AN ABSTRACT OF THE THESIS OF

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Title: CORDEAUXIA EDULIS: PRODUCTION AND FORAGE QUALITY IN CENTRAL SOMALIA.

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Availability of evergreen forage plants during the two dry seasons in arid central Somalia is very important. Cordeauxia edulis is a multistemmed evergreen legume shrub which grows in Central Somalia in plant communities dominated by deciduous shrubs. There are two growth forms of this plant. A form with small leaflets and a second form with large leaflets were studied.

The objective of this study was to determine the morphology, phenology, forage production, adaptation to grazing, and forage quality of C. edulis. The study was conducted in Central Somalia from April to September, which is from the end of the dry season through the early rainy-season to the beginning of the next dry season.

After the first rain of the season, vegetative and floral buds, initiated the previous rainy period,

continued their development. Immature fruits, from the previous rainy period which had been in diapause through the dry season, continued and completed their development. Leaflets, which had been curled during the dry season, and became turgid.

The small-leaf form of C. edulis grows on Arinic Aridic Paleoustalfs, while the large-leaf form grows on Typic Ustipsmments Arenosols. Plant density increased with distance from permanent water points and villages and was related to decreased browsing intensity. Average estimated forage production of C. edulis was 326 kg/ha, 335 kg/ha and 453 kg/ha for poor, good and excellent condition classes, respectively. C. edulis sprouted heavily from the base in response to degree of hedging, but no decline in per plant production was found.

Leaves and twigs of C. edulis contained 54% moisture during vegetative growth stages and approximately 28% moisture during dormant stages. There was no difference in crude protein content between the two growth forms although crude protein decreased as the growing season progressed. Crude protein was highest during vegetative and flowering stages. Crude protein was 14% for the small-leaf form and 12% for the large-leaf form at the flowering stages. Calcium was higher for the small-leaf form as compared to the large-leaf form. Phosphorus content was sufficient to meet the minimum amount required for normal cattle growth only during the early growth phases. _In vitro_ dry matter digestibility was low for both growth forms due to high lignin and fiber content in plant tissue. _In vitro_ dry matter digestibility was 37% during early vegetative growth but declined to approximately 30% during all other stages. The small-leaf form had higher lignin content compared to large-leaf form for most phenological phases.

CORDEAUXIA EDULIS:

PRODUCTION AND FORAGE QUALITY IN CENTRAL SOMALIA

by

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TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

CORDEAUXIA EDULIS: PRODUCTION AND FORAGE QUALITY IN CENTRAL SOMALIA

INTRODUCTION

Somalia is located in the arid and semi-arid region of northern east Africa. The entire country is within the tropics lying between 2° south to 11° north latitude and between 30° and 53° east longitude. Topography is mainly rolling hills but with highlands along the northwest section of the country. Surface water is a limited resource for the majority of the nation. There are two small permanent rivers in Somalia, the "Jubba" and "Shebeelle", both running in the southern part of the country. The Jubba adds its water into the Indian Ocean while the Shebeelle ends in sand swamps near the ocean. There are a few streams called "Waadi" in the northern part of the country. These streams are dry except during the rainy seasons when they carry the excess runoff water from the highlands.

More than two-thirds of Somalia is rangeland and is used by nomadic pastoralists for grazing. These nomads have herds of camels, goats, sheep and cattle. Livestock production from native rangelands is the most important agricultural enterprise of the country (Box 1968).

The climate is dry and hot year-round. Precipitation is bimodal in which there are two wet and two dry seasons. Rainfall comes as closely spaced thunder storms. The amount of precipitation is unpredictable and long-term droughts are common. Dry seasons are usually longer than wet seasons for the majority of the country.

Dry seasons are limiting factors for livestock production in the nomadic pastoral economy because of forage scarcity and its poor quality for herbivores. Dry twigs and weathered grass are the only available forage through the dry season. For much of Somalia however, where evergreen shrubs occur they are important and valued for their nutritional quality even if not highly palatable.

Few species of evergreen shrubs exist on Somali rangelands, however one, Cordeauxia edulis (Yeheb or jicib), grows in Central Somalia in a habitat dominated by deciduous shrub species. Other evergreen plants exist such as Boscia, Cadaba and Maerua, however they never represent more than 2% of the canopy cover (Kuchar 1987). C. edulis may fulfill the primary criteria of quality dry season forage, being a regionally abundant, evergreen leguminous shrub. C. edulis is reported to be important as a forage plant, as a producer of seeds that are eaten by Somalis, and as an alleged medicinal plant (Kuchar et al. 1985). Seeds are harvested during each wet season.

Two growth forms of C. edulis exist. They are found mostly in distinct stands, although mixtures may occur. Both forms have similar characteristics and grow within the same general plant communities, though there are some differences.

International and national interest in C. edulis as a potential plant for cultivation has been steadily building. At present only wild populations exist, but these could be domesticated if the biology and regeneration requirements of the species were known. C. edulis is threatened with extinction from most of its habitat and deserves careful protection and detailed tests in cultivation. There is little known about the biology, productivity or forage quality of C. edulis. The objectives of this study were to determine gross morphology, phenology, soil relationships, forage production, and forge quality of C. edulis.

LITERATURE REVIEW

Historical background

Cordeauxia edulis was first documented by the Italian, Robecchi, in 1871 when exploring Somali-land (Michelozzi 1957). It was next recorded by the British Captain Wellby in his report of a journey to Somali-land in 1895. Some 10 years later seeds were forwarded to the Imperial Institute in Kensington, England, by Colonel Swayne Commissioner Somali-land Protectorate, for determination of their nutritive value. A second shipment from the same source was again sent to the Imperial Institute at a later date. Seeds from the second shipment were 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. Early efforts to obtain botanical specimens from Somalia failed (Hemsley 1909).

In July of 1907 Captain Cordeaux, Commissioner Somali-land Protectorate, sent a sample of specimens to the Royal Botanical Garden for species identification. The samples proved to be leguminous, belonging to an undescribed genus in the tribe of Caesalpinieae, closely related but very distinct from *Schotia* and *Stuhlmania* (Miege and Miege 1978). To commemorate Captain Cordeaux successful work, Hemsley (1907) named the new genus

Cordeauxia and gave the species the epithet edulis, meaning "edible".

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 Institute Herbarium in England which distributed then to Kew, South Africa, Jamaica and the United States for cultivation (Greenway and Raymond 1947).

Cordeauxia edulis locally called Yeheb by Somalis is best known for its seed that are locally called yeeb, yebb, yeheb or jeheeb, which all mean the same thing, i.e. seeds of C. edulis. Seeds are commonly eaten by the Somalis which are obtained from the pods of C. edulis. The plant itself is called Gud by local nomads. C. edulis is used as forage by domestic livestock and wildlife.

Description

Cordeauxia edulis is a strongly multi-stemmed evergreen shrub which grows profusely in the "Hawd" or arid lands of Central Somalia. Mature C. edulis plant form scattered and isolated clumps. Stems are numerous, emerging, much-branched, forming a tightly bunched crown. Mature plants may reach a height of 1.6 m while a few grow to 2.5 m in favorable locations. In places where it has not been grazed it reportedly reaches a height of 3 to 4 m

(Bally 1966, Thulin 1983).

Cordeauxia edulis has persistent leathery paripinnate leaves (Bally 1966). Leaflets are generally in 4 pairs, oval-oblong with numerous glandular hairs on the margin and lower side. The glands produce chemicals that can be used as a dye. Lister et al. (1955) determined the chemical constituents of these glands to be a derivative of naphtazarine which was named Cordeauxiaquinone. Leaves contain 0.7-0.8% of this substances (Bally 1966). The dye is selectively deposited in certain tissues of livestock which feed on *C. edulis* leaves, in particular their bones become stained orange or red. Nomads believe the meat from these animals tastes better than those that do not feed on *C. edulis* (Kuchar et al. 1985).

The inflorescence of *C. edulis* is a corymb formed at the tip of each branchlet (Bally 1966). Flowers are 2.5 cm in diameter, bright yellow, with 5 spoon-shaped petals and 10 straight stamens with hairy filaments at the base. The calyx has 5 green sepals covered with red glands similar to those of the leaves. The ovary is short stalked with a terminal dense stigma (Greenway and Raymond 1947).

Fruits are ovoid, or slightly compressed, hard leathery skinned, having curved pods with a beaked apex. Pods are 1 to 2 cm in width and 0.5 to 1.5 cm in length. Pods contain from one to four round or ovoid seeds about the size of a small macadamia nut or large hazel nut. Depending on growing conditions, by age 3 years plants may begin production of pods and by 4 years of age plants may yield prolifically under favorable conditions (National Academy of Sciences 1979).

Seed germination is high immediately after harvesting but decreases rapidly. Seeds appears to retain their germinability for only a few months after harvest. Nomads dry them before storage in order to reduce germinability. Germination of over 80% in a nursery situation has been reported but seedling survival was low (Kasmi 1979). At the Galana Ranch, Kenya, seeds placed in plastic bags germinated well. However, seedling establishment was poor, perhaps due to excessive root growth (Bally 1966).

The seeds are tasty and nutritious, and are eaten by nomads either raw, roasted or cooked (Greenway and Raymond 1947). Seeds make a nourishing and balanced diet. Even though their protein and carbohydrate contents are less than those of most other pulses, the seeds contain both sugar and fats. They contain 11% fat, 13% protein, 24% sugar, 37% starch, and they also contain various minerals. Recent work, on the nutritional value of Cordeauxia edulis seeds shows that its proteins contain amino acids in a proportion similar to that of grain legumes (Greenway and Raymond 1947, Noelle and Miege 1978, Orru 1938).

Local tradition suggests that the seeds were the staple food item of the nomads. They were so much liked and relished by the people that the encouragement to work is very commonly given by quoting an old Somalia proverb "fadhi iyo fuud yicibeed laysla waa" which means one who sits idle will not get yeheb soup. Relatively small quantities of the seeds enter the commercial trade through the local and regional market (Kasmi 1979).

Distribution

Cordeauxia edulis grows in the Hawd (infertile stable sand) region of Central Somalia and Ethiopian occupied area of the Ogaden (Fig.1). The species grows on frost-free rolling, stable sand hills and plateaus with an elevation of 300-1000 m. Climate is arid to semi-arid. Rainfall is bimodal (April-May "Gu" and October-November "Dayr") with a total amount ranging from 250 to 450 mm. Rainfall increases from the north toward the southern end of the Hawd region (Watson and Nimmo 1983/84).

