 0.39[a]	8.63±0.33[a]	7.3±0.22[a]	6.96±0.31[b]	5.89±0.26[a]
Sulphuric acid	16.36 ± 0.34[b]	11.73±0.25[b]	10.25±0.21[b]	9.95±0.19[c]	7.93±0.24[b]
Boiling water	17.19 ± 0.29[b]	12.1±0.21[b]	11.47±0.22[c]	10.18±0.20[c]	8.70±0.20[b]
	62.21	34.28	60.43	65.66	16.55
P	<0.05	<0.05	<0.05	<0.05	<0.05

Data are mean ± SE; different letter in the same column indicates significant difference at $P < 0.05$
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

Plate 6.6 Seedling of *Cordeauxia edulis* at the age of eight weeks in the nursery of Jijiga, Ethiopia

As shown in Table 6.15, there were significance (P<0.05) positive allometric relationships between morphological parameters of seedlings in experiment IV (Table 6.15).

Table 6.15 Pearson's correlation (coefficient) of morphological parameters of *Cordeauxia edulis* seedlings in different seed treatments

	Root collar diameter	No of leafs	No of leaves
Height	0.63(**)	0.81(**)	0.89(**)
Root collar diameter		0.19(*)	0.17(*)
No of leaflets			0.87(**)

**= Correlation is significant at the 0.01 level, *= Correlation is significant at 0.05 level

Experiment V:

In this experiment five regimes of watering were tested. The results showed that watering regimes had significant effect on seed germination (P<0.01), seedling survival (P<0.05), seedling height (P<0.05), root collar diameter (P<0.05) and number of leaflets, but not on number of leaves (Table 6.19).

The height percentage seed germination was achieved with once a day watering in SS soil (72 ± 3.28%) followed by P+S soil (47 ± 4.91%) and the least (2 ± 0.87%) was recorded in P+C soil watering twice a day (Table 6.16).

Table 6.16 Mean seed germination (%) of *Cordeauxia edulis* in different watering regimes and growing media

Treatment	SS	P+S	P+S+C	P	P+C
Twice a day	53±3.50a	35±4.21a	9±2.10a	8±1.18a	2±0.87a
Once a day	72±3.28b	47±4.91a	28±4.21bc	27±2.39b	4±0.58a
1 day interval	48±3.90a	37±5.45a	41±4.15b	39±2.94c	17±3.01c
2 days interval	19±2.39c	10±2.63b	31±4.27bc	28±3.07b	28±4.01d
3 days interval	10±1.97c	4±1.68b	17±2.38ac	15±1.03a	11±2.53ac
F	67.24	20.757	12.465	27.117	17.014
P	<0.01	<0.01	<0.01	<0.01	<0.01

Data are mean ± SE (%); different letter in the same column indicates significant difference at P < 0.05
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

According to the results presented in Figure 6.8, the highest mean seedling survival (89%) was obtained from watering once a day in SS soil while the lowest (10%) was recorded in P soil watering twice a day. In P+C soil none of seedlings survived by watering twice a day (Figure 6.8). As shown in Table 6.17 the tallest seedlings (3.42 ± 0.16 cm) were in SS soil and the shortest (0.33 ± 0.17 cm) in P+C soil watered once a day. The highest (1.95 ± 0.03 mm) mean seedling root collar diameter was obtained in SS soil and the least (1.02 ± 0.002 cm) in P+C soil from watering once a day (Table 6.18). According to the results presented in Table 6.20, watering once a day resulted in the highest number of leaflets per seedling (17.14 ± 0.40) in SS soil and the least (3.50 ± 0.50) in P+C soil.

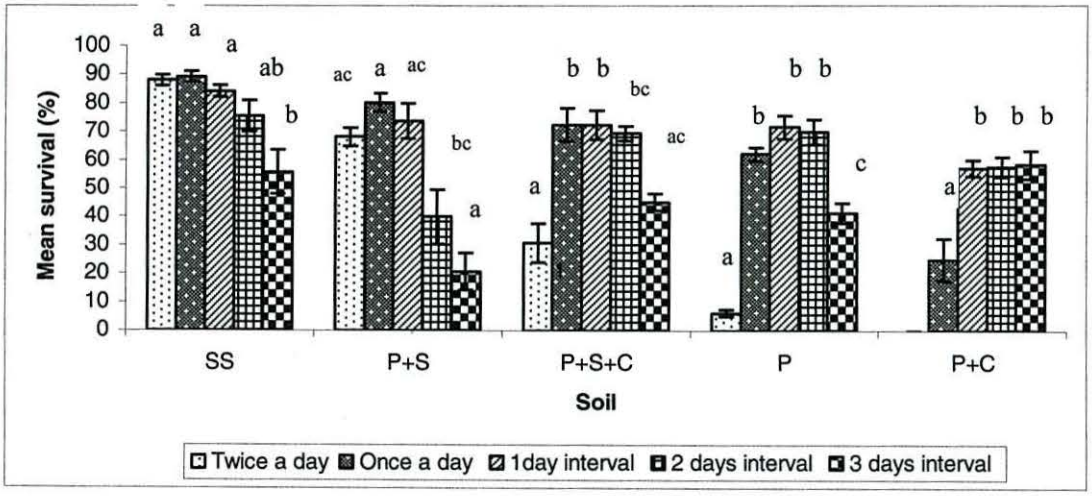

Figure 6.8 Mean survival (%) of *Cordeauxia edulis* seedling in different watering regimes and growing media

Different letter on bar chart indicates significance difference at the level of 0.05.
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

Table 6.17 Mean seedling height (cm) of *Cordeauxia edulis* in different watering regimes and growing media

Treatment	SS	P+S	P+S+C	P	P+C
Twice a day	3.06±0.17[a]	2.89±0.16[a]	0.80±0.28[a]	0.49±0.19[a]	Dead
Once a day	3.42±0.16[a]	3.11±0.13[a]	2.06±0.12[b]	1.50±0.09[bd]	0.33±0.17[a]
1day interval	2.97±0.19[a]	2.74±0.14[ab]	2.25±0.08[b]	1.93±0.09[c]	1.02±0.07[ab]
2days interval	1.74±0.26[b]	1.72±0.33[bc]	2.03±0.10[b]	1.81±0.09[dc]	1.20±0.11[bc]
3days interval	0.76±0.09[b]	0.39±0.03[c]	0.92±0.13[a]	0.73±0.11[a]	0.98±0.08[ac]
F	11.12	6.75	17.87	19.17	3.07
P	<0.05	<0.05	<0.05	<0.05	<0.05

Data are mean ± SE; different letter in the same column indicates significant difference at $P < 0.05$
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

Table 6.18 Mean seedling root collar diameter (mm) of *Cordeauxia edulis* in various watering regimes and growing media

watering regimes	SS	P+S	P+S+C	P	P+C
Twice a day	1.94±0.07[a]	1.23±0.02[a]	1.09±0.017[a]	1.03±0.006[ac]	Dead
Once a day	1.95±0.03[a]	1.33±0.03[b]	1.09±0.005[a]	1.10±0.025[ab]	1.02±0.002[a]
1day interval	1.82±0.13[a]	1.28±0.02[b]	1.10±0.003[a]	1.13±0.004[b]	1.04±0.003[a]
2 days interval	1.33±0.06[b]	1.23±0.02[a]	1.09±0.003[a]	1.11±0.003[ab]	1.06±0.004[b]
3 days interval	1.16±0.05[b]	1.11±0.01[a]	1.09±0.003[a]	1.04±0.003[c]	1.04±0.005[a]
F	7.15	4.82	0.25	6.65	10.86
P	<0.05	<0.05	>0.05	<0.05	<0.05

Data are mean ± SE; different letter in the same column indicates significant difference at $P < 0.05$
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

Table 6.19 Mean seedling number of leaves of *Cordeauxia edulis* in treatment of different watering regimes and soil

watering regimes	SS	P+S	P+S+C	P	P+C
Twice a day	1.81±0.09	1.20±0.11	1±0.00	1±0.00	Dead
Once a day	1.91±0.11	1.24±0.10	1.06±0.38	1±0.00	1±0.00
1day interval	1.71±0.13	1.25±0.13	1.14±0.25	1±0.00	1±0.00
2days interval	1.43±0.30	1±0.00	1.22±0.44	1±0.00	1±0.00
3days interval	1±0.00	1±0.00	1±0.00	1±0.00	1±0.00
F	0.92	0.05	0.54	0.03	0.02
P	>0.05	>0.05	>0.05	>0.05	>0.05

Data are mean ± SE; SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C- local soil +compost

Table 6.20 Mean seedling number of leaflets of *Cordeauxia edulis* in different watering regimes and growing media

Treatment	SS	P+S	P+S+C	P	P+C
Twice a day	14.60±0.43^{a}	10.79±0.39^{ad}	5.20±0.37^{a}	5.75±0.48^{a}	
Once a day	17.14±0.40^{b}	12.92±0.32^{b}	9.27±0.36^{bc}	8.42±0.29^{bc}	3.50±0.50^{a}
1day interval	11.03±0.76^{c}	11.33±0.28^{d}	9.85±0.21^{c}	9.28±0.27^{c}	6.33±0.29^{bc}
3 days interval	7.52±0.73^{d}	6.63±0.65^{c}	8.57±0.31^{b}	8.35±0.25^{cd}	7.27±0.28^{c}
3 days interval	6±0.53^{de}	6.50±0.50^{ac}	5.33±0.38^{a}	6.40±0.40^{a}	6.00±0.21^{b}
F	39.90	17.71	23.20	10.78	8.17
P	<0.05	<0.05	<0.05	<0.05	<0.05

Data are mean ± SE; different letter in the same column indicates significant difference at $P < 0.05$
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

The results of the analysis of allometric relationships between seedling morphological parameters in experiment V indicated that height, root collar diameter, number of leaves and leaflets were significantly ($P<0.05$) and positively correlated (Table 6.21).

Table 6.21 Pearson's correlation (Coefficient) of seedling morphological parameters in watering regimes experiment

	Root collar diameter	No of leaves	No of leaflets
Height	0.42(**)	0.79(**)	0.84(**)
Root collar diameter		0.15(*)	0.18(*)
No of leaves			0.94(**)

**= Correlation is significant at the 0.01 level, *= Correlation is significant at 0.05 level

Experiment VI:

According to the results of this experiment, nursery shade had no significant effect on seed germination (Figure 6.6) and number of leaves (Table 6.24). But shade had significant effects on seedling survival ($P<0.05$), seedling height ($P<0.05$, only in SS soil), root collar diameter ($P<0.05$, only in P+S and P+S+C soils), and number of leaflets ($P<0.05$, only in SS, P+S and P soils).

The highest survival (93%) was recorded in SS soil under intermediate shade and the least (45%) in P+C soil under full shade (Figure 6.9). Similarly, the tallest seedlings (4.06 ± 0.16 cm) were recorded in SS soil under intermediate shade and the shortest

(1.83 ± 0.13 cm) in P+C soil under full shade (Table 6.22). The highest root collar diameter (1.92 ± 0.04 mm) also recorded in SS soil under intermediate shade and the least (1.10 ± 0.01 mm) in P+C soil under full shade (Table 6.23). The highest number of leaflets (18.38 ± 0.43) was counted in SS soil under intermediate shade and the least (7.59 ± 0.45) in P+C soil without shade (Table 6.25).

