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THE INSTITUTES FOR APPLIED RESEARCH
BEN-GURION UNIVERSITY OF THE NEGEV

BGUN-ARI-45-88

Project C 5-218

PASTURE IMPROVEMENT WITH PERENNIAL FODDER SHRUBS

Progress Report

August 1986 - December 1987

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ABSTRACT

A visit was paid to Botswana to study the state of the art with regard to the role and problems of pasture and feed supply in livestock raising and the research needed to improve their contribution to the animal production of the country. At the end of the visit a work program was discussed and finalized. Research for the establishing forage gardens for supply of fodder to small stock from perennial plants was proposed.

A trainee from Botswana joined the research team in Beer-Sheva and participated in its activities for 10 months.

An experiment was carried out to improve shrub propagation techniques. The effects of light intensity, substrate composition, irrigation level and fertilization were tested on *Atriplex nummularia* propagated in speedling trays. Germination percent varied widely (30-72%). Data analysis is being carried out to determine the combined effects of treatments on growth, size, vigor, etc. of the seedlings.

Preliminary propagation trials of fodder species native to Botswana resulted in excellent germination of *Grewia flavescens* and *Colophospermum mopane*. Failure of other species could be attributed to unripe seed.

Atriplex nummularia, A. halimus and *A. lentiformis* grown in a plot in Botswana were found to have no or a very slightly salty taste; in addition, *A. halimus* appeared to be morphologically different from the type currently grown in Israel. Chemical analyses showed lower Na and Cl contents for the Botswana plants in comparison with those growing in the Negev. After being vegetatively propagated

in Beer-Sheva, the Botswana types will be tested in the field to determine if the different chemical composition is genetically controlled or only environmentally affected.

Atriplex nummularia was planted in July 1987 under the extremely saline conditions of the area south of the Dead Sea shore. When watered immediately after planting with fresh water, establishment without any additional irrigation was about 40%, while no plants survived in the control (no irrigation). Studies for improving establishment techniques will be continued.

Key words

Botswana, pasture, animal production, plant introduction, fodder plants, *Atriplex nummularia*, fodder gardens, chemical composition, germination, propagation, light intensity, substrate, irrigation, salinity

STUDY VISIT TO BOTSWANA

During November 1986 a visit was paid to Botswana with the following goals:

1. To study the conditions and characteristics of the area of the research project and to study the role of animal raising in the country's agriculture and economy, as well as the problems associated with livestock production there.

2. To determine the state of the art with regard to fodder availability and to range utilization as well as to consult scientists and specialists concerning their approach and experience in the field of introduction, domestication and utilization of native and exotic perennial fodder plants.

3. In the light of the above findings and suggestions and taking into account the facilities available, to finalize the research plan together with our Botswanan partners.

LIVESTOCK IN BOTSWANA

Livestock is one of the major resources of Botswana. Cattle is estimated at approximately 3 million head (Cooke, 1979a; Gollifer, personal communication, 1986) and small stock (sheep and goats) at 0.9 million (Patrick, 1985). Karakul sheep are raised in the extreme southwest of the country.

Sheep and goats are a traditional source of meat and milk in rural comunities and more than 70% of rural household have small herds. Meat from small ruminants is being consumed in increasing quantities by both the rural and the urban population (Patrick, 1985). Dorper sheep and Boer goat rams are used to improve the indigenous (Tswana) breeds. Since 1981 the goat population has increased relative to sheep

because the browsing habit of goats would enable them to face drought relatively well (Taylor, personal communication, 1986).

IMPACT OF OVERGRAZING AND DROUGHT ON LIVESTOCK AND ECONOMY

Livestock is basically dependent on the primary production of the rangeland, which represents the greatest part (75%) of the country. Since 70% of the population depends on rangeland (National Development Plan 1976-81, cited by Cooke, 1979a), the recurrent droughts have dramatic effects on the national economy. Cooke (1979a) mentions that in the drought of the 1960's the cattle herd shrank to less than one million. Cooke estimated the small stock population in 1978 at 1.7 million, while Patrick (1985) reported 0.9 million, a change which may reflect the consequences of drought.