Cordeauxia edulis grows as scattered to dense clumps within open tufted grasslands, and deciduous shrublands. Apart from a few scattered trees *C. edulis* is one of the taller plants present. Associated plants are species of

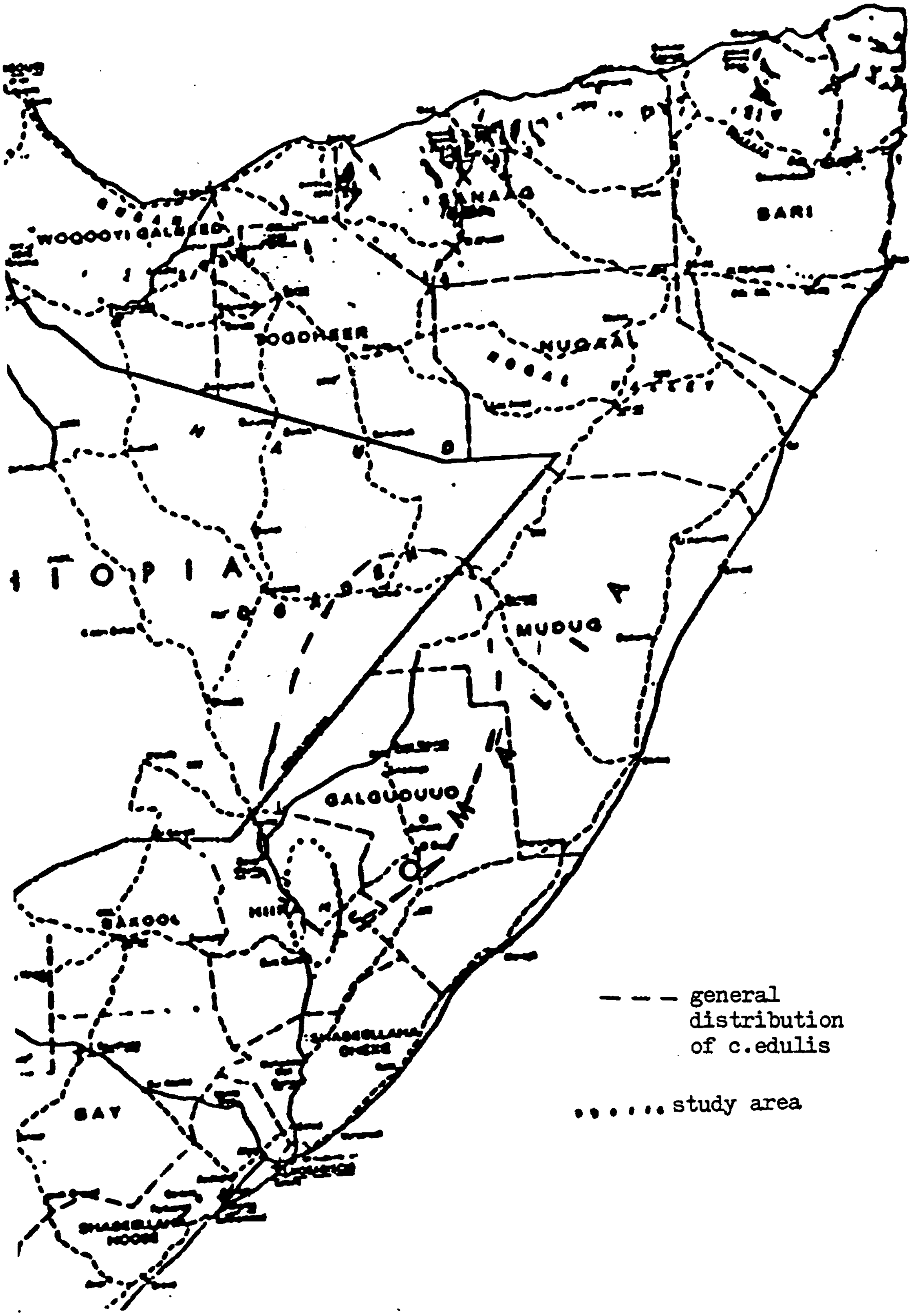

Figure 1. Map of Somalia and Ogaden region in north east Ethiopia

Acacia, Commiphora, and Indigofera, Euphorbia longispina, Cassia truncata, as well as annual and perennial grasses (Bally, 1966) .

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 early travelers (Bally 1966). The decrease may be partly due to continuous overall deterioration of the vegetation throughout Somalia and neighboring countries brought about by increasing livestock populations, droughts and wars. Exploitation of the shrub for its seeds as food, and uncontrolled livestock browsing undoubtedly have contributed to its decline (Bally 1966, Kasmi 1979, Kuchar et al. 1985).

The plant appears free of pests, however the seeds are attacked by moth larvae and weevils (Kasmi 1979). C. edulis is not fire resistant like many associated species (Kuchar et al. 1985), therefore fire may decimate populations of C. edulis.

Importance

C. edulis has a high potential for domestication because of its ability to grow well in environments where moisture is too limited for cultivation, its potential forage value, and the potential food value of the seed for human consumption.

Cordeauxia edulis has both ecological and economical importance for the region. It is a strong well adapted species in the arid environment. During the extreme drought years of 1973-76 C. edulis survived but did not flower (Kasmi 1979). The dry season is a critical time for livestock to find enough available forage of sufficient quality for maintenance. C. edulis is evergreen and an important forage for the livestock during the dry season. C. edulis represents a large component of high quality dry season feed because of its evergreen nature (Kuchar 1987). As yet there is no information available on the digestibility and nutritive value of the leaves. It is a palatable dry season browse particularly for camels and goats (Kuchar et al. 1985).

Other economical values include the pigment in the leaves that is easily extracted and used as a fabric dye (Branco 1960). Some Somalis value the plant greatly for its alleged medicinal properties.

Domestication of C. edulis is just beginning. Seeds planted in 1954 at the Mwakiki Seed Farm, Kenya, germinated and although several plants survived initially, by 1963 they could not be found (Bally 1966). Cordeaux in 1907, planted seeds at Berbera, Somalia and reported they successfully established (Branco 1960). Some 50 shrubs are under cultivation at the Central Agriculture Research

Station, Afgoye, Somalia. These grew slowly, however they flowered and produced abundant fruit (Kasmi 1979). The auther observed plantations of <u>C. edulis</u> near Mogadishu on sandy soils. They were 15 months old as of August 1987 and were growing well.

METHODS

Study Area

The study area was located in central Somalia in the Bulo Burti District approximately 300 Km north of Mogadishu, 4^{0} 3' north latitude and 46^{o} east longitude (Fig. 2). Elevation ranges from 300 to 350 m. The landscape is mostly deep stable sandplains with soils that are deep red sands, derived mostly from limestone parent materials.

The climate is arid to semi-arid with mean monthly temperatures ranging from 27^{o} C in July to 31^{o} C in March. Mean annual temperature is 29^{o} C (Watson and Nimmo 1983/84). Rainfall is mostly bimodal and highly unpredictable. Rainfall comes in April-May "Gu" and again in October-November "Dayr" with a range of 275 to 450 mm of total precipitation for the two periods. The two dry seasons are August-October "Haga" and December-April "Jilaal". Monthly mean relative humidity ranges from 55% to 64% (Watson and Nimmo 1983/84).

Vegetation is dominated by deciduous shrubs mainly thornbushes of _Acacia_ and _Commiphora_ _C. edulis_ is a co-dominant with scattered patches of grass in the understory. _C. edulis_ grows mostly in the open between other shrub species but may occur beneath them as well. The top layer of the vegetation ranges from 2 to 6 m with

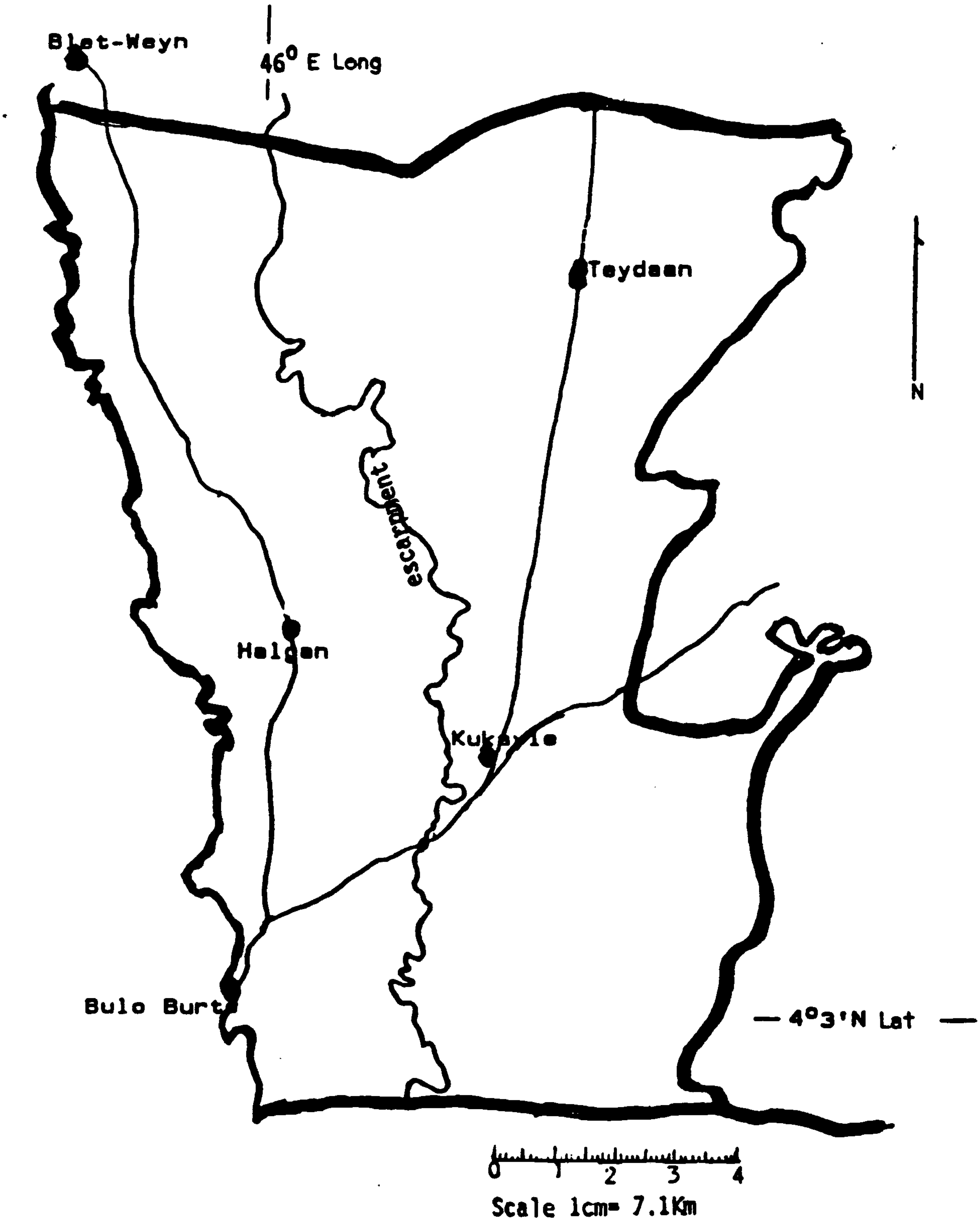

Figure 2. Map of the study area which is the eastern Bulo Burte district. (—) Roads

few emergent trees. The study area is used for grazing mainly by camels, goats and sheep. Cattle are restricted to areas proximate to permanent water points, while camels and goats graze greater distances from water.

The study area received above average rainfall during the rainy season of April-May "Gu" 1987. Total rainfall for those two months was 435 mm. The five year average (1982-1986) of those two months was less than 50 mm (Fig. 3).

There are two growth forms of C. edulis in the study area. These growth forms differ as to leaf size. One is a light green, large stem diameter plant with large leaflets. The other is a dark green, small stem diameter plant with small leaflets. The large-leaf form appears overall to be a larger plant than the small-leaf form. The large-leaf form is by far the more common and widespread while the small-leaf growth form is restricted to a few locations at the northern part of the study area. Mixtures of the two growth forms exists but are rare.