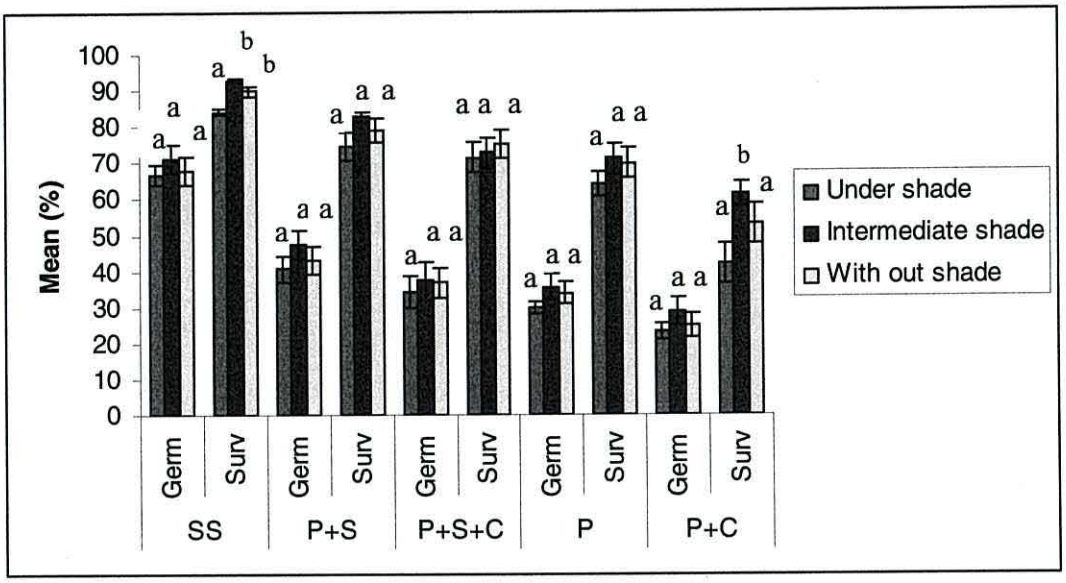

Figure 6.9 Mean seed germination and seedling survival (%) of *Cordeauxia edulis* in shade treatment of different growing media. Germ- germination, Surv-Survival

Different letter on bar chart indicates significance difference at the level of 0.05.
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

Table 6.22 Mean seedling height (cm) of *Cordeauxia edulis* in shade treatment under different growing media

Treatment	SS	P+S	P+S+C	P	P+C
Under shade	3.55±0.13[a]	3.31±0.13	2.61±0.09	2.27±0.11	1.83±0.13
Intermediate shade	4.06±0.16[b]	3.52±0.14	2.75±0.08	2.56±0.09	1.97±0.11
With out shade	3.58±0.15[a]	3.41±0.13	2.52±0.08	2.34±0.07	1.85±0.12
F	4.11	0.63	1.92	2.72	0.42
P	<0.05	>0.05	>0.05	>0.05	>0.05

Data are mean ± SE; different letter in the same column indicates significant difference at $P < 0.05$

Table 6.23 Mean seedling root collar diameter (mm) of *Cordeauxia edulis* in shade treatment of different growing media

Treatment	SS	P+S	P+S+C	P	P+C
Under shade	1.86±0.10	1.29 ±0.02[a]	1.11±0.006[a]	1.14±0.025	1.10±0.01
Intermediate shade	1.92±0.04	1.36±0.02[b]	1.13±0.003[b]	1.15±0.004	1.11±0.01
With out shade	1.91±0.03	1.32±0.02[a]	1.12±0.003[b]	1.15±0.003	1.10±0.01
F	1.38	4.57	3.38	0.27	1.26
P	>0.05	<0.05	<0.05	>0.05	>0.05

Data are mean ± SE; different letter in the same column indicates significant difference at $P < 0.05$
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

Table 6.24 Mean seedling number of leaves of *Cordeauxia edulis* in shade treatment of various growing media

Treatment	SS	P+S	P+S+C	P	P+C
Under shade	1.87±0.09	1.40±0.13	1.12±0.08	1.10±0.10	1.20±0.14
Intermediate shade	2.01±0.12	1.52±0.13	1.30±0.15	1.43±0.15	1.4±0.25
With out shade	1.75±0.09	1.29±0.10	1.21±0.11	1 ± 0.00	1.30±0.20
F	1.82	0.87	0.66	2.50	0.49
P	>0.05	>0.05	>0.05	>0.05	>0.05

Data are mean ± SE; different letter in the same column indicates significant difference at $P < 0.05$
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

Table 6.25 Mean seedling number of leaflets in shade treatment and different growing media

Treatment	SS	P+S	P+S+C	P	P+C
Under shade	15.43±0.66[a]	10.78±0.29[a]	9.82±0.39	8.56±0.42[a]	7.69±0.59
Intermediate shade	18.38±0.43[b]	12.49±0.32[bc]	9.90±0.23	9.98±0.29[b]	8.04±0.38
With out shade	16.35±0.43[a]	12.06±0.32[c]	8.98±0.28	8.61±0.23[b]	7.59±0.45
F	8.9	7.86	2.94	7.03	0.30
P	<0.05	<0.05	>0.05	<0.05	>0.05

Data are mean ± SE; different letter in the same column indicates significant difference at $P < 0.05$
SS-soil of study site, P+S-local soil + sand, P+S+C- local soil + sand+ compost, P local soil only, P+C-local soil +compost

There were significant and positive allometric relationships between all seedling parameters as shown in Table 6.26.

Table 6.26 Pearson's correlation (coefficient) of seedling morphological characters in shade treatment experiment

	Root collar diameter	No of leaves	No of leaflets
Height	0.56(**)	0.71(**)	0.79(**)
Root collar diameter		0.16(*)	0.21(*)
No of leaves			0.63(**)

**= Correlation is significant at the 0.01 level, *= Correlation is significant at 0.05 level

6.5 Discussion

6.5.1. Vegetative propagation

Brink (2006) and Booth and Wickens (1988) reported, vegetative propagation by cuttings may be possible despite no information about how successful the method was? A number of tests on vegetative propagation of *C. edulis* were conducted in the present experiment; however none met with any success. Thus, *C. edulis* can be considered a difficult species to root. Rooting ability of stem cuttings varies between species, this variability may be attributed to a lack of enzymes or their activators and/or the presence of inhibitors or the presence of enzymes that oxidize or degrade auxins or co-factors (Leakey, 1985). It is most likely that the absence of an inhibitor or lack of enzyme to activate Alpha-Naphthalene acetic acid (NAA) which was used in the present experiment may be one of the factors. In addition, it has been reported that several factors can affect root formation in stem cuttings such as; juvenility or age of the stock, environmental conditions (moisture/humidity, light, temperature) and the type of rooting media (Krishnamoorthy, 1981; Hartmann and Kester, 1997; Leakey, 1983).

6.5.2. Propagation from seed

The present study found that the most efficient propagation method for *C.edulis* is from seed. This was also confirmed by Bekele *et al.* (1993) who reported that *Cordeauxia edulis* (Yeheb) is normally propagated by seed.

Seed germination started 10 days after sowing and all viable seeds fully germinated by the end of two weeks in the six experiments conducted in the present study. The highest seed germination of *C.edulis* achieved in the present study was 72%, in soil from the study site (SS), with seeds that were pretreated with boiling water, and watered once a day in Experiment V. There have been no previous experiments on pretreatments and watering regimes reported in the literature, however, Assefa *et al* (1997) found 30-50% germination rate, while 70%-80% germination rates have also been reported by Miege and Miege (1978), Kazmi (1979) and FAO (1988).

The low germination rates in Experiments I and II may have been due to the hard seed coat of *C. edulis*. Several species of dry land plants have also been reported to exhibit similar low germination rates. For example, *Temarindus indica*, *Acacia auriculiformis and Chamaecytisus palmensis* have been reported to have a physical or chemical inhibitor to germination so that the seed will only germinate when conditions are favorable (Roshetko, 1995). In some cases the inhibitor can be overcome by pre-treatment of the seed before sowing but with others, successful germination has defied all attempts. For those species of which the seed has a natural inhibitor to germination (or dormancy) due to a seed coat, pre-treatment must be provided for successful germination (Wrigley and Fagg, 1996). *C.edulis* seems to be among plant species that need pretreatment as demonstrated in the present study (Experiments III-VI). Seed pretreatment gave high germination rates although they varied in their effects on germination. In Experiment IV, untreated seeds gave only 41% germination while pretreatment resulted in higher germination: hot water (boiling) 65% and sulphuric acid 64%. Pretreated seeds also resulted in higher seedling survival, seedling height, root collar diameter, number of leaves and leaflets (boiling water and sulphuric acid) when

compared with untreated seeds. According to Adjers and Srivastava (1993) and Asenga and Otyina (1996), the use of boiling water improved germination in many leguminous species such as *Acacia polyacantha*, *Sesbania rostrata* and many other hard seed coat species. Similarly, in the present study the highest result was obtained from seed treated with boiling water and sulphuric acid. Thus, seed treatment with boiling water as well as sulphuric acid may be considered the best methods for good germination and growth performance of *Cordeauxia* seedling in the nursery. However, the application of sulphuric acid seed treatment is expensive and also dangerous which needs careful use. Hence, treatment with boiling water is recommended as it is easier and cheaper to use. Precautions are required however as boiling water can also kill seeds. Thus, it is important not to soak the seed for longer than 5 minutes (Roshetko, 1995).

In the present study, poor germination (24% in SS growing media) was obtained in Experiment I using cooked seeds. Seed cooking is a routine practice by local people to protect seeds against insect pests. They usually cook fresh harvested fruit by burying them in hot ash (See Chapter 7) also to prolong the shelf life of the seeds. Thus, it is difficult to find uncooked viable seeds as almost every seed found in the market is cooked. The present study indicated that the indigenous practice of cooking has had a negative effect on germination. The lack of uncooked seeds has also been reported by Von Carlowitz (1986) who pointed out that viable seeds of *C.edulis* are not readily available; seed used and sold on the local market are rendered unviable by roasting (cooking). It has also been reported that due to competition by local users yeheb seeds are often harvested before maturity, and this (immature seeds) may also be another factor for the low seed viability often encountered (Brink, 2006).

The findings in Experiments I - VI revealed that seed germination as well as seedling performance of *C.edulis* was highest in the study site (SS) soil. Thus, soil from the study site is most probably the best medium for growing seedlings of *C.edulis*. Several previous authors also mentioned about the effect of the study site soil (SS) on growth of *C.edulis*. According to Drechsel and Zech (1988) and Seegeler (1983) natural distribution of *C.edulis* is limited to this area due to the special characteristics of the soil

called *Haud*. This means growing *C. edulis* outside its range may be difficult due to its specific soil requirement. However, the results of the present study also showed that satisfactory seed germination and seedling performance were achieved using the soil in Jijjiga by adding sand to it (P+S). Seed germination and growth performance parameters of the Jijjaga soil plus sand (P+S) showed successful result next to the study site soil (SS). This might be due to the sand mixed with it; since the study site soil (SS) called Haud is sandy in texture as reported in Chapter IV and also confirmed by Bally (1966) and FAO (988). Therefore, the present study has demonstrated that *C. edulis* can be grown satisfactorily outside its range by adding sand to local soil as transporting the study site soil is logistically impossible, ecologically unsustainable and environmentally destructive.

In the present study, the lowest seed germination and seedling performance were recorded in local soil plus compost (P+C). This is most probably due to the quality of the compost used which may have adverse effects on *C. edulis* seed germination.

The present study also found that seedlings of *Cordeauxia* sensitive to watering regimes and their performance varied significantly between treatments (watering intervals). According to Brink (2006) and Booth and Wickens (1988), a lot of water is needed for establishments of yeheb seedlings. However, the amount of water consumed can vary greatly depending on soil type and quality (Carter *et al.*, 2004). For example, in the present study for seedlings grown on the site soil (SS), the optimum amount was watering once a day which gave the best result of seed germination (72%), seedling survival (93%) and growth performance. Whereas watering at two days intervals was optimum for local soil plus compost; this might be due to the benefit of compost in soil of improving the water holding capacity (Carter *et al.*, 2004; Buttler, 2006; Celik *et al.*, 2004).

The growth performance of *C. edulis* was very slow. The mean height of seedlings in the study site soil (SS) at the age of 16 months was 13.46 cm which was considered as an extremely slow growth. According to Brink (2006) and Booth and Wickens (1988)

seedlings of *C.edulis* are characterised by slow shoot and aerial growth. In addition to its naturally slow growth, the environmental factors in Jijiga, where the study was carried out, may also have affected the growth, since altitude and temperature were different from its native area (Boh district).

The survival of seedlings decreased almost exponentially until the age of 12 months. The highest seedling mortality was observed at the age of 4 months. This was most likely due to damage of roots during transplantation to larger pots as tap roots grew very deep and was difficult to remove seedlings during transplantation as also reported by Kasmi (1979). Thus, early transplantation before deep tap roots develop is recommended to partially solve this problem. Seedlings also need to be transported with care so as not to damage the taproot (Anonymous, 2004).

The finding of the present study indicated that nursery shade had no effect on seed germination. Seedling survival (in SS and P+C), height (in SS), root collar diameter (in P+S and P+S+C) and number of leaflets (in SS, P+S and P) varied significantly between types of shade. The highest mean values of these parameters were recorded in seedlings under intermediate shade. There are, however, no previous studies have been reported in the literature about the effect of shade on seedlings of *C.edulis*. The present finding suggests that partial shade is optimal for seedling growth of *C. edulis*. Excessive light level can cause stress if water supply is limited. This reduces the rate of photosynthesis because the leaf is unable to utilise the absorbed light energy. This phenomenon is termed 'photoinhibition'. Also under full shadow associated with low temperatures, cold-induced photoinhibition can also occur (Greer and Laing, 1988). Hence, the seedlings of *Cordeauxia* in nursery responded negatively to both too much sun light and complete shade (low sun light) perhaps due to photoinhibition.