The recent introduction and rapid expansion of cattle has brought about a series of changes in the vegetation and induced degradation. In many instances the fodder grass vegetation has been replaced by dense thickets of *Acacia* spp. and *Dichrostachys cinerea* within a few decades (van Vegten, 1983, cited by Tolsma, 1986). This encroachment has reduced the availability of edible grasses and increased the grazing pressure on other species, resulting in consumption of the edible components of woody plants by cattle (Tolsma, 1986). Excessive livestock and uncontrolled grazing in communal land use systems and the concentration of animals in the vicinity of water points result in degradation of the soil structure and the creeping expansion of wasted land (Cooke, 1979a).

CHARACTERISTICS OF THE AREAS VISITED

Aspects of the processes described above could be observed during the visit to Botswana. The excursion was limited to a small portion of the country, roughly from Takatokwane, about 160 km by road NW of Gaborone to the vicinity of Sebina, N of Francistown and some 450-500 km NE of Gaborone. The mean altitude of this region is about 1000 m above sea level.

The areas visited are largely covered by sandy soils of variable characteristics, but neutral or lower pH, low Ca content and deficiency in essential minerals, particularly phosphate, are common (Leistner, 1967). These deficiencies also affect the chemical composition of plants. Smaller areas have surface or sand capped calcrete. Mostly the region is flat, but hills arising from the plain and covered by large boulders lend the landscape a characteristic aspect. Among the boulders and in crevices grows a woody vegetation (e.g. *Croton gratissimum*, *Combretum* spp., *Ficus soldanella*).

Seasonally flooded depressions are scattered throughout the region. They have an unusually high pH, fine, poor soil structure, bad drainage, and a high accumulation of minerals (calcpans) or are heavily salt affected (saltpans). Vegetation is either absent, or very poor, or halophytic.

Rainfall occurs almost exclusively (about 90%) in the summer (November to April), decreasing from the NE corner of the country (some 650 mm annual mean) to the extreme SW (250 mm). Large variations from year to year are typical. Cooke (1979b) reports the following data for Gaborone and Francistown and similar data are cited for many locations (e.g. the rainfall in the ranches of the Animal Production Research Unit, reported by A.P.R.U., 1984).

Table 1. Rainfall in Gaborone and Francistown

Parameter	Gaborone	Francistown
Mean annual rainfall, mm	518.0	~600
Rainfall, wettest year, mm	927.2 (1966-7)	770.1 (1966-7)
Rainfall, driest year, mm	307.6 (1961-2)	227.6 (1964-5)

Winters have warm days and cool nights, often with frost. Summers are hot. Cooke (1979b) gives the following temperature data for Gaborone:

Table 2. Temperatures in Gaborone

Temperature	Wet year (1966-7)	Dry year (1961-2)
Hottest month (October)		
Mean max.	30.6	33.3
Mean min.	16.4	14.5
Coldest month (June)		
Mean max.	20.8	24.5
Mean min.	3.4	2.8

There is a gradation of mean temperature from north to south with risk of frost higher in the south (Timberlake, 1980b). Open-water evaporation is high, up to 7.5 mm daily in the summer.

VEGETATION

In the area visited the vegetation is essentially bush and woodland underlaid by grasses and other herbaceous species. Many or possibly most species are deciduous . This seems an important trait to be considered in designing a plant introduction and development program to help bridge seasonal fodder shortages. During the November 1986 visit, the vegetation response to rain was dramatic, with very quick recovery of perennials from drought stress and rapid germination of annuals.

Vegetation varies according to the soil characteristics, temperature, rainfall, etc. and is affected by human and animal exploitation. Encroachment by undesirable thickets (*Acacia tortilis, A. mellifera, A. fleckii* and others) and use of fire were frequently observed.

Sandy soils (sandveld) support an open tree and bush savanna of *Acacia* spp. and broadleaved trees like *Terminalia sericea, Burkea africana, Lonchocarpus nelsii;* while loamy soils and rock (hardveld) generally have a more dense tree and shrub savanna of *Acacia* spp. and *Combretum* spp. (Timberlake, 1986b). In the NE of Gaborone, *A. nigrescens* becomes dominant and further on (possibly some 250 km from the town) the increasing frequency of vegetation including and often dominated by *Colophospermum mopane* appears to be associated with higher temperatures.