The study was conducted from April through September 1987, starting at the end of the dry season, continuing through the rainy (growing) season, and into the beginning of the next dry season.

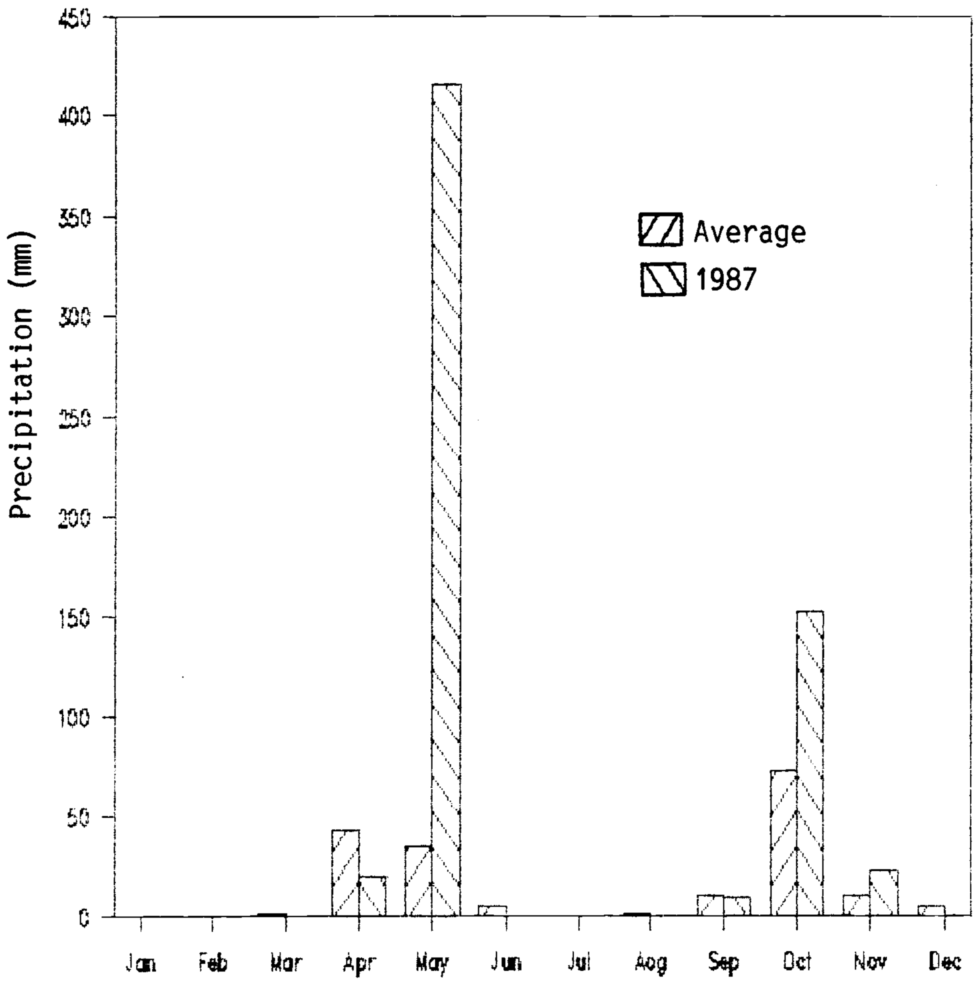

Figure 3. Five year average monthly precipitation (1982 to 1986) and 1987 precipitation by months for Belet-Weyn (see Fig. 1)

Morphology

Gross morphology of C. edulis was qualitatively described in the field. Stem branching, plant shape, plant height, leaf orientation, root distribution, and location of vegetative and floral buds were observed and described.

Phenology

Plants of C. edulis were tagged in different stands for phenological observation. Forty (40) plants were tagged, ten in each of four stands, at the end of dry season. Measurements began before the growing season while plants were dormant and were continued through the growing season into the beginning of the next dry season. Observations were made at intervals ranging from 1 to 4 weeks. Developmental phases recorded were 1) Dormant, 2) Bud break (vegetative and floral), 3) Leaf; expansion, senescence and fall. 4) Reproductive: anthesis, fruiting, fruit maturation and seed dispersal.

Soils

Soils associated with the large and small-leaf C. edulis stands were studied. One soil pit was dug in the interspace area between shrubs near the middle of stands containing each of the C. edulis growth forms. A soil profile was described from a stand of small-leaf C. edulis 6.0 km from the small village "Teydan" which is 94 km northeast of Bulo Burte. The second profile was described between shrubs in a stand of large-leaf C. edulis at "Kukayle" 45 km northeast of Bulo Burte. Profiles were described following U.S.Soil Conservation Service procedures (U.S.Department of Agriculture 1975). Soil samples were collected from three different depths in each profile. Chemical and physical analysis of the soil samples were completed at the Faculty of Agriculture Laboratory, Somali National University Mogadishu. Texture was determined using sieves, Day (1965). Cation exchange capacity was determined using methods by Polemio and Rhoades (1977). Organic matter was measured using procedures by Nelson and Sommers (1982). Carbonates were determined using methods by Peterson et al. (1966). Exchangeable cations were determined using procedures of Thomas (1982) and pH was determined using methods of Brown (1943).

Density

Density of C. edulis was measured in different range conditions classes as classified by Kuchar et al. (1985) in which condition is based on abundance and vigor of C. edulis. Measurements were made only on the large-leaf form, since it is the dominant growth-form occurring in the study area. Density was determined using the point centered quarter method (Drow 1944). Sample locations were selected randomly in each range condition class. At each location using line transects, points were chosen systematically at 30 meter intervals. In each of excellent and good conditions (Kuchar et al. 1985) 60 points were chosen, and from poor conditions 38 points were chosen. At each point, distances were measured from that point to the nearest C. edulis plant in each of four quadrants. Density was calculated from these data for different range conditions using the formula: Density = 1/MA, where MA is the mean area per plant in m^2 and equals d^2 and d is the mean distance of the 4 plants from the point.

Data were analyzed using ANOVA at the $P<0.05$ level and means were separated using LSD to determine significant differences exist among condition classes (Steele, and Torrie. 1980).

Available Forage Production

Dimension analysis was used to determine available forage production (Whittaker and Woodwell 1968) from 161 plants selected randomly from different locations within the study area. Each plant was measured to the nearest centimeter for height (H), maximum crown diameter (D1), and crown diameter (D2) which was at right angles to D1. Each of the 161 plants were divided into four symmetrical horizontal quarters. Available forage (leaves and twigs) from the last growing season and the current year were harvested from one randomly chosen quarter. Harvested material was dried in a forced air oven for 48 hours at 60^{o} C and weighed to the nearest 0.1 gram.

Crown cover was calculated for each plant by the formula 3.14/4(D1)(D2). Volume was calculated for each plant using formula 3.14/4(D1)(D2)H. Available forage production per plant was calculated by multiplying harvested material by four and available forage per unit area was calculated from density data. Measurements were used to predict available forage per unit area using equations obtained from the regression of forage weight and the dimensional parameters in this section and density values.

Available forage production was regressed on height, crown cover, and canopy volume using linear and multiple regression. Square root transformations of available forage were used to improve regression equations. The best regression model was used to predict available production per unit area using data from the point center quarter method. To test the significance of the F value for the correlation a probability value of ($P<0.05$) was calculated throughout the analysis (Steele and Torrie 1980).

Response to Grazing

Classes of hedging and sprouting were used to measure the effect of browsing on sprouting. Plants were placed into one of three classes of hedging: light, medium and heavy. Plants that had lost all of their leaves at the top were classified as heavily hedged. Those that were lightly browsed were classified as lightly hedged and medium hedged plants showed moderate amount of browsing. Basal sprouting classes used were light, medium and heavy, and were related to the abundance of sprouts at the base. Regression analysis was used to measure correlation between hedging and sprouting (Steele and Toorie 1980).

Forage Quality

Five samples of leaves and twigs of C. edulis were collected from each of the two growth forms at five different phenological stages. The phenological stages included vegetative, flowering, fruiting, early dormant and late dormant phases of growth. Samples were weighted before and after oven drying a 60^{o} C for 48 hours, to determine percent moisture. Samples were then ground through a 0.2 mm^2 sieve. Crude protein was analyzed following the Copper Catalyst Kjeldahl Micro Method (A.O.A.C, 1984) and calcium and phosphorus were determined according the A.O.A.C. method (1975). In vitro Dry Matter Digestibility was analyzed using the modified in vitro DMD method of Tilley and Terry (1963). Acid detergent fiber and lignin were determined by the permanganate technique of Van Soest and Wine (1968).

Analyses were conducted at Oregon State University, Corvallis. Two-way analysis of variance (Ostel and Mensing 1975) and LSD mean separation was used to determine significant differences in chemical composition among phenological stages and between growth forms (Steele and Torrie 1980).

RESULTS

Morphology

In 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. C. edulis usually grows to 1.4 m height but may grow to 2.1 m in some locations.

Leaves for both the small and large-leaf forms are 2-8 cm long pinnately compound, with 2-4 pairs of leaflets. Leaflets are 3.0-3.6 cm long and 1.3-2.0 cm wide for the large-leaf form. The small-leaf form has leaflets that are 1.7-2.3 cm long and 0.43-1.0 cm wide. Leaflet length width ratios are 0.20 for the large-leaf form and 0.28 for the small-leaf form. Leaflets have purple to orange red glands on margins and lower side of the leaves. Newer twigs and stems are also covered with glands.

Floral and vegetative auxiliary buds develop apically and also laterally from branchlets. Flowers develop over the surface of the entire plant crown.

The root system of C. edulis is dominated by a central taproot which reaches to below 2 m in depth. Lateral roots form 10 cm below the soil surface and spread horizontally a distance of 2.3 m. Lateral root development was found again at a depth of 40 cm. These lateral roots rebranch at intervals forming a profuse network of medium and fine roots.

Small-leaf and large-leaf forms of C. edulis generally do not grow in mixed stands, though mixed stands may occur. The small-leaf form has pods that contain a large single seed. The large-leaf form has pods that contain more than one seed, however, the seeds are compressed laterally and are smaller in size than in the small-leaf form. Nomads claim that the small-leaf form produces sweeter seeds than the large-leaf form. Locally the small-leaf is called (Suuleey) and large-leaf form is called (Muqleey).

Phenology

Phenological phases observed during the time of this research were given numerical codes (Table 1). Phenological development for C. edulis included nine for vegetative phases and nine for reproductive phases.

On April 22, 1987 leaflets were curled inward from the tip (Fig. 4). They were dehydrated but were green, hard and leathery. Vegetative and floral buds initiated the previous rainy season continued to develop. Fruits which initiated their development during the previous rainy season were immature and were in diapause.

On May 3, a few days after the first rain, leaflets

Table 1. Phenological observations of <u>C. edulis</u> from April to September.