CHAPTER-VII

HARVESTING, PROCESSING, STORAGE AND MARKETING OF FRUITS OF *CORDEAUXIA EDULIS* (YEHEB)

7.1 Introduction

After the fruits of *Cordeauxia edulis* are picked (harvested) from the plant, the pod is peeled off and the seeds are placed in sacks. The fruits are often harvested before maturity, which may be a factor in the low seed viability often encountered. Usually all fruits are removed from the plant at the same time, hampering regeneration of natural stands. Fruits can be harvested twice a year, provided rainfall is adequate during both rainy seasons (Brink, 2006). *C. edulis* can produce up to 1527 kg ha^{-1} $year^{-1}$, and considering the dry conditions and poor management of sites at which *C. edulis* grows, such yield may be considered high (Ali, 1988; Yahya and Durand, 1993).

The shrub is virtually free of insect pests but weevils and moth larvae attack the seeds. To prevent fruit from being attacked by insects, freshly picked seeds are roasted or boiled to kill insects and harden the seed coat. However this practice contributes to the difficulty of obtaining viable seed for planting (Ismail, 1975).

The seeds of *C. edulis* are mostly consumed locally, but are also sold in local market. Demand exceeds supply because of rapidly diminishing plant populations. From Ethiopia the seeds are exported to Somalia and Arab countries, but no quantitative information is available (Brink, 2006). The nuts of C. *edulis* have export potential for European markets as 'dessert nuts' (Bally, 1966). However, according to Kazmi (1979), relatively small quantities of the nuts ever enter the commercial trade, and few are brought to the markets in Somali towns.

However, lack of processing technology, poor market information and access, weak and exploitive marketing channels and difficulties in entering into trade, all present major hindrances to producers wishing to develop the commercial potential of such indigenous wild fruits (Emerton *et al*, 2000).

Since, ways of supplying these products to wider markets within and outside the region is a key challenge, marketing of the fruits within and outside the local markets needs considerable research and development efforts. In particular, processing, selection for taste, value adding, marketing and storage are areas that require detailed studies.

Therefore, the present study was carried out to investigate the harvesting, processing, storage and marketing of the fruit of *C. edulis* and develop improved village level harvesting and storage technology so that the values and income from the fruit can be enhanced.

7.2 Specific Objectives:

1. To analyse current practices of harvesting, processing and storage of fruit of *Cordeauxia edulis*,
2. To analyse current marketing practices including marketing channels, and
3. To undertake studies and develop improved harvesting and storage methods.

Hypothesis and Research question of the study

a. What insect species attack the fruit in store?

b. Do local people supply fruit for marketing?

c. Where are the market centres of the fruit of C.*edulis?*

d. There is no variation between fruit harvested prematurely and those harvested at maturity with respect of their resistance to insect pests during storage.

7.3 Materials and Methods

7.3.1 Harvesting, processing, storage and marketing survey

The study on harvesting, processing, storage and marketing was conducted in Boh district, Ogaden, Ethiopia. All ten villages (Maned, Godirwayis, Gambare, Mirafadle, Afardod, Damerjog, Dalhamur, Dudun, Foye ade and Dabhabalan) where *C. edulis* is found growing were included in the study. Very little or no secondary data exists in either in the region or the literature with regard to harvesting, processing, storage, current marketing practices and channels of *Cordeauxia edulis* (Yeheb) fruit. Thus, the present study was the first attempt to collect this information in the region. Data were collected using PRA tools including structured and semi-structured interviews, key informant interviews, focus group discussions, pair wise and direct matrix rankings, and diagramming techniques. For the structured interviews a household based questionnaire was designed (Appendix 2). The same household samples randomly selected for surveying traditional knowledge and local constraints of C.*edulis* presented in chapter 3 of this thesis were used to conduct this study. A minimum of 10% of the households was selected randomly from the list of households in each village. The number of samples in each village varied from 10 to 32 households depending on the number of households in each village. In total, 182 household samples were randomly selected for the structured questionnaire survey from the ten villages and four enumerators were involved for completing the questionnaire. Furthermore, traders were also included in the marketing study. A total of 32 traders were interviewed through a structured questionnaire developed for this purpose (Appendix 2) and also focus group discussion was conducted with them.

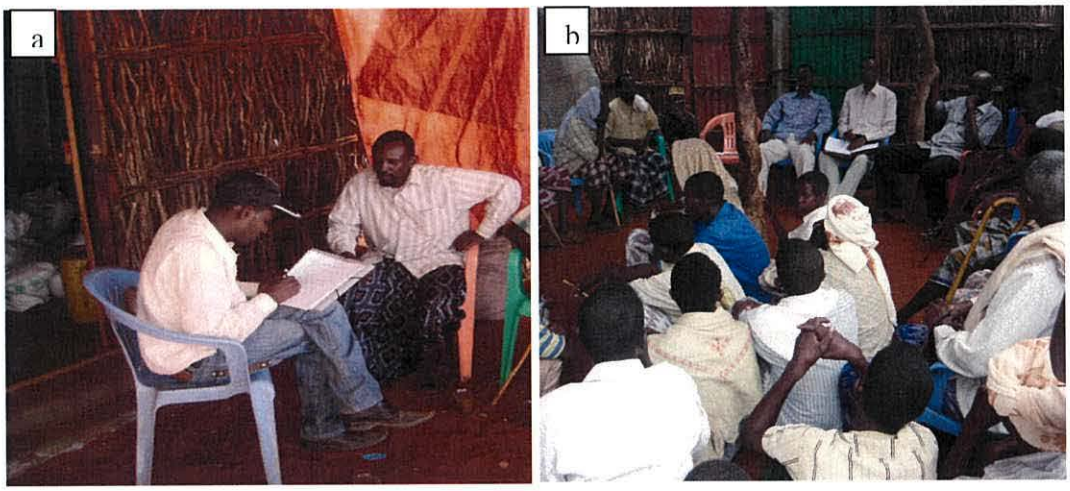

Plate 7.1 a) Interview with sampled household, b) Focus group discussion with selected local users

7.3.2 Study on improved harvesting and storage

The major constraint identified as a result of the above study on harvesting, processing, storage and marketing was seed attack by insect pests during storage. A study aimed at developing methods of combating insect pest attack of yeheb fruit in store was, therefore, conducted in Boh district. The study was based on the range of local practices of harvesting the fruit of C. *edulis*: harvesting fruit before it reaches physiological maturity or premature (a common practice) and harvesting fully matured fruit (a recommended practice). Leaf of Neem (*Azandirachta indica*) which is known to have pesticidal property (Lyons *et al.* 1998; Helson *et al.* 1999) was used as a biopesticide treatment.

The experiment involved four treatments (Plate 7.2):

1. Premature harvesting,
2. Premature harvesting + biopesticide treatment,
3. Mature harvesting, and
4. Mature harvesting + biopesticide treatment.

The experiment was conducted as a participatory research activity with six households selected randomly from each of the six villages in the district (Maned, Godir wayis, Gambare, Mirafadle, Aferdod, Dudun), i.e. a total of 36 samples of households were involved in the study. The experimental design was a completely randomised design (CRD) involving the above four treatments and the 36 sample households as replications. Equal amount of fruit (5 kg) and biopesticide (0.5kg) were used for each treatment. The four fruit samples were stored in each of the homes of the 36 participant households. The performance of the stored fruit samples were monitored for one year. Data were collected every 15 days for the first 6 months and at one month intervals for the remaining 6 months.

Plate 7.2 Fruit of yeheb in store for experiment at Boh, Ogaden, Ethiopia

a) Premature harvesting b) Premature harvesting plus biopesticide c) Matured harvesting d) Matured harvesting plus biopesticide

Samples of insect pests that attacked the fruit in store were collected. Since most of samples were in larva stage, they were taken to laboratory at Jijiga Agricultural research centre. The larvae were grown in Petri dishes (Plate7.3) and identified with the assistance of an entomologist, when they reached adult stage. Insects which were observed attacking leaf and stem of yeheb were also identified.

Plate 7.3 Larvae of insects growing inside Petri dish in laboratory of Jijiga agricultural research centre (Photo by: Mussa M.Yusuf)

7.3.3 Data analysis

Data were processed using Ms *excel* spread sheet and analysed using descriptive statistics. A one-way analysis of variance (ANOVA) and pair wise t-test were also applied to the data to make comparison between treatments using SPSS version 12.

7.4 Results

7.4.1 Harvesting, processing, storage and marketing survey

7.4.1.1 Harvesting

All respondents (100%) used the same method of harvesting; fruit of *Cordeauxia* were harvested manually. 76% of the respondents reported that the fruit was harvested by children closely followed by mothers (69%). Only 36% mentioned fathers as harvesters (Table 7.1).

A majority (91%) of the respondents normally harvested yeheb twice a year. Only 9% of the respondents said they harvested the fruits once a year.

Table 7.1 Responses (% ± SE) on participation of household members in harvesting

Who harvest fruit	Response
Mother	69±2.4
Father	36±2.0
Children	76±2.7

As shown in Figure 7.1, a majority (92%) of the respondents mentioned that they collected yeheb for both household consumption and marketing, 7% of the respondents reported that they harvested for household consumption only, while few (1%) collected for sale only.

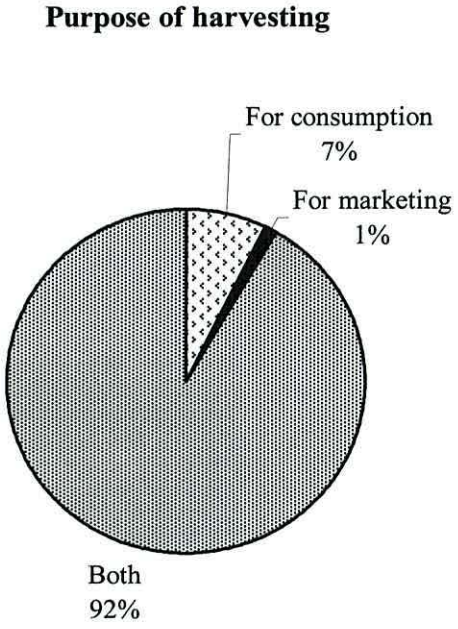

Figure 7.1 Responses (%) on the purpose of harvesting yeheb fruit in Boh, Ogaden, Ethiopia

Figure 7.2 present constraints usually faced during harvesting of the fruit and the results indicated that physical damage to fruit harvesters (78%) by wood of *C.edulis* was among the major problem.

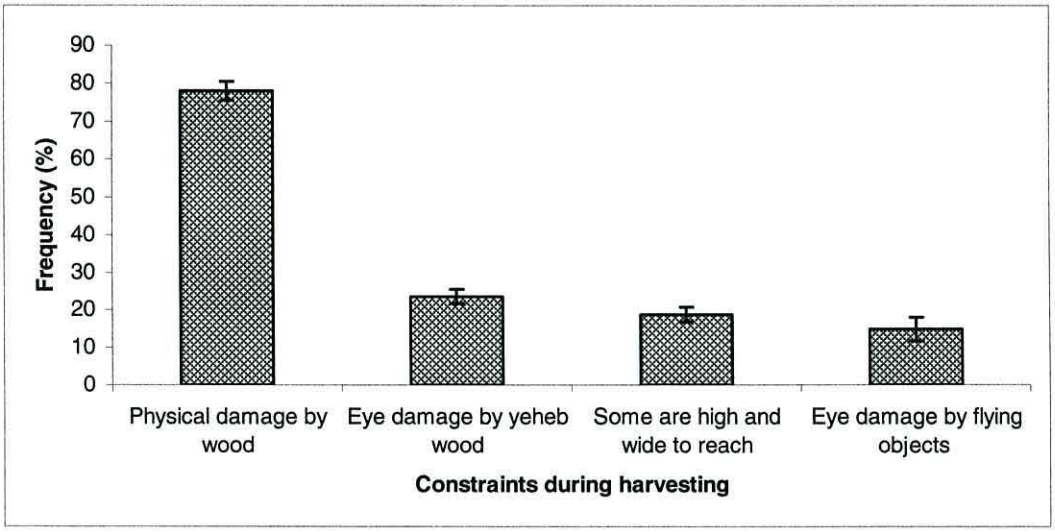

Figure 7.2 Responses (% ± SE) on constraints during harvesting of yeheb fruit in Boh, Ogaden, Ethiopia

7.4.1.2 Processing

All respondents (100%) used the same processing method. After the fresh pods are harvested, they are air dried under shade for 7-10 days. This is followed by manual removal of the seed coat using a knife, before the lengthy process of hardening the second seed coat in ash to kill insect eggs and minimising fungal attacks starts. This is done by burning fuel wood, and then extinguishing the fire, the air dried seed is then buried in the hot ash. After roasting, the seed is removed and placed in sacks for storage. 73% of respondents said such method of processing has its own negative effects on both the environment and the seeds. Cutting *C.edulis* to use for fuel wood for this process was among the major problem reported by 70% of the respondents followed by poor quality of fruit (62%) due to impurity and damage caused by fire (28%) and hard and long time taken to process the fruits (25%) (Figure 7.3). In addition, the method of processing affects seed viability, and poor germination (%) and growth performance as reported in Chapter 6 of this thesis.