Several species have economic interest independently of their fodder potential. In sandy soils in open areas the grapple plant (*Harpagophytum procumbens*) and the remarkably frequent marama bean (*Tylosema esculentum*) have promise as sources of medicinal products and food, respectively. Higher plants like *Pelthoforum africanum, Acacia nigrescens, Ficus soldanella, Gardenia volkensii, Sclerocarya caffra* (Morula) have potential as ornamentals, while the Morula itself, *Strychnos cocculoides, S. pungens* and others are being tested as fruit trees.

After being cleared of their woody vegetation and fenced , tracts of variable dimensions are cultivated during the rainy season for production of crops, mostly maize, sorghum, millet, sunflower, water melons, ground nuts, etc. After harvesting, these areas return to communal utilization and are grazed. If neglected, they are rapidly re-infested with woody species. During clearing, certain trees are usually spared, particularly *Boscia albitrunca, B. foetida,* and Morula, possibly for their value as suppliers of fodder and fruits. The respect for these and for several *Acacia* species is also striking in densely populated areas and in villages, where man and livestock pressure have initiated processes of depletion and degradation. Thus also here plants -- at least as individual isolated, large trees -- are a frequent component of the landscape.

EXPERIMENTAL SITES

1. Kumakwane introduction plot

The Kumakwane experimental plot is located about 40 km west of Gaborone in a flat sandy soil region extensively cleared of the native vegetation for agricultural exploitation. It is operated by the Village Development Committee with the assistance and collaboration of Thusano Lefatsheng and may be defined as the initial stage of an introduction and/or domestication program. It includes a variety of plant species of potential value for fruit, food, industrial, aromatic and medicinal uses. The species tested are either native, such as the Marama bean (*Tylosema esculentum*) and grapple (*Harpagophytum procumbens*), or introduced such as jojoba (*Simmondsia chinensis*) and figs (*Ficus carica*). The collection of fodder plants includes southern African species like:

Pollichia campestris (Caryophyllaceae)
Osteosperum sinuatum (Compositae)
O. pachypteris
Monochlamys albicans (Chenopodiaceae)

and introduced species like:

Opuntia ficus-indica (Cactaceae), spiny and spineless varieties

Atriplex semibaccata (Chenopodiaceae)
A. halimus
A. lentiformis
A. nummularia

Seeds of all the shrub species listed above were received from the Cape Province of South Africa. After propagation in a nursery, they were transplanted in December 1985. Seedlings were planted on the bottom of furrows in rain-moistened soil, and grown under average rainfall conditions. In November 1986, at the age of about one year, these species displayed promising growth and excellent overall condition (good biomass, and healthy succulent foliage).

Some points are worth noting:

1. In Israel the two *Osteospermum* species, especially *O. sinuatum* , performed less well than the *Atriplex* species in terms of biomass, survival, drought and grazing tolerance.
2. In Israel leaves of the chenopods have a salty taste. In Kumakwane the leaves tasted much less salty.
3. *Atriplex halimus* was found to be quite different morphologically from the type native to and common in Israel, being more erect and compact. The Middle Eastern type has thin, flexible, downward bending branches, at least when young, appears to have longer and less dense infructescences and has a tendency to develop predominantly in the lateral direction. The identity of the South African type should perhaps be re-examined, but, independent from the taxonomy, its different habit could offer certain advantages under grazing conditions or as a cut forage.

Several species of fodder shrubs are also cultivated in the vicinity of the experimental plot, in the Martin farm. This seems to be older material; now developed to adult size, it was apparently subjected to more intense watering. In addition to the *Atriplex* spp., this farm also includes excellent examples of *Cassia sturtii*.