Codes	Phenological phases
1	Leaves are curled
2	Leaves are uncurled
3	Bud break
4	Early leaf development
5	Mid leaf development
6	Late leaf development
7	Leaf development stops
8	New bud formation
9	Leaves are curly (revert to 1)
10	Floral buds develop
11	Early flowering
12	Mid flowering
13	Late flowering
14	Flowers start to develop into fruits
15	Seed development stops (diapause)
16	Seeds are in diapause (from last season)
17	Seeds develop fully
18	Seeds mature

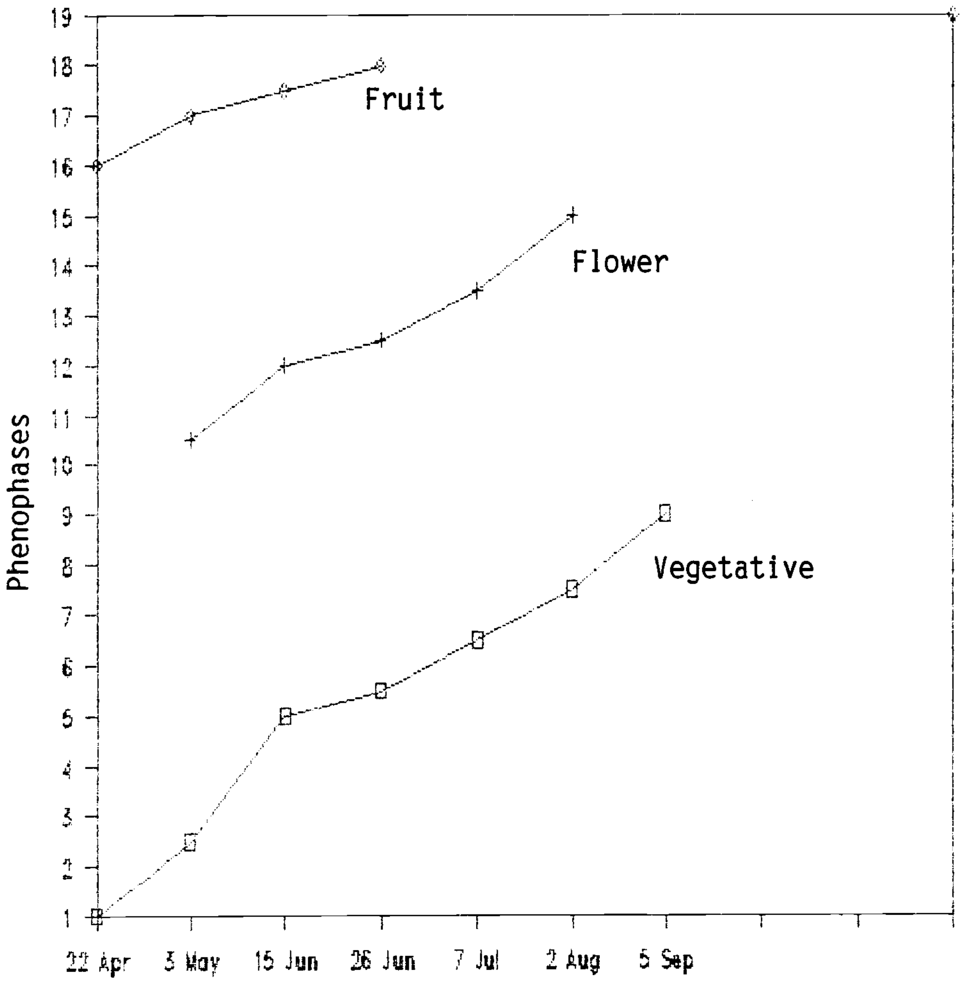

Figure 4. Vegetative and reproductive development of C. edulis during months of April through September by phenological phases (Table 1)

had opened and regained their turgidity. By June 15, new leaves were about one-half developed, flowers were in early to mid development and fruits were completing their development.

On June 26, leaves were in their late development stages and new fruits were in their early stages of developments. Fruits from the preceding rainy season of 1986 had matured and had all been harvested.

By July 7, leaf development had stopped and new buds were forming. Fruit development was slowing rapidly. On August 2, the plants had ceased their vegetative development, and newly formed fruits went into diapause. By September 5, leaflets were again curled and appeared dehydrated.

Soils

Climate is expected to be similar between stands of the large and small-leaf forms of C. edulis, however soils associated with the large and small-leaf forms of C. edulis appear to be different. The small-leaf form grows on Renic Aridic Paleoustalfa and large-leaf form grows on Typic Ustipsmments Arenosols (Appendices 1 and 2). Renic Aricic Paleoustalfa were red loamy sand with a neutral to mild alkaline reaction. The large-leaf form grows on yellowish red sandy soils with a moderate alkaline reaction (Table 2).

Table 2. Chemical analysis of soils from small and large leaf stands of *C. edulis*.
T,1,2,3= samples from Teydan (small-leaf) by depth, K,1,2= samples from Kukayle (large-leaf form) by depth, *= not detectable, 1= Electrical conductivity of soil, O.M.= Organic matter, C.S.= course sand. F.S.= fine sand.

						Exchangeable Cation (Cmol/100g.soil)				Texture			
Sample	depth cm	pH	Ecs[1]	CaCo3%	O.M.%	Na	K	Ca	Mg	C.S.	F.S.	Silt	clay
small-leaf													
T1	15	7.37	4.26	nd*	0.02	4.26	1.18	20.2	8.42	79.8	5.4	0.00	14.8
T2	65	7.57	3.26	nd	0.23	6.96	1.58	38.4	11.75	71.6	11.2	1.4	15.8
T3	130	7.83	1.58	nd	0.23	4.48	0.95	22.2	1.75	71.9	10.4	1.2	16.5
large-leaf													
K1	15	8.06	0.18	0.00	0.20	3.35	0.87	13.2	1.61	88.2	4.4	0.00	7.4
K2	130	8.2	0.16	0.00	0.20	2.26	0.51	9.1	0.00	89.3	5.3	0.00	5.4

Electrical conductivity was higher in soils associated with the small-leaf form than that of the large- leaf form. Calcium and magnesium were higher in soils associated with the small-leaf form. Cation exchange capacity was lower and pH was higher in soils associated with the large-leaf form. Soils associated with small-leaf form contained higher clay content than soils associated with the large-leaf form. There was no silt in the soils associated with the large-leaf form and it had fewer fine sand particles, but was higher in course sand particles than soils associated with the small-leaf form.

Density

Densities of C. edulis in different range conditions ranged from 162 plants/ha in poor sites,to 226 plants/ha in good conditions to 319 plants/ha on sites in excellent condition. All the poor C. edulis stands were near to permanent water points and villages where livestock and people density were high. Excellent C. edulis stands were at least 30 km away from the nearest water point. Plant height was least in low density stands (Table 3). Crown cover per plant and volume per plant tended to decreased as density increased.

Table 3 Density of C. edulis and some related plant morphological aspects such as height, cover and volume.

Density Plant/ha	Height kg/ha	Cover m^2	Volume m^3
162a	0.92	2.88	3.74
226ab	1.23	1.89	2.71
319b	1.26	1.77	2.53

Different letters in a column indicated significance difference ($P<0.05$)

Available Forage production

Results of regression analysis of height, crown cover and crown volume on total available production per plant are shown in (Table 4). Height was least correlated with available forage production compared to crown cover and crown volume. Although crown cover had the highest correlation coefficient (Fig. 5), there is not much difference between crown cover and volume. The correlation coefficient between height and total available forage was improved after available forage was transformed to the power of 0.50.

For multiple regression analysis correlation coefficients were greatest for height and crown cover, followed by crown cover and crown volume and least for height crown volume. Total available forage production of C. edulis/ha for the different densities were calculated

Table 4. Regression of available forage production per plant on height, crown cover, and crown volume, (Forage= Available forage) n= 161 plants.

Parameter	R^2	b0	b1	b2	Level of signif.
Height(H)(m)	.56	-1	2.1		P<.05
Forage $(kg/Plant)^{0.5}$	.64	.14	.82		P<.05
Cover m^2	.71	.50	.52		P<.05
Volume m^3	.68	.75	.26		P<.05
Height + Cover	.73	-.07	.61	.41	P<.05
Height + Volume	.70	.19	.57	.20	P<.05
Cover + Volume	.71	.52	.49	.02	P<.05

Table 5. Density of C. edulis and estimation of available forage per unit area and per plant.

Density Plant/ha	St.err of mean Density	Available Forage kg/ha	Forage kg/plant
162a	0.63	325.62	1.99a
226ab	0.37	334.48	1.48a
319b	0.33	452.98	1.42a

Different letters in column indicate significance difference (P<0.05)

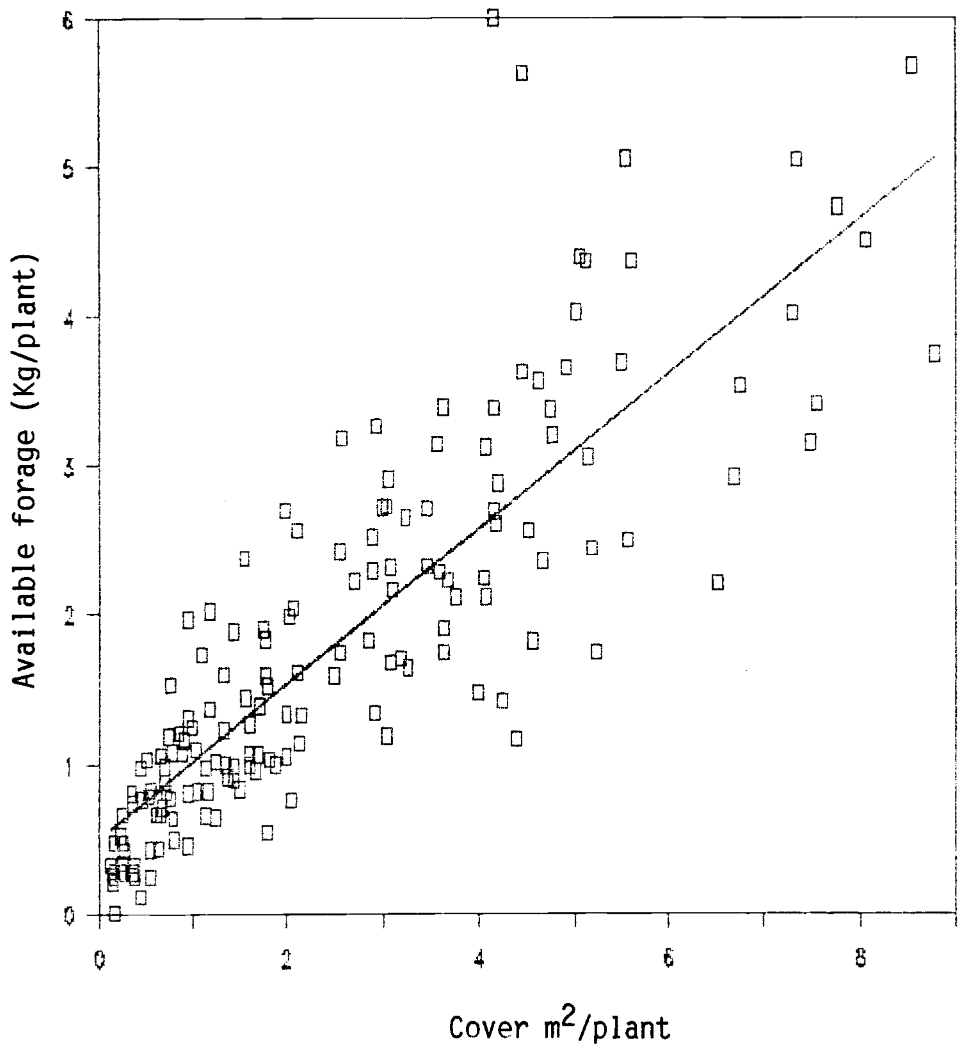

Figure 5. Scattered plot and fitted regression line of available forage per plant and crown cover $Y= 0.50+0.52X$ $R^2= 0.71$

using the regression model [Available forage =0.50 + 0.52(cover)]. Available forage ranged from 326 kg/ha for poor conditions to 453 kg/ha for excellent condition sites (Table 5). Available forage production per plant for different densities were not significantly different and ranged from 1.42 kg/plant, to 1.99 kg/plant (Table 5).