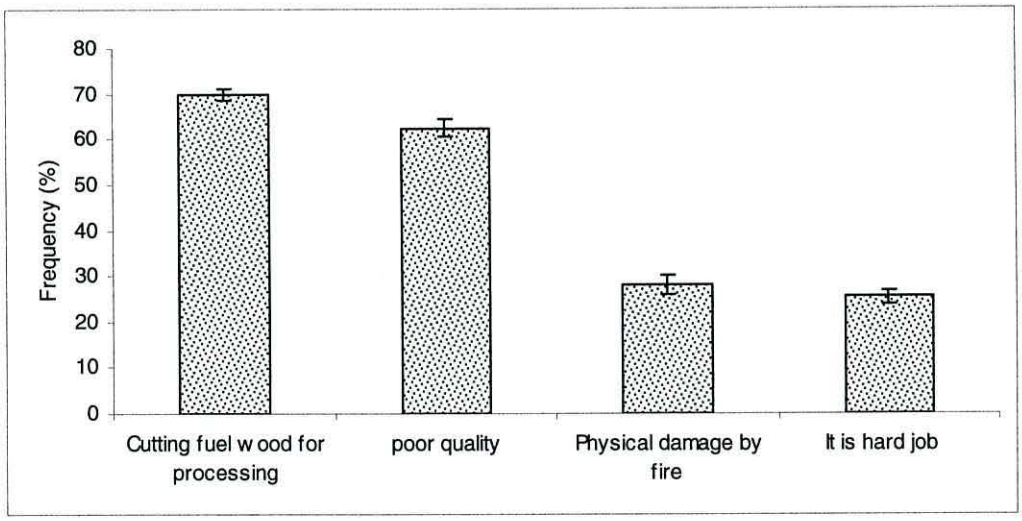

Figure 7.3 Responses (% ± SE) on problems of indigenous processing method of yeheb fruit in Boh, Ogaden, Ethiopia

7.4.1.3. Storage

About 80% of the respondents stored fruit in their houses using sacks, while a minority (20%) stored in holes prepared in the ground. They reported that they usually stored seed in the ground when large a quantity of fruit was harvested. As shown in Figure 7.4, fruit was stored in the house for the following reasons: relatively less insect pest attack in the house (82%), less damage due to high moisture (70%), and easy access and inspection (68%).

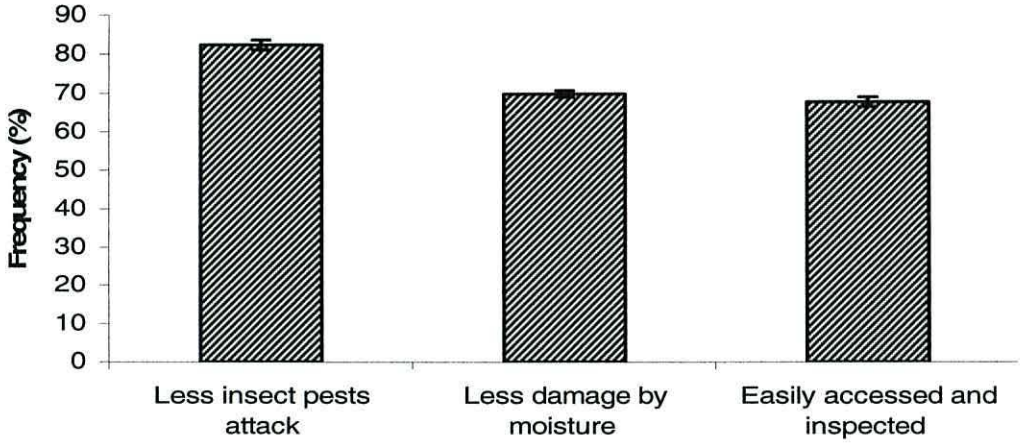

Figure 7.4 Responses (% ± SE) on reasons for storing yeheb fruit inside house in Boh, Ogaden, Ethiopia

According to 84% of the respondents, loss of fruit results from both traditional methods of storage (hole or house) (Plate 7.5). The main cause of fruit damage is mostly due to insect pests (88%), closely followed by rodent (81%), moisture or rainfall (72%) and 49% mentioned losses due to birds (Figure 7.5).

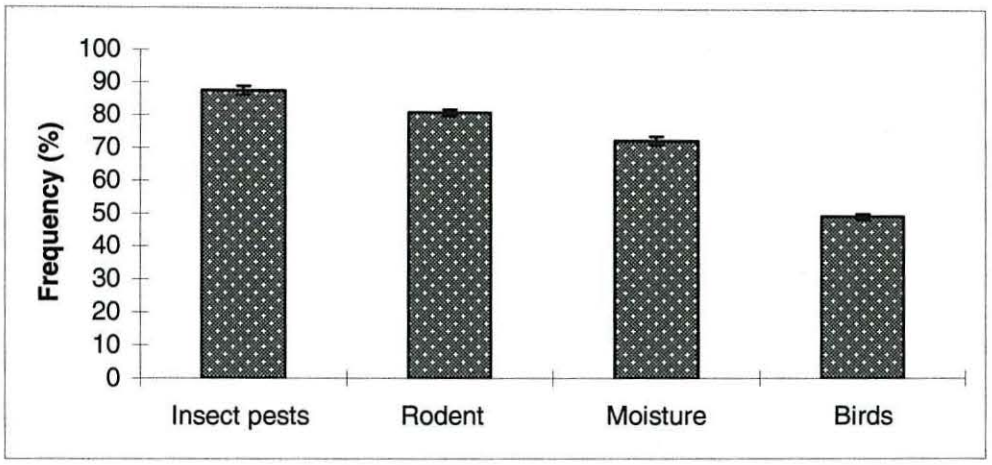

Figure 7.5 Responses (% ± SE) on loss of yeheb fruit in storage in Boh, Ogaden, Ethiopia

7.4.1.4 Marketing

A majority (75%) of the respondents reported that women are the major suppliers of fruit to the market among the household member followed by children (49%). Only 19.8% mentioned marketing by men (Table 7.2).

Table 7.2 Response (% ± SE) on house hold member in marketing and purpose of using the cash income from yeheb fruit in Boh, Ogaden, Ethiopia

Who sell fruit	Response
Women	75±3.4
Men	20±2.7
Children	49±3.5

Plate 7.4 Yeheb fruit on sale at Gambare village, Boh, Ogaden, Ethiopia

(Photo by: Mussa M. Yusuf)

Table 7.3 shows mean quantity of yeheb fruit harvested, marketed, income gained and percentage contribution to the household income in all localities. The result shows homogeneity across all localities and there was no significance variation ($P>0.05$) between villages. The highest mean amount of fruit harvested was 152±9 kg per year per household while the lowest was 140±12 kg. Out of the total harvested fruit, the highest mean quantity of fruit sold on the market was 105±6 kg per household whereas 96±9 kg was the lowest mean amount recorded. Mean highest income gained from the sale of the fruit per household was 930±43 EB (Ethiopia birr) and 870±48 EB was the lowest income earned per household. The result also indicates that the income from marketing of yeheb fruit contributed almost more than half of all income sources per household. The mean percentage contribution to household income of all localities ranged from 50% to 56% which is considered high (Table 7.3).

Table 7.3 Responses (% ± SE) on mean quantity harvested, quantity for marketing, income gained and percentage contribution to the house hold income of yeheb fruit in Boh, Ogaden, Ethiopia

Village	Mean quantity harvested/year (kg)	Mean Quantity sold (kg)	Mean income (EB)	Mean percentage contribution to HH income
Maned	152±9	105±6	930±43	56±2
Godir wayis	149±11	101±8	909±42	55±2
Gambare	150±8	103±6	925±52	56±3
Mirafadle	1401±2	98±9	886±51	54±2
Afardod	144±10	100±7	847±62	53±2
Damerjog	144±2	101±9	888±51	52±3
Dalhamur	145±12	97±9	909±64	54±3
Dudun	141±10	97±7	870±48	53±3
Foye ade	140±12	97±9	897±51	53±3
Dabhablan	143±13	96±9	870±51	50±2
F	0.2	0.15	0.28	0.47
P	>0.05	>0.05	>0.05	>0.05

EB indicates Ethiopian birr, the exchange rate for Ethiopian Birr against US dollar in 2008 was 1 US$ = 8 EB

Gambare was the main market centre for yeheb according to 94% of the respondents followed by Mirafadle (84.1%), Goldogob (81.3%), Boh (79.1%), Borsalah (77.5%) while few (3.8%) mentioned they also sometimes supplied for market of Muqadisho (Figure 7.6).

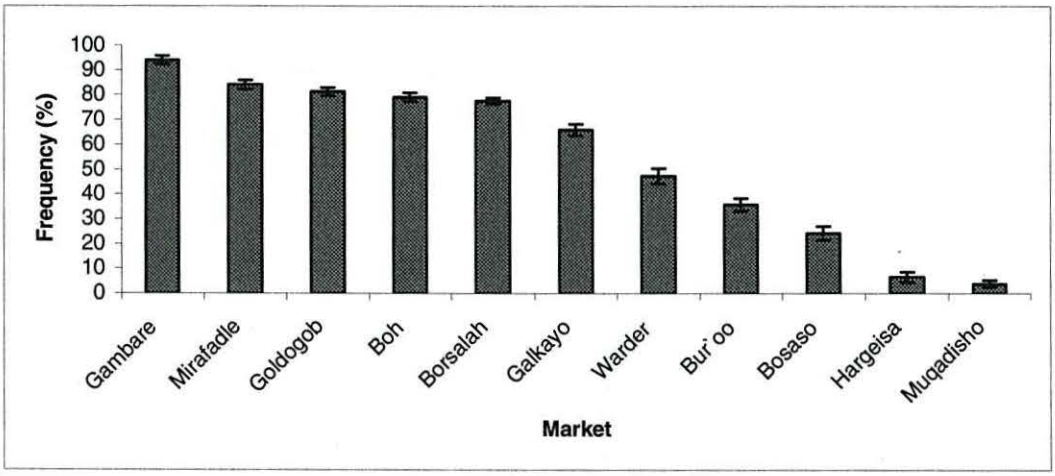

Figure 7.6 Responses (% ± SE) on market centre of yeheb fruit of producers in Boh, Ogaden, Ethiopia

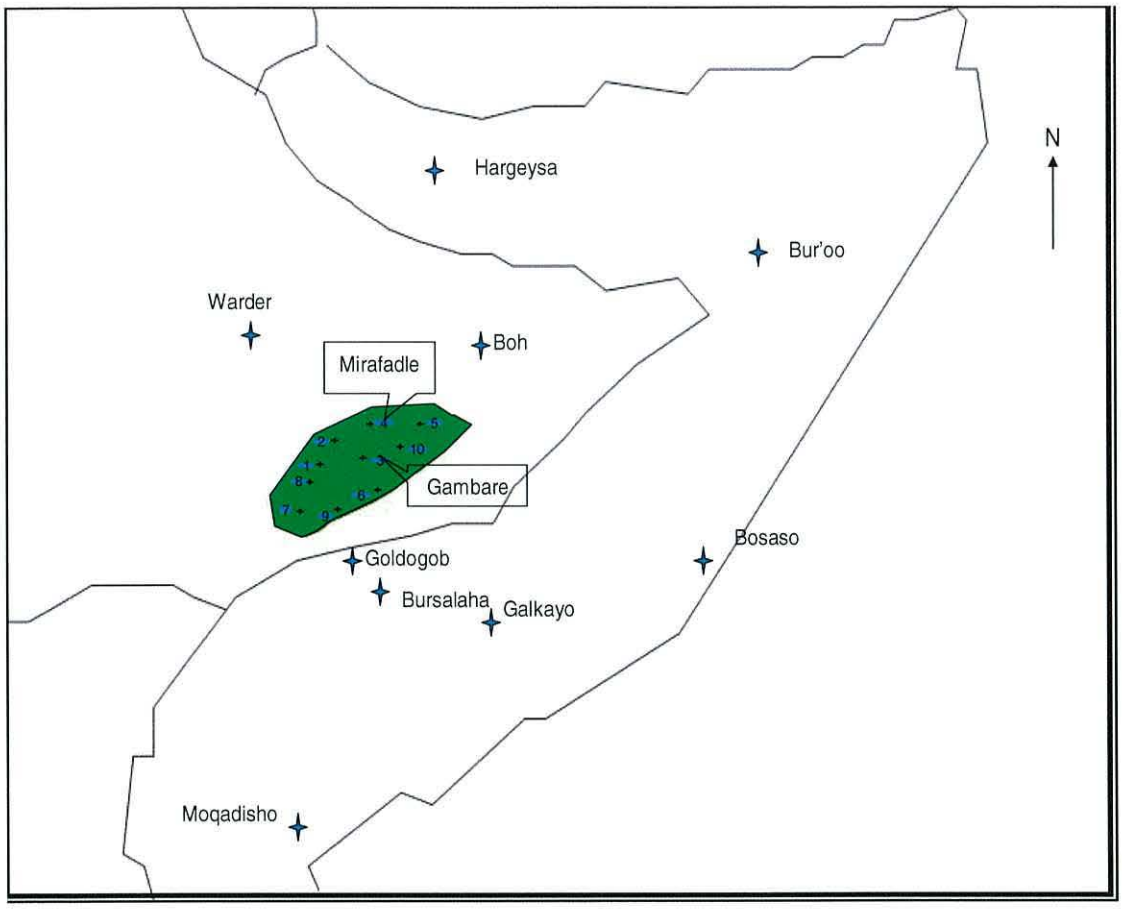

Figure 7.7 Map showing villages and market centre yeheb fruit

Figure 7.8 shows market chain map or channel and mean price of yeheb fruit per kombo (0.5 kg container). Most of the market centres of yeheb fruit are in the neighboring country (Somalia) except Gambare, Mirafadle, Boh and Warder of the Ogaden, Ethiopia (Figure7.8).

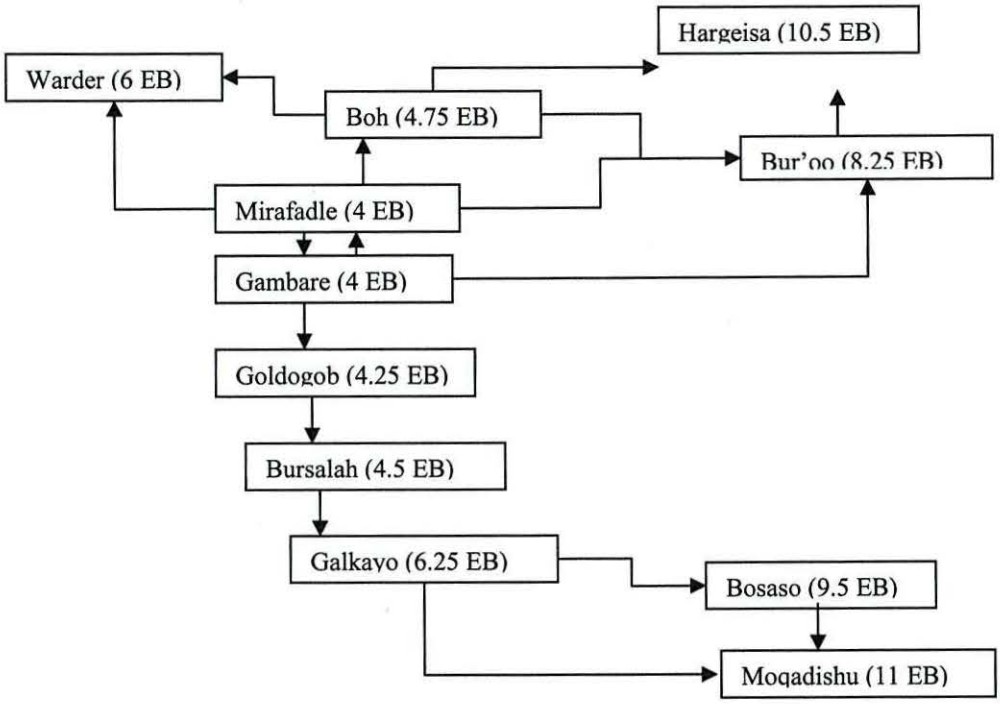

Figure 7.8 Market channel and mean price per kombo (0.5kg) of yeheb fruit in Boh district, Ogaden, Ethiopia

(EB indicates Ethiopian birr, the exchange rate for Ethiopian Birr against US dollar in 2008 was 1 US$ = 8 EB)

There were five factors which affected the price of the fruit in the market, according to 93% of respondents. Majority (78%) of them mentioned demand and supply as the main factor that affected the price of the fruit and 64% and 56% reported drought and season, and fruit quality respectively while the least (25%) reported that food aid by government and NGOs can also affect price (Figure 7.9). If there were sufficient food supply in the locality, prices went down.

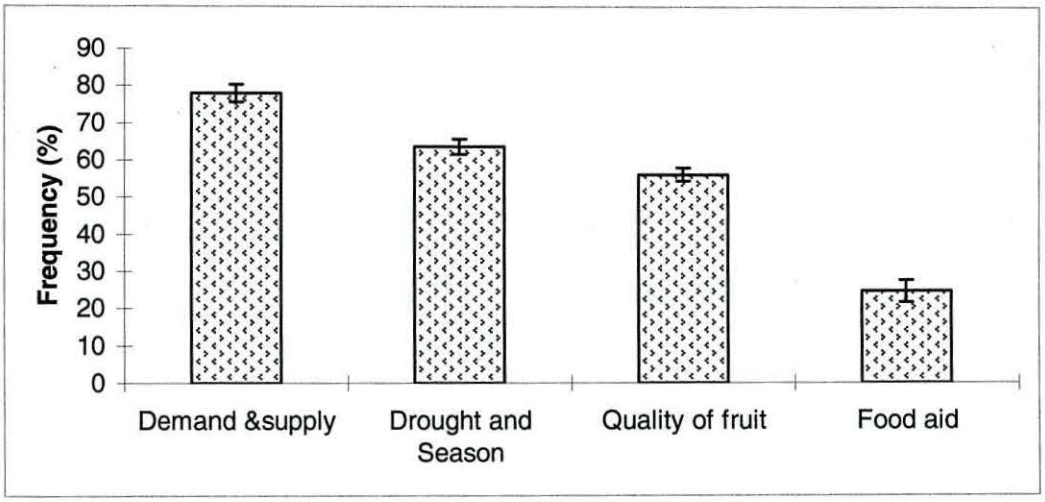

Figure 7.9 Response (% ± SE) on factors that affect market price of yeheb in Boh, Ogaden, Ethiopia

Lack of transport was mentioned by 76% of the respondents as the main problem of marketing yeheb, followed by the lack of a nearby market (71%), while a few (10%) mentioned lack of demand (Table 7.4).

When respondents were asked to give opinion as to how income from sale of fruit could be increased in the future, 75% mentioned that protecting the species from extinction can enhance production and harvest which could then increase income and 65% suggested establishing a plantation as a means to increase production and income.

Table 7.4 Responses (% ± SE) on marketing constraints and intervention to increasing income from yeheb fruit in Boh, Ogaden, Ethiopia

Marketing constraints	Response	Increasing income	Responses
Lack of transportation	76±2.4	Protection	75±1.3
Lack of nearby market	71±2.3	Plantation	65±2.1
Low price due to poor quality	61±2.6	Maintain fruit quality	32±1.8
Lack of demand	10±2.1	Presence of middlemen	9±2.3

In addition to yeheb production and marketing, local users are involved in different income generating activities such as livestock production (88%), trade or business (2%) and both livestock and trading (11%) (Figure7.9a). 62% of the respondents reported to prefer livestock production as main income generating activity while 35% of them reported they preferred yeheb production and marketing and few (4%) selected trading (Figure 7.9b). According to 77% of the respondents who preferred livestock, the reason for their preference was because livestock was the bases for their livelihood whereas 23.2% mentioned that livestock generated higher income than other activities.

In response to the question whether or not they made any saving some of the income from the sale of yeheb fruit, the majority (87.9%) of the respondents never made any saving while a minority (12.1%) managed to save some of the income from the fruit.

Majority (95%) of the respondents carried out marketing of yeheb fruit individually while few (5%) mentioned that they supplied one village member to market on their behalf. The reasons given by those who sold as a group were cost saving (21%) (transportation and personal expenses), time saving (10%) and both cost and time saving (69%) (Figure 7.10).

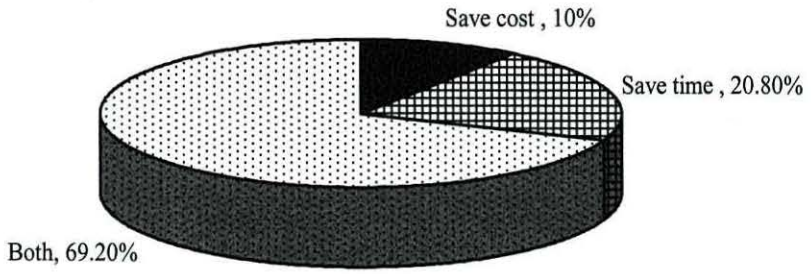

Figure 7.10 Responses (%) on advantage of marketing yeheb fruit in a group at Boh, Ogaden, Ethiopia

Means of transportation for marketing usually depends on the amount of fruit and distance from the market. 100% of the respondents used a vehicle for transporting fruit to market located at far distance. However, for nearby markets such as Gambare, Mirafadle Goldogob and Borsalah, they used a mixture of vehicle, animal power or carried the fruit themselves on their back (human power) (Figure 7.11). A majority of respondents in Gambare market carried their produce to the market using human power (82%) as well as animal power (80%). Similarly, in Mirafadle market, they also used human (80%) and animal power (79%). However, a minority (15% and 14 %) reported to use vehicle for Gambare and Mirafadle market, respectively (Figure 7.11). For Goldogob and Borsalah markets however, producer used vehicle according to 74% and 82% of respondents respectively (Figure 7.11).

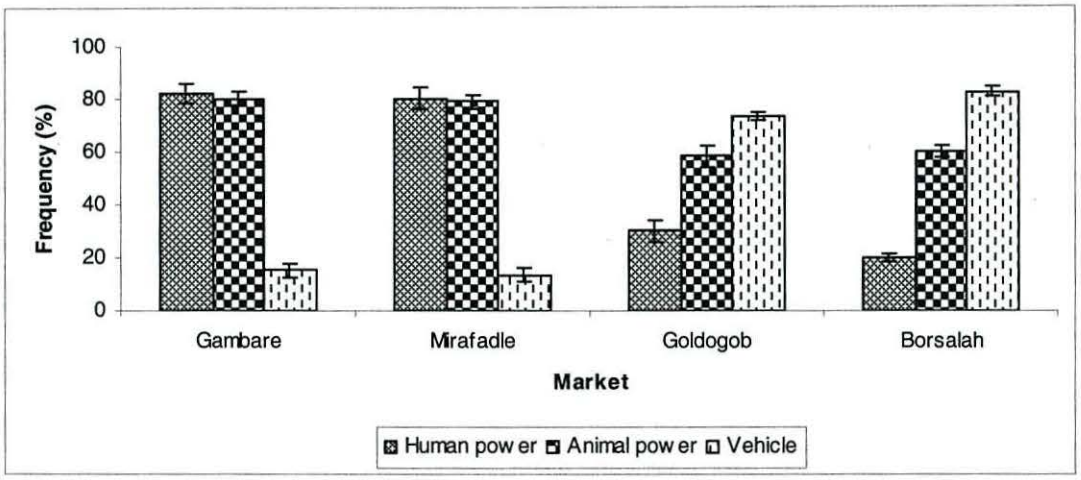

Figure 7.11 Responses (% ± SE) on means of transportation for marketing of yeheb fruit in Boh, Ogaden, Ethiopia

According to 100% of respondents no Government organizations existed that helped them in marketing yeheb fruit.

7.4.1.5 Traders of *Cordeauxia* fruit

The majority of the traders interviewed (88%) were retailers, while the remaining 13% were *C.edulis* fruit wholesalers. 81% of the traders reported that they went and

purchased the fruit from producers at the market while 18.8% mentioned that the fruit was delivered to them by the producers.

The 32 traders interviewed traded a total quantity of 38320 kg (383 quintals) of yeheb fruit per year and the mean income gained from yeheb fruit trade constituted of 50% of their income (Table 7.5).