Response to grazing

Cordeauxia edulis appears to be resistant to browsing because of its resprouting ability. Plants heavily browsed tended to resprout profusely from the base (Fig. 6). There was a difference in sprouting from the base among the different hedging classes. Heighest sprouting appeared from under plants that were heavily hedged, while plants that were hedged to light and medium intensity sprouted lightly and medium, respectively. Although a difference in sprouting occurred there were no significant difference in available forage production per plant between the different hedging classes. Forage production per plant ranged from 1.03 kg to 1.56 kg.

Forage Quality

Moisture Content

Leaf and twig moisture content is low in *C. edulis* even during the middle of growing season when plants have their highest moisture content. Collected materials

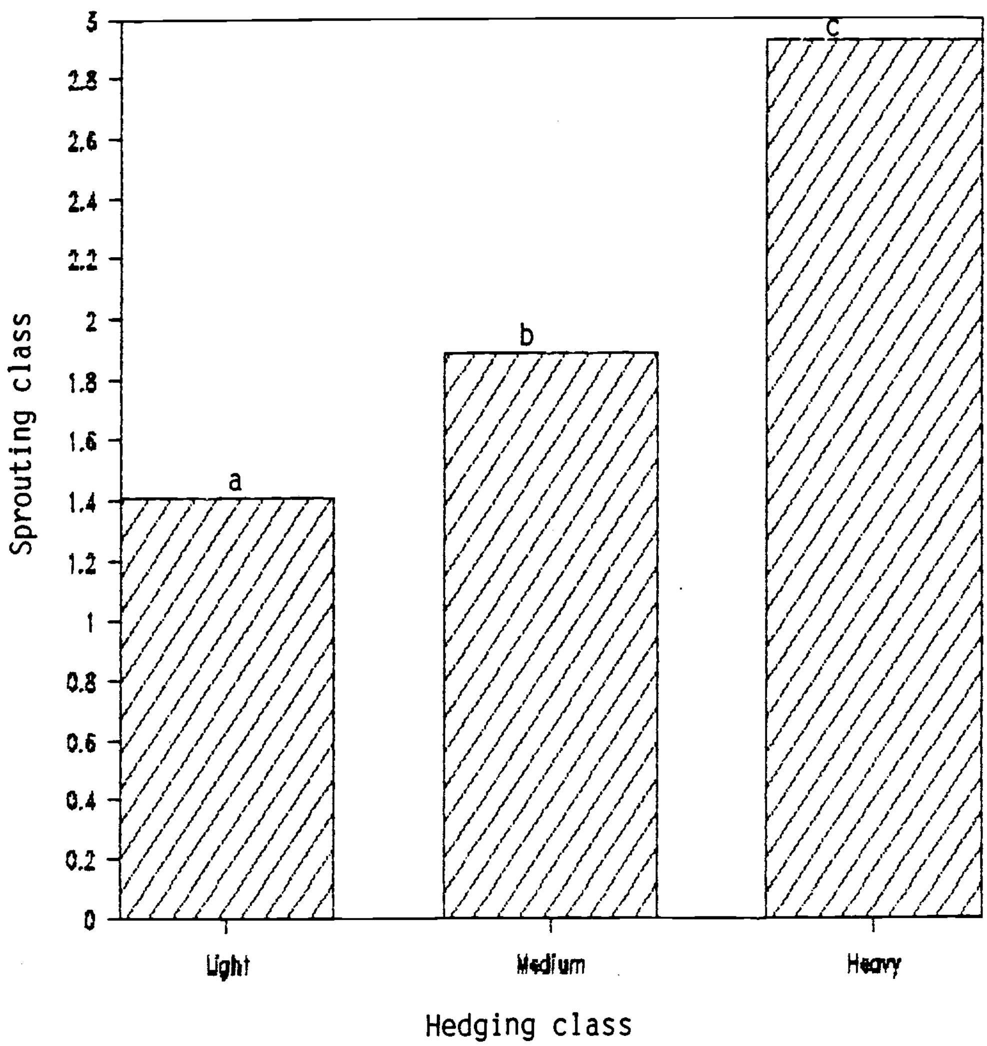

Figure 6. Relationship of sprouting abundance to sevirity of hedging. $R^2 = 0.58$ $Y = 0.51+0.78X$ where X= hedging. Different letters indicate significance difference of sprouting at ($P<0.05$)

contained less than 55% moisture when plant has its highest moisture content (Table 6, Fig. 7). There was significant difference in moisture content between the growth and dormant conditions. Moisture content declined to less than 30% during the dry season. There was no significant difference in moisture content between the two growth forms of C. edulis .

Crude Protein

Cordeauxia edulis forage is high in crude protein (% N X 6.25). There was a significant difference in crude protein at different phenological stages (Table 6, Fig. 8). Crude protein increased slightly from vegetative to the flowering stage in the small-leaf form. After flowering, protein content tended to decrease slightly as the dry season advanced. The plant has its highest protein during flowering with a value of 13.2% (average of the two forms). Crude protein content was 11.0% (average of the two forms) during the late dormant period. There was no significant difference in protein content between the two forms of C. edulis (Table 6). However, the large- leaf form appears to have a slightly higher protein content in the vegetative phase while the small-leaf form appears higher in protein in the flowering phase.

Calcium

Calcium content in C. edulis is within the levels of requirements for growing animal (National Research

Table 6. Some nutritive aspects of C. edulis at different phenological stages. H_2O= moisture, CP= crude protein, Ca=calcium, P= phosphorus, SL= small-leaf form, LL= large-leaf form.

Phenology	H_2O		CP%		Ca%		P%	
	SL	LL	SL	LL	SL	LL	SL	LL
Veget.	53.9b	54.1b	10.7a	12.9b	1.3*	1.0*	0.17a	0.17a
Flow.	51.3b	53.0b	14.2b	12.2a	1.2*	0.9*	0.22b	0.19a
Fruit	50.7b	51.3b	10.5a	11.7a	1.3*	1.2*	0.14ac	0.17ac
E.Dormt	29.5a	31.2a	11.8a	11.8a	1.4*	1.3*	0.15c	0.14c
L.Dormt	26.9a	29.3a	11.2a	10.7a	1.5*	1.0*	0.13d	0.11d

Different letters in column indicate significance different among phenological stages ($P<0.05$)

* Difference between growth forms was significant ($P<0.05$)1984).

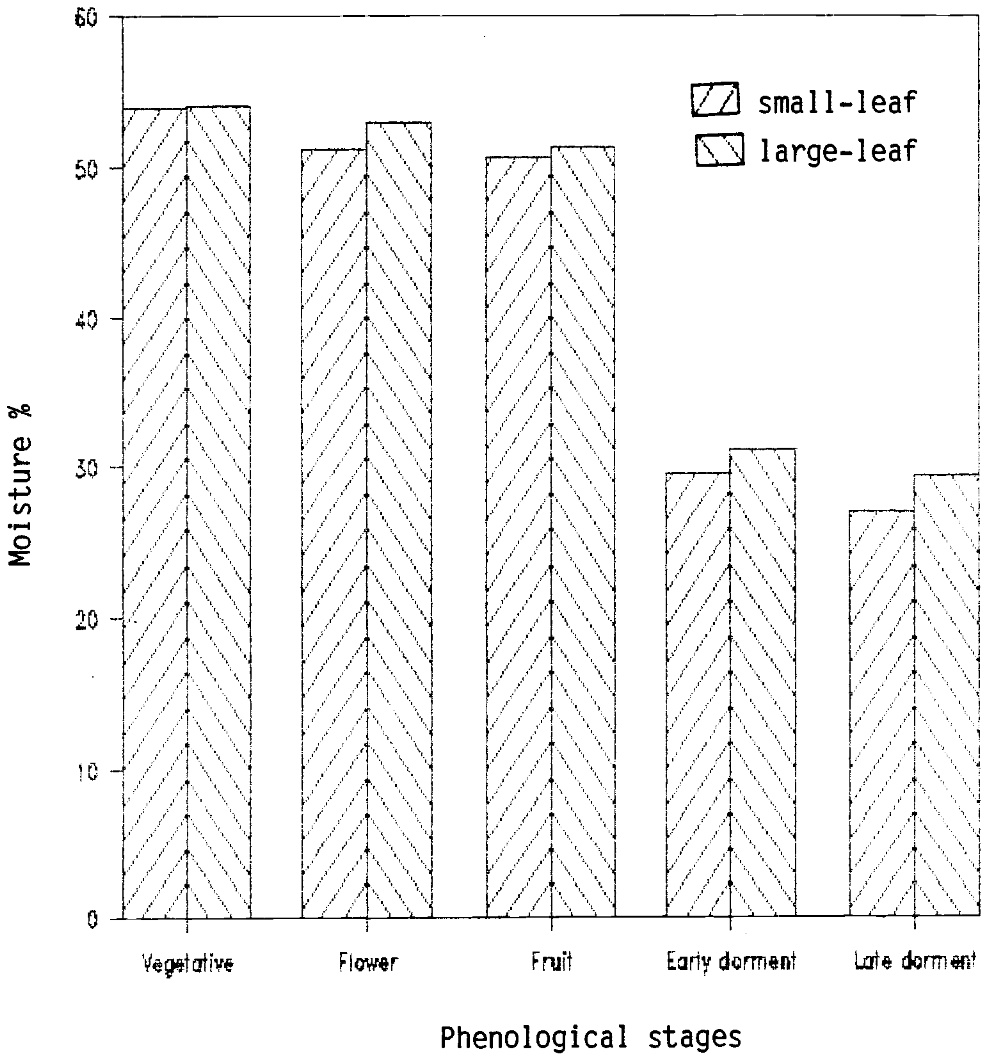

Figure 7. Percent moisture in small and large-leaf forms OF C.edulis at different phenological stages