Table 7.5 Total quantity supplied, mean quantity supplied per trader and percentage of trader's earned from yeheb

Total quantity supplied/year (kg)	Mean quantity supplied/year(kg)	Mean income per trader (%)
38320	1198	50

Majority (84%) of the traders obtained fruit from Gambare locality, closely followed by Maned (75%) while the least (16%) reported to get from Afardod (Figure 7.12).

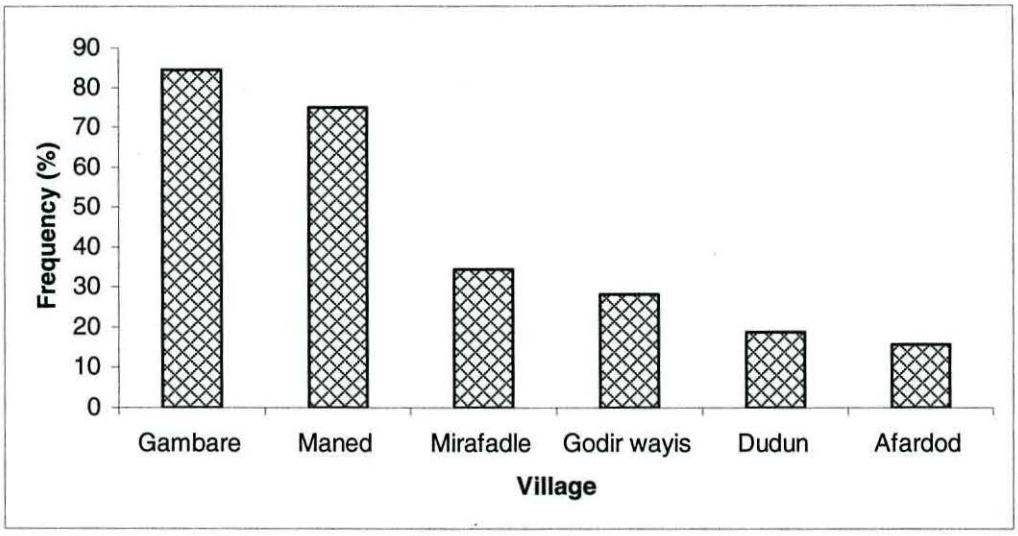

Figure 7.12 Responses (%age) on where fruit of traders typically come from in Boh, Ogaden, Ethiopia

Most of the traders (78%) sold fruit without storing. Only 21% stored fruits before selling. The length of storage period depended on the price (profit gained) and demand;

however they usually kept fruit for between 2 - 8 months. According to the traders, they made decisions on the sale or purchase price by considering profit they would gain (88%) and 75% said they also consider demand and supply while a few (13%) mentioned that price was fixed through discussion with other traders (Figure 7.13)

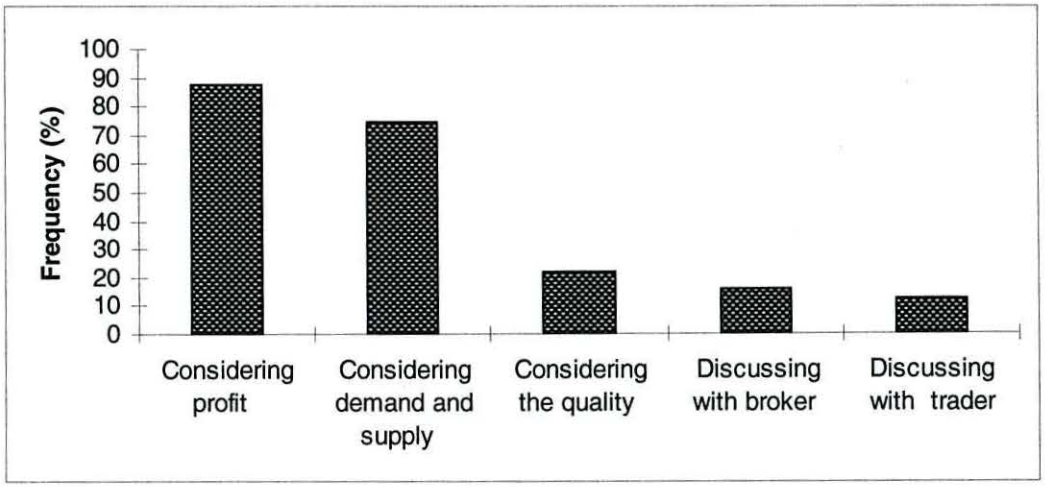

Figure 7.13 Responses (%) on criteria for fixing purchasing and selling prices of yeheb fruit by traders in Boh, Ogaden, Ethiopia

The lack of nearby market (69%) and transportation (63%) were among the main constraints mentioned by traders on trading yeheb fruit (Figure 7.14).

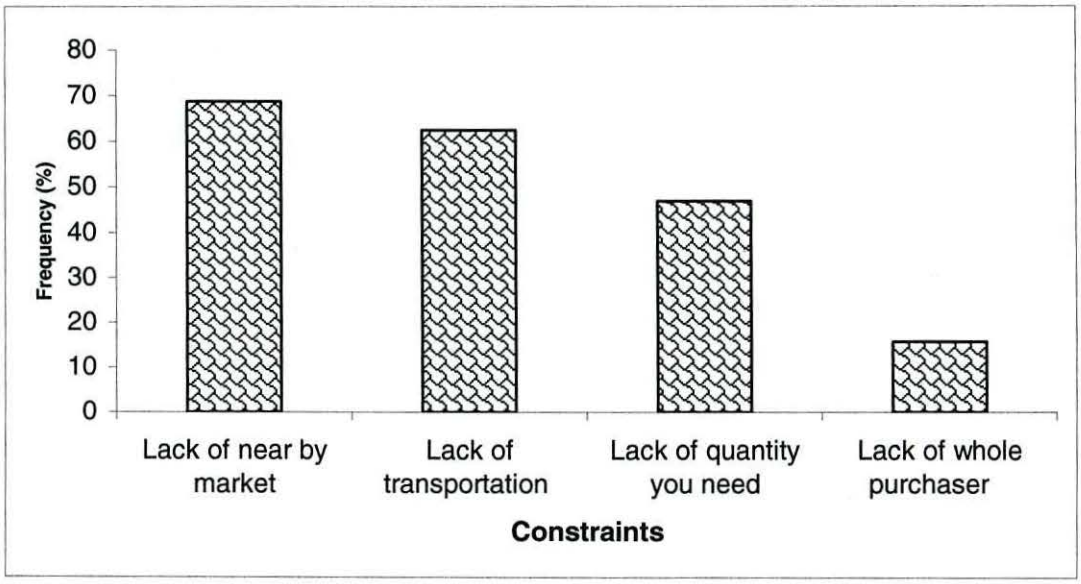

Figure 7.14 Responses (%) on constraints encountered in trading fruit of yeheb in Boh, Ogaden, Ethiopia

Concerning transportation, a few (3%) traders reported to use their own vehicle whereas majority (97%) of them used public transportation.

A majority of traders (78%) traded bulk of the yeheb fruit at Galkayo market, followed by Bur'oo (53%) while a minority mentioned supplying Borsalah (16%) and Boh (16%) markets. The price for transportation depended on the distance of market centre. Mean transportation price for 100 kg of fruit from Gambare to Galkayo was 25 EB and to Bur'oo 35 EB while transporting to Boh market was 12 EB (Table 7.6).

Table 7.6 Market center of trader and transportation price per 100kg of yeheb fruit from Gambare

Market center	Responses (%)	Mean price of transportation /100kg(EB)
Galkayo	78	25
Buro'o	53	35
Bosaso	41	43
Goldogob	19	13
Borsalah	16	16
Boh	16	12

EB indicates Ethiopian birr, the exchange rate for Ethiopian Birr against US dollar in 2008 was 1 US$ = 8 EB

7.4.2. Result of the study on improved harvesting and storage methods

There was a significance difference ($P<0.01$) between treatments in all durations of storage (Table 7.7). Fruit harvested after maturity to which biopesticide applied showed the best resistance to insects. 77% of samples stored were not attacked by insect pests after 12 months of storage. This was followed by matured fruits without biopesticide (44%). Poor performance was recorded for fruit harvested when premature; all the fruits were destroyed by insects after six month of duration (Table 7.7).

Table 7.7 Undamaged (% ± SE) yeheb fruit following improved harvesting and storagemethod at Boh, Ogaden, Ethiopia

Occasion	Premature harvest	Premature harvest + biopesticide	Matured harvest	Matured harvest + biopesticide	F	P
3Months	3±0.98a	22±5.98b	72±7.15c	89±4.76c	42	<0.01
6Months	0	12±3.1a	59±6.96b	85±5.19b	24	<0.01
9Months	0	7±3.8a	51±6.09b	79±6.06c	35	<0.01
12Months	0	6±1.46a	44±7.81b	76±8.40c	28	<0.01

Values are mean percentage and SEM, different letter in the same row indicates significance difference at level of 0.05

Plate 7.5 Fruit attacked in store by insect pests in Boh, Ogaden, Ethiopia

(Photo by: Mussa M. Yusuf)

The result of the laboratory identification of insect pests showed that the common species that attacked yeheb fruit included: Red flour beetle (*Tribolium castaneum*), Tropical werehouse moth (*Ephestia cautella*), Angoumois grain moth (*Sitotroga cerealella*) and maize weevil (*Sitophilus zeamais*). The most common insect that was

observed attacking leaf and stem of C. *edulis* was identified as whitefly (*Siphoninus phillyreae*).

7.4 Discussion

The result of the present study revealed that seed roasting was a common practice by local users as also reported by previous workers (Ismail, 1975; Kasmi, 1979). This is done to prevent fruit from being attacked by insects. Freshly picked seeds are roasted or boiled to kill insects and their eggs, as well as to harden the seed coat. This practice also contributes to the difficulty of obtaining viable seeds for planting as demonstrated by the result presented in Chapter 6. Local people also admitted that the indigenous method of roasting seeds caused problems such as cutting yeheb wood for fuel of this process, poor quality of seed due to burning and impurity. Hence, the result of the present study of improving harvesting and storage by applying Neem as a pesticide may partially solve these problems. According to the results of the experiment, successful results were obtained with fruit harvested after maturity to which biopesticide (leaf of Neem tree) was applied. 76.47% of samples stored were not attacked after 12 months in storage. The lowest resistance to insect attack was observed in seeds which were harvested prematurely. This is in close agreement with the report by Kazmi (1979) who mentioned that fruits of *Cordeauxia edulis* are usually collected prematurely, as a result of which they become susceptible to attacks by weevils and larvae. The use of Neem as pesticide was preferred because most chemical pesticides are harmful for human health and environment (Soler *et al.*, 2004). Children are more susceptible to chemicals since they consume relatively large quantities of fruit (Soler *et al.*, 2004; Alberto *at al.*, 2005). The use of Neem as biopesticide (leaf of Neem tree) has been reported to be not harmful for human, and it is environmentally sound, cheap and easy to implement (Lyons *et al.* 1998). The harvesting and storage experiment was conducted with the participation of local users, suggesting that the technology developed is likely to be easy for adaptation and implementation. No previous research on the use of biopesticide on fruit of *C.edulis* has been done. However, several authors reported the importance of

Neem tree as a pesticide. Neem tree (*Azandirachta indica*) as biopesticide has been used to control insect pests, particularly leaf, seed, bark, and branch which has been reported to have insecticidal effects (Lyons *et al.* 1998; Helson *et al.* 1999). Schmutterer and Singh (2002) also reported that Neem tree (Azandirachta indica) possesses insecticidal activity against many insect pests such as *Helicoverpa armigera*, *Spodoptera litura*, *Plutella xylostella*, *Sitophilus oryzae*, *Sitophilus zeamis*, *Earis vitella*, *Aphis gossypii*, *Tribolium castaneum, Bemicia tabaci*, *Ephestia cautella, Pectiniphora gossypiella*, nematodes like *Cosmopilitis sordidus* etc.

Natural stands of *C.edulis* have been reported to essentially be free from insect pests, however, fruits in store are usually attacked by weevils and moth larvae such as *Tribolium castaneum* (rust red flour beetle), Lepidoptera *Ephestia cautella* (Tropical warehouse moth), *Ephestia kuehniella* (Mediterranean flour moth), *Carpophilus dimidiatus* (Dried fruit beetle) and *Cryptolestes pusillus* (Flat grain beetle), all of which are well known store pests, and not crop specific (Wickens and Storey, 1984). The results of the present study are in accordance with the above findings: red flour beetle (*Tribolium castaneum*), Tropical werehouse moth (*Ephestia cautella*), Angoumois grain moth (*Sitotroga cerealella*) and maize weevil (*Sitophilus zeamais*) were found attacking fruit of *Cordeauxia* in store. Among these *Ephestia cautella* were the most serious pest.

The present study found that besides being used for household consumption, yeheb fruit is sold in market to generate income. Similarly, Kucher (1987) reported that yeheb yields a large number of edible nuts which has obvious potential as a commercial nut crop. The maximum mean quantity harvested was 152.19 kg per household year^{-1} and almost 68% of this (104.69 kg) was sold in local market. Although the major livelihood of local people is livestock production, harvesting yeheb fruit played a vital role as an additional source of income for many of them; it contributed 50% to 56% of household income.

There are also a large number of traders of yeheb fruit in the area. On average a trader supplied about 1197.5 kg of fruit per year and income from the sale of the fruit constituted 49.78% of the trader's income. There are, however, no previous reports in the literature on marketing of yeheb fruit as source of income.

Gambare and Mirafadle villages were the major local markets where yeheb fruit was usually sold. Producers and traders also sold fruits to neighbouring Somalia in places such as Galkayo, Bur'oo, Glodogob, Bursalah and Bosaso where the fruit is highly popular and demandable. Generally, Glakayo is considered as the main market centre for the fruit of C.*edulis* among the markets in the neighbouring Somalia. Brink (2006) and Bally (1966) similarly reported that the fruit from Ethiopia is exported to Somalia and sold on the local market where they are much in demand.

Fruit traders reported that most of yeheb fruit came from Gambare and Maned villages where producers harvested the fruit in large quantities. This might be due to higher population densities of the shrub as reported in Chapter 5. 110 and 100 shrubs ha^{-1} were recorded in Maned and Gambare localities, respectively (See chapter 5).

According to Guinand & Lemessa (2002), in Mirafadle settlement in Boh district, a tin full of nuts, locally called kombo (equivalent to 0.5 kg), was sold for 4000 Somali Shillings (*ca.* 0.25 US $) in July 2001. However, the present study conducted in February, 2008 found that the price of fruit had doubled. One kombo in Gambare and Mirafadle market was sold at 4 EB (0.50 US $). This sale price was higher than other food crops such as sorghum and maize which were sold at 2 EB for the same quantity (0.25 US $) (own observation). This might be because of the high demand for the fruit as also reported by Anonymous (2004) who stated that fruit demand exceeds supply because of rapidly diminishing plant populations.

Local producers claimed that price increased during the dry season and drought period. In addition to this, demand and supply, and quality of fruit were some of the factors that affected price of fruit in the market.

Access to market and availability of transport have been reported as the key factors in determining the commercialisation of any product (Packham, 1993). Similarly, the present study also found that lack of a nearby market and transportation were problems identified by the respondents in marketing of yeheb fruit. Producers either carried on their back or used animal power to transport fruit for long distances to supply local market (Gambare and Mirafadle). Poor infrastructure may have contributed to the lack of easy transportation. Both producers and traders reported that sometimes they had to wait for public transport for more than a week to supply markets located in remote areas such as Galkayo and Bur'oo which resulted to insect pest attack and wastage of fruit due to improper store during transit.

CHAPTER-VIII

GENERAL DISCUSSION, CONCLUSION AND RECCOMENDATION

8.1 Introduction

Plant species adapted to low soil fertility and water or salinity stresses may provide the possibility of using marginal land for food and forage production (NAS, 1979). One such plant is *Cordeauxia edulis* Hemsley (Yeheb) which is a multipurpose plant with great potential to be a valuable source of food in hot and dry regions where the soils are poor, rainfall low and uncertain, and a need exists for a reliable source of protein (Yahya and Durand, 1993; Vietmeyer, 1985).

Yeheb produces a large edible nut, tasty and nutritious, with excellent keeping quality (Ismail, 1975). The nut has been an important component of the diets of the nomadic community in the Somali region (Bally, 1966). According to the local people, it is the number one wild edible food plant, unfortunately, rarely available now in local markets. Every one loves eating the fruit though not every one collects it. *C. edulis* is evergreen and a main source of fodder for livestock particularly in the dry season (Kucher, 1987). Furthermore, it is used as fire-wood for cooking (Vietmeyer, 1985) and as a construction material for houses and fences; the plant also protects the soil against erosion (Liew, 2003). The nut and the leaves are also used for medicine (Anonymous, 2004; Brink 2006)

Today yeheb is threatened with extinction because of over-utilisation caused by drought (Vietmeyer, 1985). According to Kucher (1987) yeheb is in decline, and its area has been shrinking for decades and perhaps centuries. This is not a starling revelation because for decades people have been deploring its decline and disappearance over

large areas of its natural range. These have been voices crying in the wilderness unheeded and perhaps unauthoritative (Kucher, 1987).

Both locally and abroad yeheb is recognized as a nut bearing plant of some economic potential, but the full significance of this, particularly when coupled with its drastic decline, seems to have been missed (NAS, 1979). Kucher (1978) also points out that yeheb has several extraordinary feature of ecological and economical significance. Despite these quite amazing combinations of outstanding attributes, it has been subjected to no concerted research effort and only small sporadic attempts have been made to grow and preserve it (Kucher, 1987).

In order to really understand and effectively manage this superb but dwindling natural resource, baseline data on methods of establishment, growth, propagation, ecology, feed value, current limits and vigour are required (Kucher, 1987; Booth and Wickens, 1988). Review panels on tropical legumes noted that yeheb "deserves careful protection and detailed testing in cultivation.'' It is a matter of urgency to obtain viable seed and set up experimental plantation of *Cordeauxia* so that it may be saved and the best methods for successful cultivation and utilisation discovered (NAS, 1979). Liew (2003) also recommended study on management, environmental requirement, cultivation techniques, nutritional value, phenology, factors affecting yield and regeneration, population dynamics and responses to harvesting, taxonomy, variation and possible selection criteria are needed.

The present set of studies were, therefore, carried out to generate information needed for improved management and utilisation of *C. edulis* in Boh district, Somali Regional State (Ogaden) of Ethiopia. Five research activities were conducted, focusing on traditional knowledge of use and management, local opportunities and constraints for growing the species; ecological and biological characteristics of the species and the nutritional composition of its fruit; population status and associated tree species; propagation methods; and improved village level harvesting and storage methods, and market possibilities.

8.2 General discussion

The finding of the present study indicated that *C. edulis* (Yeheb) is a multipurpose plant used by local communities for food, construction, forage, fuel, fence and medicines. The plant produces nut that is locally used as stable food; this being the most utilised part of the plant, the wood is also used for construction of houses and fences and fuel wood and leaves are used as forage for livestock and medicine. Many previous authors also reported that the plant is a multipurpose evergreen shrub used as valuable food, dry season animal feed, firewood, building material, medicine and for dyeing of textiles for garments for the local population in the border areas of Somalia and Ethiopia (Booth and Wickens, 1988; Brink, 2006, Miege and Miege, 1978; Kucher, 1987; Ali, 1988; Kazmi, 1979). Foliage of yeheb plays a vital role as a source of fodder for livestock especially for survival during dry season due to its evergreen nature. According to Kucher (1987), without yeheb, current livestock numbers could not be maintained in those regions where yeheb is predominant and it comes as no surprise that pastoralists in yeheb zone are substantially richer in livestock, notably camel, than those whose home range lacks yeheb.

The results of the present study revealed that yeheb is a communal resource (open access) and that no management or control of utilisation existed. Thus, it is subjected to overexploitation such as overcutting, overbrowsing and fruit overharvesting, as a result of excessive drought and because there is a lack of awareness in sustainable utilisation. Consequently, mean population density of 67 clumps ha^{-1} was recorded in the present study which was considered extremely low when compared with previous reports of 162 plants ha^{-1} in poor sites and 319 plants ha^{-1} on sites in excellent condition (Ali, 1988). Hence, the population of *C. edulis* seems to be declining at an alarming rate in Boh district of Ogaden. Local communities are aware of this decline and admitted that the population is endangered with extinction. They blamed the excessive drought in the area that led them to overexploit the species for survival. They also reported that currently there was no ongoing activity to save the species. These findings agree with NAS (1979) who reported that the decline of yeheb is lamentable, but even more

frustrating is lack of reaction to this. Over harvesting has also resulted in no natural regeneration of *C. edulis* as shown in chapter of the present study. Out of the ten populations of *C. edulis* surveyed in Boh district no seedling was found in six populations, while only one seedling was recorded per plot in each of the remaining four populations. Previous authors suggested that over browsing, fruit overharvesting, cutting, fire, erosion and war caused reduction in the area and population of yeheb (Booth and Wickens, 1988; Miege and Miege, 1978; Kazmi, 1979). The cause of the decline was not understood very well (Kucher, 1987) and overbrowsing was considered as the only culprit. However, the present study found that overcutting for house and fence construction and for fuelwood seemed to be the main cause for the decline of the species in Boh district. As a result of the population decline, C.*edulis* is now in the red list as endangered species by International Union for Conservation of Nature (IUCN, 1997).

The present study found that yeheb is growing on a slightly alkaline, sandy soil that is poor in essential nutrients such as organic matter, available phosphorus, potassium and total nitrogen. This finding is an agreement with many previous authors who reported that C.*edulis* grows on nutrient poor soil (Bally, 1966; Yahya and Durand, 1993; FAO, 1988; Drechsel and Zech, 1988). The type of soil on which yeheb grows is locally called "*Haud*" which is a specific soil type found only in areas where yeheb grows starting from central eastern part of Ogaden in Ethiopia and crosses the border till the neighbouring central Somalia (Drechsel and Zech, 1988; Seegeler, 1983). The present finding, however, showed that soil nutrients such as Ca, total N, and organic matter were higher in the surface soil under the shrub than away. This shows that the species has the potential to improve the soil.

Moisture is a limiting factor for production of *C. edulis* since an extremely strong positive relation between fruit production and seasonal precipitation was found in the present study. A total annual rainfall of 229 mm and 238 mm were registered in 2008 and 2009 years of the present study, respectively, that are distributed in two wet seasons from March to June and from September to December in each year. *C. edulis* seems to

be adapted to this climate by flowering and producing fruit in both seasons. Furthermore, if seasonal rainfall starts and fails to continue in this semi desert area, the plant has mechanism of adaptation whereby the developing fruit diapauses instead of dying and ripens in the early rainfall of next rainy season. This finding has been confirmed by Ali (1988) and Ismail (1975) who reported that fertilized ovaries of yeheb remain undeveloped up to 4 - 5 months if rain fails and they may ripen in 5 - 6 days in the next rainy season. Deep tap roots that allow the plant to tap deep soil moisture, and the unusual anatomy of its leaves which roll during extreme water stress are mechanisms that allow the plant to survive an arid climate with extended dry periods (Curtis *et al.*, 1996).

The result of the present study on nutritional composition showed that the nut of *C. edulis* is characterized by high carbohydrate (36%) and fat (12.58%) contents. Its high sugar content is significant as it is the main source of energy in this semi-desert area where food is uncertain and life is a bit harsh. NAS (1979) mentioned that the main characteristics of the seeds are their high sugar and fat contents compared to other seeds of species in the Fabaceae family. Even though the protein content of the fruit (16.54%) is low, it is significant for the area (Bally, 1966). The present study estimated that eating daily 340 g (for adult male) and 279 g (for adult female) of nut can satisfy their daily demand for protein; hence yeheb is a good source of protein for those who use the plant as a staple food. Additional, it can also be a source of macronutrients such as phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) which are found in large quantities in the fruit.

The study on propagation of C.*edulis* revealed that vegetative propagation by stem cutting was not a success but propagation from seed is the most efficient method. Local people claimed that seed of yeheb easily germinated after harvesting. Hence, they dried it immediately after harvesting to avoid this problem. The present study found that the highest mean seed germination was 36.87% which was very low. Germination was, however, enhanced to 72% after pretreating the seed by boiling in water. The low germination might be due to seed dormancy as a result of the hard seed coat. The pretreatment improved the permeability of the seeds to moisture and air and/or

overcame the mechanical resistance imposed by seed coat to embryo growth (Nikolaeva, 1977; Nwoboshi, 1982). The highest seed germination (72%) found was obtained in the soil of the study site (Boh) with seed pre-treated in boiling water and watered once a day. According to the results of the present study, the best seed germination, seedling survival and growth performance were recorded in soil from the study site (Boh). However, the local soil from Jijiga with sand was added was the second most successful growing media for *Cordeauxia* seedlings. This shows that the plant can be grown outside its natural range by mixing local soil with sand.