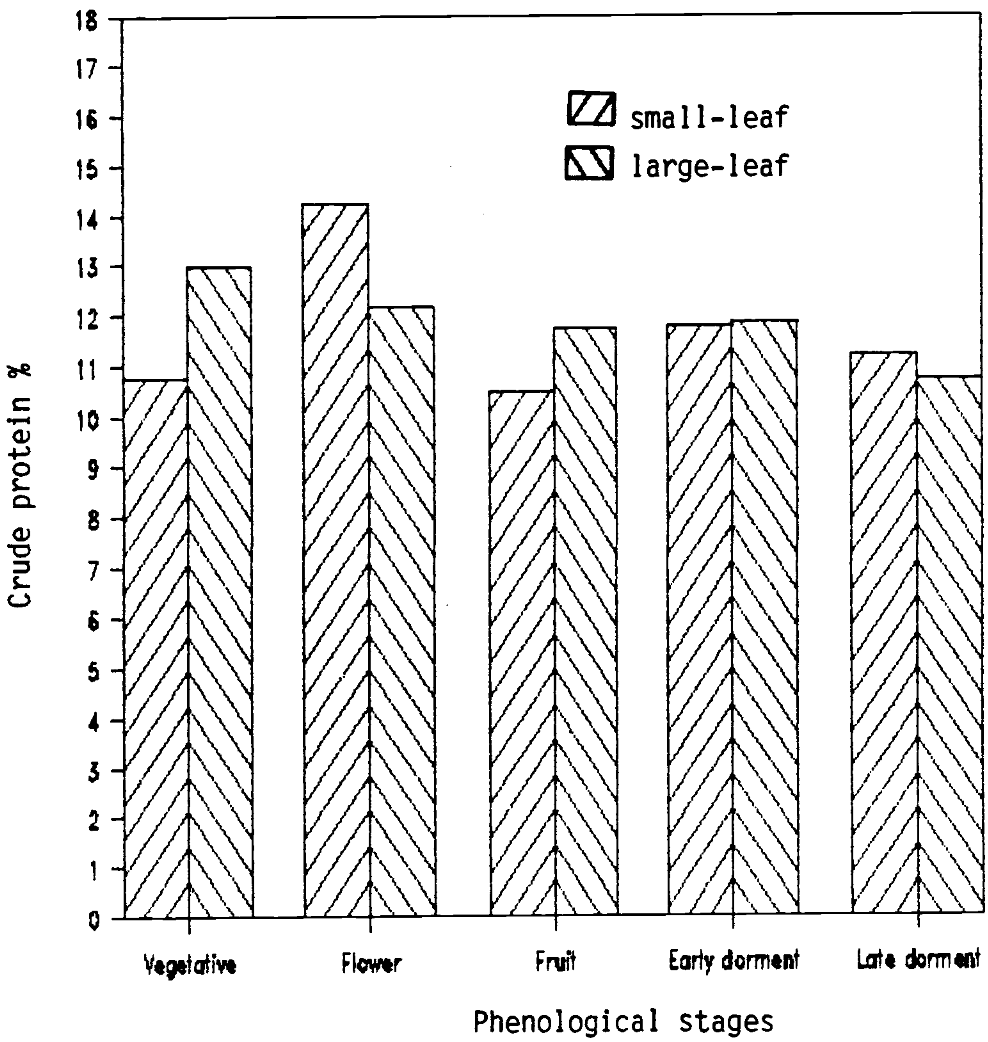

Figure 8. Crude protein content of small and large-leaf forms of C. edulis at different phenological stages.

Council 1984). There was a significant difference in calcium between the two forms. The small-leaf form had higher calcium in all phenological stages than the large-leaf form (Table 6, Fig. 9), however there was no significant difference in calcium between phenological stages for either forms. Calcium was 1.4% and 1.3% (average of the two forms) during early and late dormancy respectively.

Phosphorus

There was a significant difference in percent phosphorus among the different phenological stages of C. edulis. C. edulis has its highest phosphorus content at flowering, and then decreases gradually after that, with the lowest content in late dormancy. There is no significant difference in percent phosphorus between the two growth forms of C. edulis. however, the small-leaf form has higher phosphorus in the flowering stages while the large-leaf form has the highest phosphorus content from vegetative through fruiting phases (Table 6, Fig. 10).

In Vitro Dry Matter Digestibility

In vitro dry matter digestibility (DMD) is low for C. edulis. There was no significant difference in DMD between the two growth forms (Table 7, Fig. 11). In vitro DMD% was highest for both growth forms at the vegetative phases (Table 7).

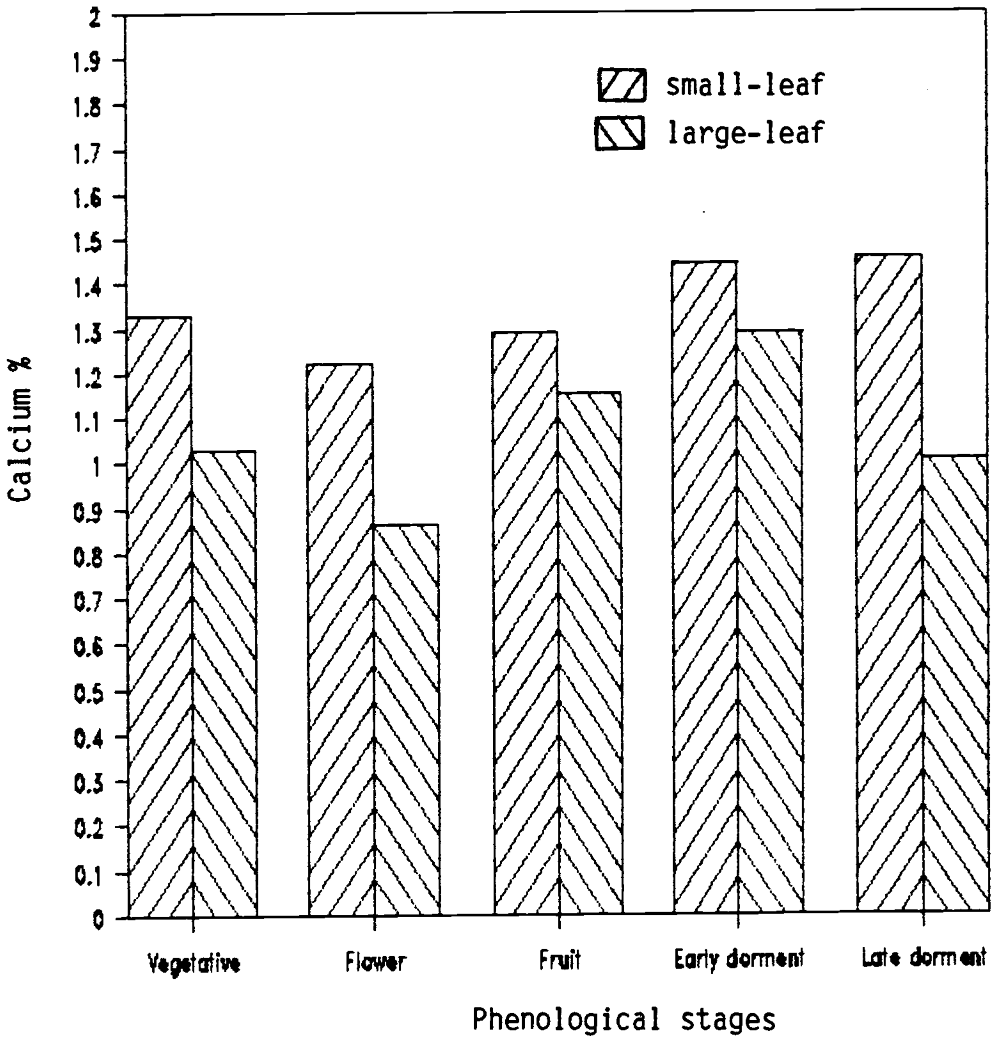

Figure 9. Percent calcium of small and large-leaf forms of
C. edulis at different phenological stages

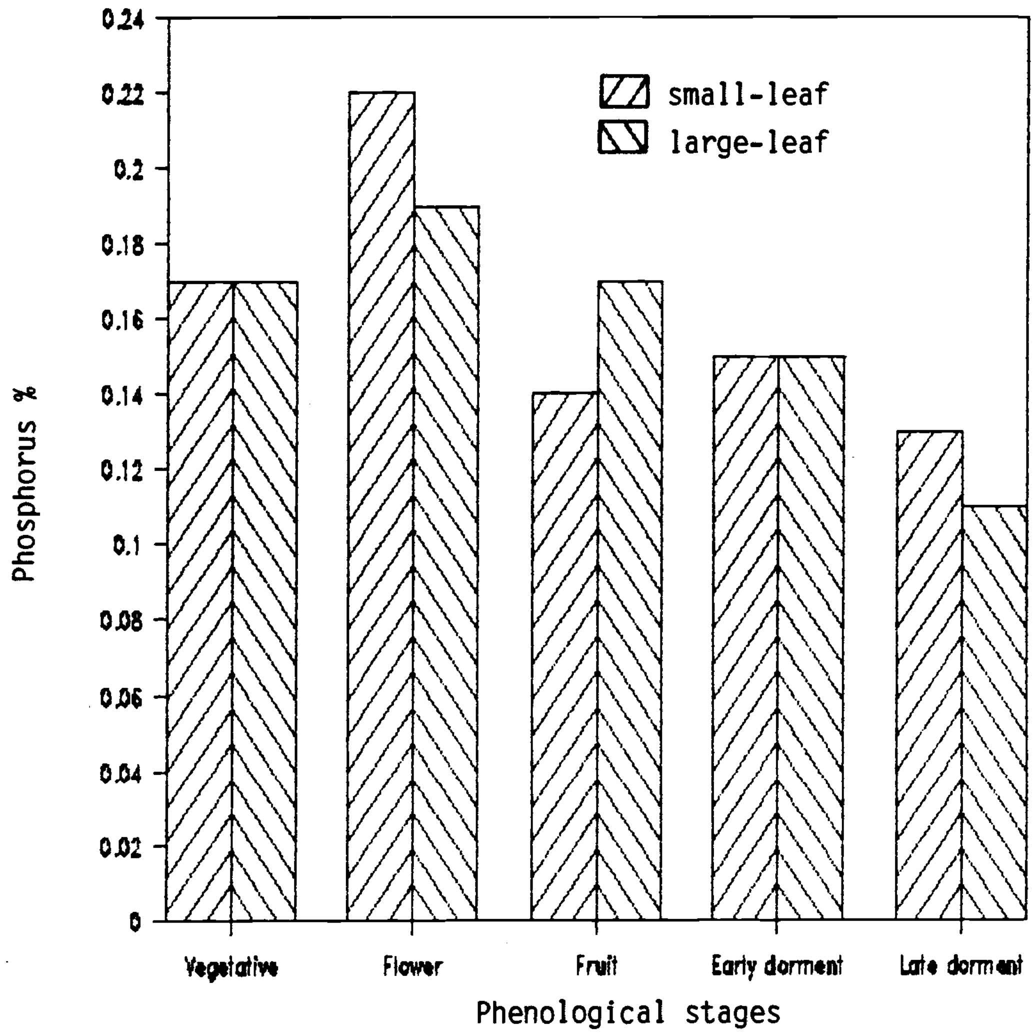

Figure 10. Percent phosphorus in small and large-leaf forms of C. edulis at different phenological stages.

Table 7. In vitro dry matter digestibility and related factors in C. edulis at different phenological stages. DMD= Dry matter digestibility, Lignin and ADF= Acid detergent fiber, SL= Small-leaf form, LL= Large-leaf form.

Phenology	DMD%		Lignin%		ADF%	
	SL	LL	SL	LL	SL	LL
Vegetative	34.6a	39.8a	9.8*a	7.9*a	34.4a	28.9a
Flowering	31.9b	27.9b	9.0*a	9.8*a	32.6a	37.9b
Fruiting	28.8b	31.1b	11.2*b	9.7*a	38.3b	35.8b
Early dormant	30.7b	29.9b	11.4*b	11.1*b	37.7b	37.3b
Late dormant	27.2b	32.7b	10.5*b	10.2*b	28.8a	32.1a

Different letters in column indicate significant different among phenological stages (P<0.05)

* Difference between growth forms was significant (P<0.05)

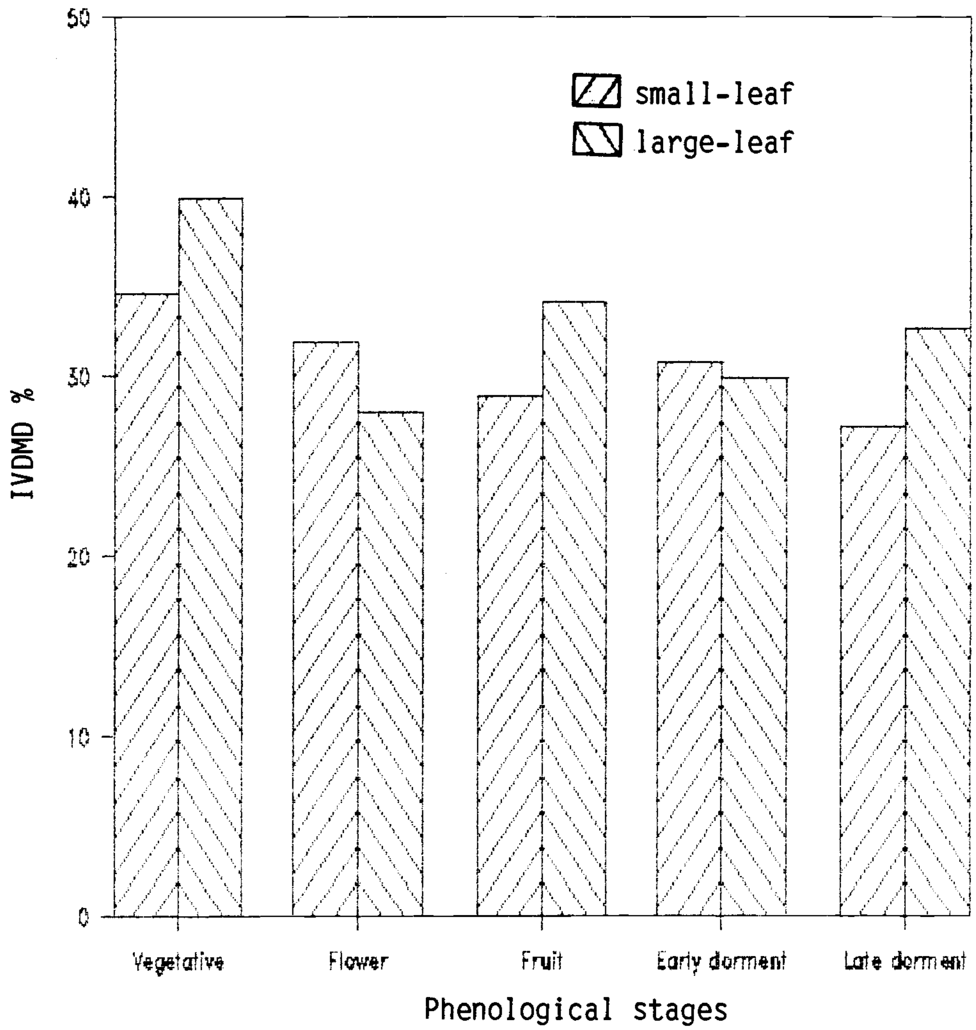

Figure 11. *In vitro* dry matter digestibility (IVDMD) of small and large-leaf forms of *C. edulis* at different phenological stages.

Lignin

Percent lignin in the small-leaf form was significantly higher than in the large-leaf form at most phenological stages. The small-leaf form had higher lignin content at flowering (Table 7, Fig. 12). Lignin content varies to some extent with phenological stage. Highest lignin content was reached by fruiting, or early dormant stages of development.

Acid Detergent Fiber

Acid detergent fiber (ADF) content ranged from 28.8% to 38.3% for C. edulis. There was a significant difference in ADF content among the different phenological stages with highest ADF occurring from flowering through early dormancy. The lowest ADF was found at vegetative and late dormant stages with values of 31.67% and 30.48%, respectively (average of the two forms) (Table 7). ADF did not differ significantly between the two growth forms, however the small-leaf form tends to have higher ADF at vegetative and fruiting phases (Fig. 12), while the large-leaf growth form appeared to have higher ADF in the flowering and late dormant stages.

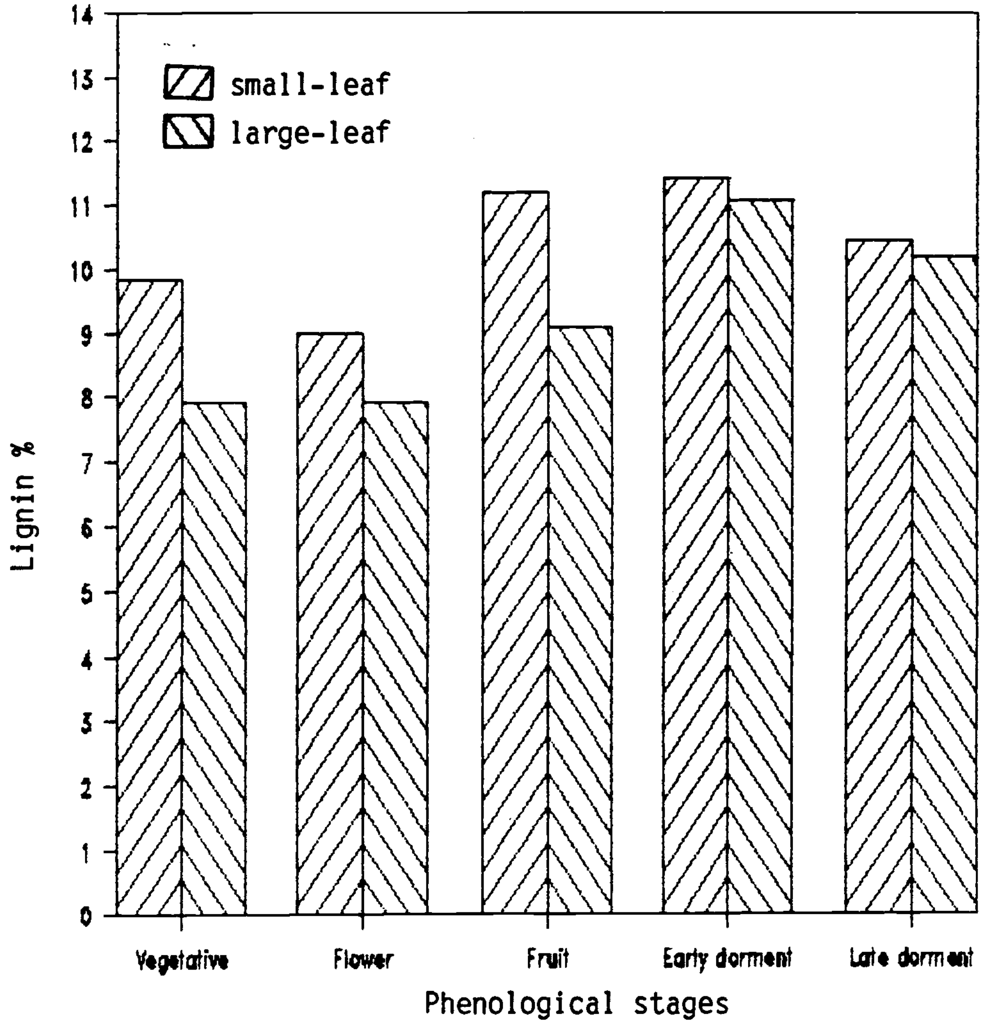

Figure 12. Percent lignin content of small and large-leaf forms of C. edulis at different phenological stages

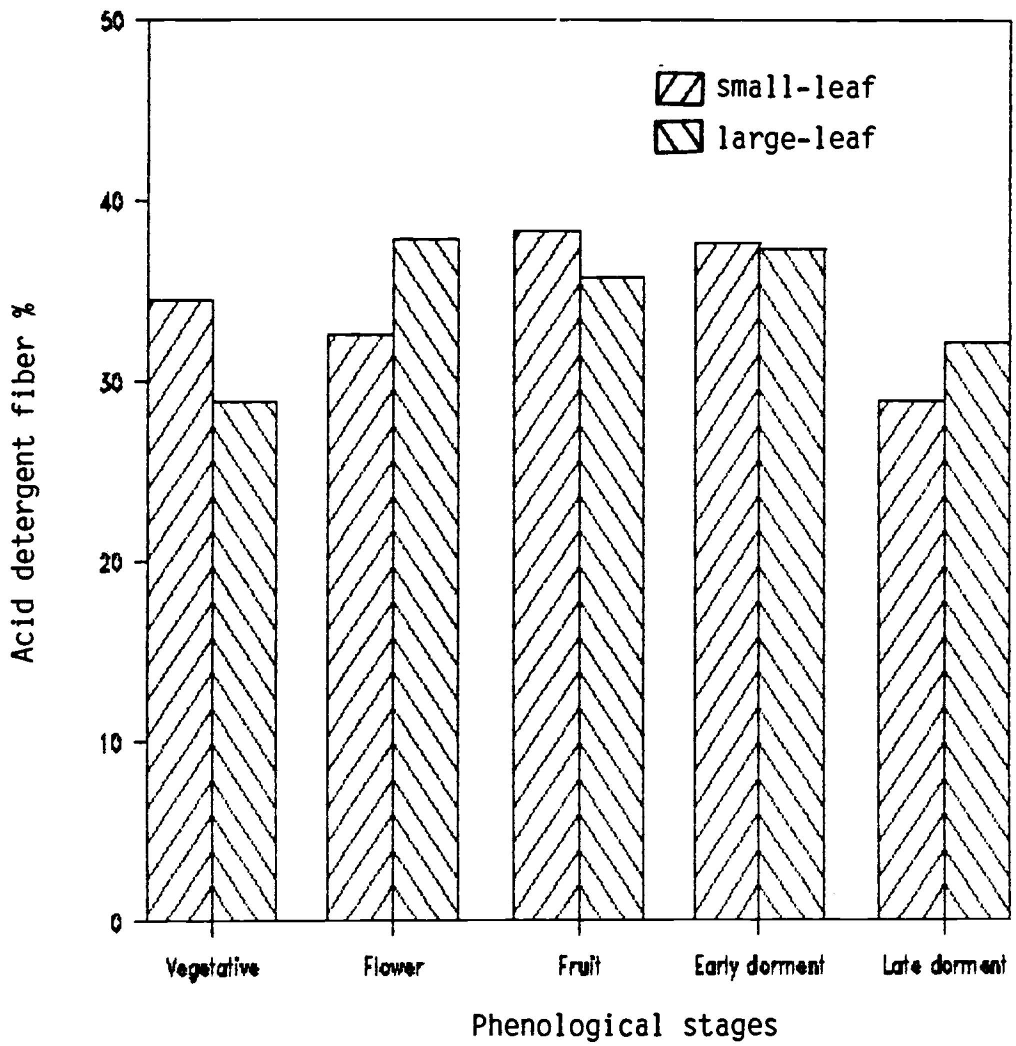

Figure 13. Percent acid detergent fiber in small and large-leaf forms of C. edulis at different phenological stages

DISCUSSION AND CONCLUSIONS

Large-leaf and small-leaf C. edulis have similar general morphological characteristics. They both reach the same height and are a multi-stemmed thick crowned shrubs. Differences found include leaflet size, fruit and seed form and stem diameter. Small-leaf forms have leaflets that are 1.7-2.3 cm long and 0.4-1 cm wide while large-leaf form have leaflets that are 3-3.6 cm long and 1.3-2 cm wide. The small-leaf form may have an advantage in responding better to stress in plant water relations, through increased air flowing between the leaflets which could result in greater cooling. Small-leaf forms also have smaller stem diameter size as compared to the large-leaf form.