Despite the fact that the population of *C. edulis* has declined, the present study found that the mean quantity of fruit harvested was 152.19 kg per household per year. In addition to household consumption, the fruit harvested was also supplied to the local market. Hence, it played a vital role for the livelihood of the local community by contributing almost half (49.8% to 56.06%) of the household income. However, lack of nearby markets and transportation were reported to be some of constraints for marketing of *C. edulis*. In general, according to Yahya and Durand (1993) production levels of up to 1527 kg ha^{-1} $year^{-1}$ of fruit has been reported which is considered very high from this semi desert area. This indicates that fruit of yeheb has a potential to substitute for rice, sorghum and maize not only for the local community but also people in the region (Ogaden) that usually suffer food insecurity. However, this will only be possible if current plant populations are conserved and large areas of *Haud* are replanted and complemented with improved management including irrigation.

The study on improved methods of harvesting and storage showed that harvesting fruit after it was physiologically matured and applying biopesticide (leaf of Neem tree) to the harvested fruit prolonged its shelf life by almost one year. Poor resistance to insect pest was observed in fruit harvested prematurely which is the stage at which local people usually collected the fruit. Immediately after collection, they roast the seed to protect it against insect pests. As the result, seeds sold in local market are usually unviable. In addition, the price offered in the local market for such seeds are low due to poor quality resulting from improper roasting. By applying the improved method of harvesting and

storage, overcutting of *Cordeauxia* that is done to produce fuel for roasting seeds can be avoided. However, this should be supplemented with training and extension services to the local communities so that they become aware of the benefit of the improved system.

8.3 General conclusions

The following conclusions are drawn based on the results of the present study:

Cordeauxia edulis is an extremely useful species for the local community in every aspect including food, forage, construction (home and fence), fuel wood, and medicine.

C. edulis is a communal resource with no management or control of utilisation and no involvement of the government in its utilisation and management. As a result, the population of C.*edulis* is declining due to overexploitation including over cutting of wood, over browsing of foliage by livestock and overharvesting of fruit and severe drought.

Superior quality fruit yielding shrubs of C.*edulis* are characterised by the local communities as those that are large sized, possess many branches, smooth bark, and small leaf.

Due to nomadic lifestyle of the local community, there is no culture of planting and so *C. edulis* has not been domesticated yet.

The soil of *C. edulis* stand is slightly alkaline and varying in texture from sandy loam to loamy sand but poor in essential nutrient content including organic matter, available phosphorus, potassium and total nitrogen. Soil nutrient content including Ca, total N, organic matter were, however, higher under *C. edulis* crowns than further away.

Rainfall in the natural habitat of yeheb is bimodal: March to June and September to December. Depending on the rainfall amount, C.*edulis* flowers and produces fruit in each rainy season. There was a strong positive relationship between the reproductive phase (flowering and fruiting) and vegetative phase (leaf flushing) of C.*edulis* and seasonal precipitation as well as between leaf flushing and flowering of C.*edulis* and maximum temperature.

Fruit of C.*edulis* is high in carbohydrate (36%) and fat (12.58%) contents.

Density of C.*edulis* varied from 30 to 110 clumps ha^{-1} with mean density of 67 clumps ha^{-1}. Morphological characteristics including height and basal diameter of C.*edulis* varied between populations and were higher in relatively higher density populations. Natural regeneration of C.*edulis* was almost negligible with no seedling found in six of ten populations studied. The most common associated species of *C. edulis* were *Acacia* spp, *Commiphora* spp and *Boswellia neglecta.*

Vegetative propagation by stem cutting was not successful. But *C. edulis* can easily be propagated from seed. *Haud* where *C.edulis* is found naturally where soils the best growing media for growing seedlings of *C. edulis* followed by soil of Jijiga to which sand was added. Boiling seeds in water enhanced germination, seedling survival and growth of *C. edulis*. Watering once a day produced the highest seed germination, seedling survival and growth of *C.edulis*.

Local people collected fruits of *C. edulis* manually before it matured. These are dried under shade and buried in hot ash to kill insect eggs. The roasted seed is then placed in sacks and stored in the house. Such practices reduced seed viability, plant population and fruit quality. Fruit harvested after it physiologically matured on mother tree and was then treated which biopesticide (Leaf of Neem tree) prolonged the shelf life of the fruit and its viability.

Besides household consumption, fruit of *C. edulis* is sold in local market for income generation and contributed between 49.8% and 56.06% of household income. Gambare, Mirafadle, Boh, Goldogob, Borsalah and Galkayo were the main market centers for yeheb fruit. The fruit is transported to the neighbouring Somalia where there is high demand for it.

8.4 General recommendation

Based on the results of the present study the following general recommendations are made.

1. It is recommended that education is given to local communities to increase their awareness about the importance of this resource and the consequence of its extinction on their livelihood and encourage conservation of the species by controlling browsing, excessive seed harvesting and cutting and establishing reserves with good management.

2. Sustainable management is needed to reduce pressure on yeheb such as; browsing and harvesting by rotation system, providing alternative source of construction and energy (like biogas, solar and wind energy, and electricity), fencing plots of land for natural regeneration, and diversification of the livelihood of the local communities (like in trading activities).

3. Government legislation is required by putting in place the appropriate policies that provide sustainable utilisation and conservation to protect and save the species; resource use and environmental policy.

4. *C. edulis* is a wild plant found in an extremely remote and isolated area. As a result little research has been conducted on it so far and much remains to be learned about the plant.

5. The problems of marketing should be overcome through the intervention of Government in collaboration with traders. Enhancing market transparency, market literacy and investing in infrastructure related to the chain of market activities could be of great benefit to the community to enhance their livelihoods.

6. Research is required on sustainable utilisation of the species such as optimum browsing capacity and coppicing potential.

7. It is recommended that further investigation is needed on the function of the natural pigment present in the leaves known as Cordeauxiaquinone for dyeing textiles and other purposes like medicinal values as it is reported by Brink (2006) to synthesize red blood cell.

8. More research on marketing and ways to increase income from the fruit is also recommended. For example, value addition through transformation of the fruit into other products such as cakes.

9. Research on anti-nutritional factors (enzyme inhibitors), toxicity and long term effect of fruit on human nutrition and health is recommended.

10. Further research on fodder value and its effects on livestock are also recommended.

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APPENDICES

Appendix 1: Study on traditional knowledge and local constraints of *Cordeauxia edulis* (yeheb).

1. Personal profile of household head

1.1Name of the respondent:
a. Sex: Male..... Female..... b. Age.....
1.2 Clan / tribe.....
1.3 Locality/village.....

2. Do yeheb grow in your area?
a) Yes..... b) No.....
2.1 If yes, for what purpose do you use it?
...../...../...../.....
...../...../.....
2.2 If you use yeheb fruit for food, please rank the way you consume the product?
a) Eaten fresh.....
b) Dried.....
c) Roasted or boiled.....
d) Soup.....
e) Other.....

2.3 If you use yeheb plant for fodder, please fill the table below?

Type of animals	Specific function for animals. If any!	Season of grazing or browsing	Rank preference as a fodder

3. Who is the owner of yeheb resource in your area?
a) State.....b) Community.....c) Private.....d) other.....

4. How do you manage yeheb resource in your area?
a) By traditional..... b) By Government..... c) No management or control..... d) Other.....

5. Have you ever seen any conflict over utilisation of yeheb resource in your area?
a) Yes..... B) No.....

6. Do women participate in the activities of yeheb in your area?
a) Yes.....b) No.....
6.1 If yes, in what way please specify?
...../...../.....
..../...../...../.....

7. Do you think the number of yeheb shrubs in your area has been declining?
a) Yes.....b) No.....c) Other.....
7.1 If it is declining what is the reason?
...../...../.....
..../...../...../.....
7.2 What do you think should be done to mitigate the problem of declining plant population?
...../...../.....
..../...../...../.....

8. Do you think yeheb population will disappear from your area in the future?
a) Yes ..... b) No..... c) Other.....
8.1 If yes, what are you doing to save the plant?
...../...../.....
..../...../...../.....

9. What are the characteristics of shrubs that yield good quality fruit?
...../...../...../.....
...../...../...../...../.....
.....

10. Do you collect seeds from good quality shrubs only?
a) Yes..... b) No.....
10.1 If not why?
...../...../...../.....
...../...../...../.....

11. What type of fruits are good qualities?
a) Large size..... b) Sweet taste.....C) Both large size and sweet taste.....
d) Other.....

12. Are there any different varieties of yeheb found in your area?
a) Yes..... b) No.....
12.1 If yes, please mention them and what are the major differences between them?
...../.....

13. Have you ever planted yeheb?

a) Yes..... b) No.....

13.1 If No, why have you not planted up to now?

.....

.....

14. Have you ever planted any other trees?

a) Yes..... b) No.....

14.1 If yes, where did you get the seeds or seedlings from?

.....

15. What is your opinion on increasing the production and quality of yeheb?

.....

.....

Appendix 2: Study on local harvesting, processing and storage method and marketing of fruits of *Cordeauxia edulis* (Yeheb)

A. For local user (producer)

1. Personal profile of household head

1.1Name of the respondent:
a. Sex: Male..... Female..... b. Age.....
1.2 Clan / tribe.....
1.3 Locality/village.....

2. How do you harvest fruit of yeheb?
...../.....

3. In the house hold who is usually harvesting fruit of yeheb?
...../...../.....

4. How many times do you harvest in a year?
...../...../.....

5. Fruits are harvested for what?
a) House hold consumption..... b) Marketing..... c) Both house hold consumption and marketing.....

6. What problems do you face during harvesting of yeheb fruit?
...../...../.....
...../...../.....

7. How do you process harvested fruit of yeheb?
.....
.....

8 .Are there any disadvantage or problems with local processing method of harvested yeheb fruit?
a) Yes..... b) No.....
8.1 If yes, please explain?
...../...../.....
...../...../.....

9. Where and how do you store yeheb fruit?
...../.....
9.1 If there are a number of storage systems, please specify which is better or best and what is the reason?
...../.....
...../...../.....

10. Are there any insects, rodents, other animals and other factors which affect yeheb fruit during Storage?

a) Yes..... b) No.....

10.1 If yes, please mention them?

...../...../.....
...../...../.....

11. In the household who usually supply fruit of yeheb for market?

...../...../.....

12. How much fruit do you harvest usually in a year?

.....

12.1 How much for consumption and how much for sale?

For consumption.....For sale.....

12.2 How much is your income from the sale .....and its percentage contribution to your household income? .....

13. What do you use the cash income from marketing of yeheb?

...../...../.....

14. Where are market centre of yeheb fruit, price / kombo and means of transportation?

...../...../...../.....
...../...../...../.....
.....

15. Are there any factors which affect price of fruit in the market?

a) Yes..... b) No.....

15.1 If yes, please mention them?

...../...../.....
...../...../.....

16. What problems do you experience in marketing of yeheb fruit?

...../...../.....

17. What do you think should be done to increase income from marketing of fruit of yeheb?

...../...../.....
...../...../.....

18. What are the major income generating activities you are involved in other than yeheb fruit?

...../...../.....

18.1 Which income generating activity do you prefer including yeheb fruit and why?

...../...../.....
...../...../.....

19. Do you save money from marketing of yeheb fruit?
a) Yes..... b) No.....
19.1 If yes, how much do you save at a time? .....

20. Do you carry out marketing activities with others in a group or alone?
.....
20.1 If it is in a group are there any advantage?
...../...../.....

21. Are there any institutions which support marketing of yeheb fruit?
a) Yes..... b) No.....
21.1 If yes, please mention them and what kind of support do they give?
...../...../.....

B. For trader

1. Personal profile

1.1 Name of the trader.....
1.2 Sex.....age.....
1.3 Clan/ tribe.....
1.4 Locality/village.....

2. Are you a wholesaler? or a retailer?.....

3. Is yeheb fruit delivered to you or go get it? .....

4. What is your current supply of yeheb fruit you sell per year? .....
4.1 What is your income percentage from yeheb fruit trade? .....

5. Where is your yeheb fruit typically coming from?
...../...../...../.....

6. What is your sale strategy? Store or sell as soon as possible? .....
6.1 If you store. How long do you store before you sell it? .....

7. How do you decide the sale and purchase prices?
...../...../.....

8 What are the main problems you encounter in your yeheb fruit trade?
...../...../.....
...../...../.....

9. Do you use your own car or other vehicle for transportation? .....

10. Where are your trading market centres of yeheb fruit and price of transportation /100kg?

……../……../……
……/……../……..