Large-leaf forms have pods that contain more than one seed but of a smaller size, while the small-leaf form produces pods that contain a single large seed. Seeds of small-leaf form may be higher in sugar, since the nomads prefer them, claiming they have a sweeter taste.

Plants of both growth forms have deep taproots and widespread laterals at several depths in the soil profile. The rooting system may help explain why C. edulis is drought resistant, since it can presumably acquire nutrients from a rather large volume of soil.

At the onset of the rainy season C. edulis starts new vegetative and floral development as well as continuing vegetative and reproductive development initiated the previous rainy season. After flowers develop to the first stages of fruit formation, fruits go into a diapause 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. These observations verify and expand on the report of Brill and Mulas (1939). 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.

Unlike most plants, seeds of this species 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. According to the nomads, seeds do not require water to germinate immediately after harvest, and will germinate in storage if not immediately dried in the sun first. According to a local farmer, a 30-day-old seedling had a taproot that was over 40 cm deep. Therefore C. edulis may be able to germinate and establish during the rainy season when there is enough moisture in the soil.

Brill and Mulas (1939) mentioned that sometimes plants may flower a few days before the rain and the fruit may mature within the same growing season. It may be possible for plants to take up water from the atmosphere through the leaf surface (Wallace and Romney 1972). Leaves of C. edulis contain less than 30% water in the dry season, so that leaf water potential may be such that moisture can be extracted from the atmosphere during the humid period prior to the rainy season. This phenomenon of flowering before the rainy season has been frequently observed in Acacias in the area.

Leaves start to curl as soil moisture content drops. In late dry season, leaves are curled even though they remain green. At the onset of the first rain, leaves uncurl and regain their turgidity. This may be one of several adaptative traits allowing C. edulis to survive under stressful environments. Changing leaf size and shape may reduce the amount of solar energy absorbed through selfimposed shading and thereby reduce water loss (Mooney et al. 1977). This phenomenon is common for grasses and results in a reduction of leaf area which reduces energy load on the plant and in turn may effectively reduce transpiration losses and increase water use efficiency (Oppenheimer 1960, and Johns 1978).

Leaves of C. edulis have a leathery glandular epidermis which may assist plant in reduce leaf absorbance of energy by increasing surface reflectance. Exposed surface area of curled leaves is less than that of a normal leaf, effectively reducing leaf area exposed to direct sun light. Stomatal location, abundance and size remain unknown, but since the leaves curl inward, stomates are likely to be on the upper surface and protected from direct radiation. Physiological response of the stomata would assist in understanding how this plant survives the drought period. These factors plus other unknowns may make C. edulis a drought resistant plant.

Limited soil analysis indicates that the small-leaf form of C. edulis appears to grow on sandy loam soils while the large-leaf form grows on sandy soils. There were also chemical property differences in these soils such as pH, exchangeable cations, and electrical conductivity. Nutrients and moisture availability may be different. Small-leaf C. edulis may prefer a more mineral soil compared to large-leaf form. Both the large and small-leaf forms grow in areas where the general climatic factors appear to be similar and precipitation and topography are not different. They also grow in association with similar plant species, so edaphic factors may be of greater importance in separating the two forms.

Density of C. edulis decreases with proximity to permanent water points and conversely increases gradually with distance from villages and water points, also noted by Kuchar et al. (1985). Height of plants was directly proportional to density, while crown cover and volume were inversely proportional to density. Height was greatest for plants with high density, while crown cover and volume per plant was least. Plants heavily browsed near water points were reduced in height but were expanding laterally by the formation of new branches. Brill and Mulas (1939) and Kuchar et al. (1985) noted that plants were less vigorous near villages and water points as was found in this research.

According to Brill and Mulas (1939) C. edulis is a long-lived plant and may live more than 200 years. No investigations of the age of C. edulis were made in this study, but dying stems were found within the central part of the canopy and new stems were developing at the base, as Brill and Mulas (1939) reported.

In the study area few young plants were observed, indicating that little regeneration has occurred for the last few decades. Since C. edulis is an evergreen and a dry season forage, it is heavily used by livestock. Additionally, people use it for its seeds. These two factors undoubtedly contribute to its reduction in density and eliminate establishment of new individuals and regeneration of the plant. This may explain why the distribution of C. edulis has been declining and why it is losing its density near permanent water points.

Available forage production per plant may be estimated from regression models. The model that had the lowest standard error and highest coefficient of significance with a good R^2 was chosen, because R^2 by itself does not indicate whether the model best predicts forage production. The model $Y= 0.5 +0.52X$ where X equals cover in square m, with an R^2 of 0.71, has the smallest standard error. All its coefficients are significant and it appears to be the best predictor of forage production.

Predicted available forage per plant was negatively correlated with density and predicted available production per unit area was positively correlated with density. This corresponds to the relationship found where cover per plant decreases as density per unit area increases. Forage was harvested during the growing season while plants were in vegetative growth. This study was conducted after a long drought in which plants had been overgrazed by livestock and nomads were harvesting plant material and hauling it to different locations for feeding. Measurements were made on available forage and not current year's growth, therefore the figures probably overestimate current years production.

Sprouting varied in response to hedging class. A similar relation was found by Brill and Mulas (1939). <u>C. edulis</u> appears resistant to grazing due its sprouting characteristics but in the long run it may die.

Kuchar et al. (1985) stated that fire is a threat to <u>C. edulis</u>, although the ability of fire to kill a plant depends on the fire intensity and other environmental factors. However, fires are relatively small in extent and frequency in occurrence in these environments because of inadequate fuel to carry a fire.

Forage production per plant did not vary with different hedging classes. This may be because the study was conducted after a five year drought during which precipitation was about 50 mm for each year during the early rain as compared to an average of 300 mm. Available forage production may have been moderated out by the differential effects of drought on plant size and form.

Crude protein content was high during vegetative and flowering for the large-leaf form while crude protein was high for the small-leaf form during flowering, but late in the season crude protein decreases for both growth forms. Both the small and large-leaf forms have higher crude protein at all times than the minimum required for cattle (NAS-NRC 1968).

Soils in which C. edulis grows are low in organic matter so the plant may be fixing nitrogen from the atmosphere, since it is in the family Leguminoseae.

The mineral requirement for normal growth and maintenance of cattle is 0.21% calcium and 0.16% phosphorus (NAS-NRC 1968). Calcium concentration was high for both growth forms although the small-leaf form had higher calcium content at all phenological stages. Higher content of ca in soils associated with the small-leaf form may have promoted high ca in the plant. Phosphorus was least in C. edulis during the growing season and was below (0.16) during dry season, less than that required for normal growth of cattle.

The nutritive values reported above appear adequate, but since C. edulis is mainly utilized by camels, their nutrient requirements may be higher or lower than those for cattle.

In vitro DMD of the leathery leaves and twigs of C. edulis is low. This may be due to a high content of Acid Detergent Fiber. In vitro digestion may be different from in vivo digestion, nevertheless, these results give a general idea about the relative digestibility of C. edulis. C. edulis has similar in vitro DMD as compare to woody legumes such as Acacia berlandiera, Acacia rigidula, Acacia tortuosa, Acacia wrightii, and Prosopis (Lytle et al. 1982, Joshi et al. 1985) but lower DMD than Medicago (Larry and Wight 1984). C. edulis has low lignin and acid detergent fiber content as compared to Prosopis Joshi et al. (1985).

In this study rumen inoculum from cows at Oregon State University was used and may not give a very accurate estimate of digestion. In vitro digestion would have been best determined using inoculum from camels or goats (Van Dyne 1962), and best results would be obtained by using inoculum from camels or goats using these Somalia rangelands.

In general, deciduous plants expose their leaves to herbivores for only half to one quarter of the year, while evergreen plants expose their leaves year-round to herbivores. Evergreens are less susceptible to leaching (Reader 1978), so nutrients tend to be locked in the leaves. Despite their high nutritive value during the dry period evergreens may not be available as livestock forage, because of structural or chemical defenses such as spiny, leathery leaves, bad taste or poisonous properties. Some are high in tannin content which lowers palatability, protein utilization and digestibility (McDowell 1984).

The leaves of C. edulis are leathery and contain a low amount of moisture during the dry period. The crown of browsed plants develops a hedged form which may protect it from camel browsing. at the onset of the first rain, the plant has the potential through its mature leaves to begin photosynthesis immediately without putting energy into new leaf formation.

Cordeauxia edulis has good forage quality especially during the dry season, relative to other plants. The plant population is declining over most of its habitat where it once was a dominant shrub. The decline in population may be due to overgrazing or seed harvesting or both. The decline is probably due to a combination of several factors. Seed harvesting is an important factor, as nomads compete with each other for these seeds. They start harvesting before seeds are physiologically mature, fearing someone else may harvest ahead of them. Wildlife, especially baboons also eat the seeds. Insects take their share, distroying the seeds in various stages of development. Periodic drought for the last decade is another important factor contributing to its decline.

To maintain density, and to introduce C. edulis into similar environments, study is needed on regeneration requirements. A proper grazing system for C. edulis and its carrying capacity should be studied. It may be difficult in the near future to introduce and adapt different grazing systems to the nomads and encourage them to forget their traditional way of land use. This would require a complete socioeconomic change to the lives of nomads and the nomadic system would not continue in its present form. However, the creation of dry season reserves in areas where the plant is in danger is necessary.

In areas where C. edulis is in a good condition, intensive managements of the resources is needed. The plant deserves careful protection and detailed testing in cultivation in the future.

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APPENDICES

Appendix 1. Soils description from a stand of small-leaf *C. edulis*.

Location: about 6 km south of Teydan, which is 96 km northeast of Bulo Burte

Vegetation: Bushland dominated by *Acacia*, *Commiphora*, and the small-leaf form of *C. edulis*

Elevation: about 325 m

Topography: flat

Drainage: well drained

Parent material: sandy stone.

Erosion: limited slight sheet erosion

Classification: Renic Aridic Paleoustalfa

B1 0-55 cm red (2.5YR 4/6.5) loamy sand; massive with some single grains; slightly hard weakly cemented (dry); medium to large roots; macro pores; argillaus and sessquans coating.

B2t 55-180 cm red (2.5YR 4/6) sandy loam; less massive structure; weak cemented slightly hard (dry); medium and fine; macro pores; argillaus sessquans coating.

Appendix 2. Soils description from a stand of large-leaf *C. edulis*.

Location: 45 km northeast of Bulo Burte.

Vegetation: Bushland dominated with *Acacia*, *Commiphera*, large-leaf form of *C. edulis*, and perennial grasses.

Elevation: 300 m.

Drainage: excessively drained.

Parent material: sandy stone.

Classification: Typic Ustipsmments Arenosols.

A1 0-130 cm Yellowish red (5YR 5/8) sand; structureless; loose; medium to large roots; fine to medium pores; gradual wavy boundary.

A2 130-210 cm red (2.5YR 5/8) sand; structureless; soft; common fine roots; few very fine pores; slightly clay coating.