2. Takatokwane introduction area

This experimental area is located about 160 km NW. of Gaborone in sandy soil and was established by clearing the native woody plant formation, largely composed of *Acacia* spp. The area is much larger than the Kumakwane plot and was planted in October 1982 by the Botswana Forestry Association (Mr. Ralph Nickerson). It was neglected for a certain period and its management was recently taken over by the Kweneng Bophirina Development Association under the supervision of Mr. Bob LeRoy. Plantations were irrigated monthly during 1985 and recovered fairly well. Water is supplied from buckets, individually to each plant. The area is planted mostly with trees (*Eucalyptus* spp., *Rhus lancea, Prosopis juliflora*), among which *Prosopis juliflora* seems to do better than the *Eucalyptus* spp. It also includes a rather large plot of *Atriplex nummularia*. Propagated from seed supplied by the Forestry Commission of Pretoria in the late seventies and spaced at intervals of 4 m, the shrubs display good survival, variable size (up to about 1.60 m high) and fair leaf cover. The fact that they received auxiliary irrigation makes it difficult to evaluate the potential of the species under the strictly natural conditions of the site.

3. Improving animal feeding: The Kumakwane smallscale dairy project

Efforts are being made in Botswana to improve livestock performance by cross-breeding indigenous (Tswana) breeds with others, by veterinary care and by improved feeding. Consequently, attempts are being made to incorporate sown fodder in mixed farming systems, using crops like fodder *Sorghum, Dolichos lablab, Dolichos leichardt, Cenchrus ciliaris,* Siratro *(Macroptilium atropurpureum)* (A.P.R.U., 1984). In addition, efforts are being made to encourage a more rational use of crop residues for ruminant feeding. For cereals (sorghum, maize and millet) the common practice is to harvest only the heads, leaving the standing stover in the field. In the case of legumes (cowpeas, groundnuts, mung beans), only the pods are removed and the residues are similarly left in the field (A.P.R.U., 1984). Chaff and husks are often burnt after threshing. After harvest livestock is given access to fields

to graze the stover. Since grazing is mostly communal and uncontrolled, the individual farmer who has cultivated the field does not benefit from its residues. In addition, the utilization efficiency of residues is reduced, since leaves are grazed and stalks refused (A.P.R.U., 1984).

The Kumakwane smallscale dairy project, which was visited on this trip, is one of the projects intended to demonstrate the effect of improved practices on animal production. After grain harvest, sorghum stover is cut, stored and fed gradually to animals. When pasture starts becoming poor, Simmental x Tswana cows are fed daily with 4 kg *Dolichos lablab* hay. This is added to about 200 g sorghum bran and to sorghum stover *ad lib.* Since in Botswanan feeds the mineral content, especially phosphorus, is usually low, salt and bone meal complete the ration. Performance data are being collected. Daily monitoring of milk production and monthly weighing are being carried out. The first three-quarters of the mother milk are used for human consumption and, except for the first days, calves are allowed to suck only the last quarter.

MEETINGS

To complete the information and investigate the relevance of the proposed research project for Botswana, a number of specialists were consulted. A list is presented in Appendix 1. In general, the outlines of the proposal were favorably received with many of the interviewed persons insisting on the importance of including species native to Botswana in the work program. These species, well adapted to Botswanan conditions, could perform better than the introduced ones (Tietema, 1986). In Table 3 the indigenous species of good forage desirability published by Hendzel (1981) is presented. This list largely agrees with evaluations or information provided by other authors (e.g. Leistner, 1967; van Rensburg, 1971; Moss and Taylor, 1983; A.P.R.U., 1984; I.B.R.G.R., 1984). The persons consulted expressed considerable agreement as to which species among those listed in Table 3 should be given priority in a domestication program, as follows:

Grewia spp.
Boscia foetida
Boscia albitrunca
Bahuinia macrantha
Colophosphermum mopane
Acacia tortilis
Acacia erioloba

It was, however, pointed out that the information available on fodder plants is only descriptive. Research is in progress on the dietary preferences of animals and on the nutritive value of forages from native vegetation (A.P.R.U., 1984), as well as on the seasonal variation of nutrients in various components of fodder plants (Tolsma *et al.*). Details on the various species can be found in Field (1976), Woolard (1984) and

Table 3. Botswanan native species of good forage desirability (Hendzel, 1981)

Acacia karroo	*G. flavescens*
Albizia anthelmintica	*G. monticola*
A. harveyi	*G. retinervis*
Bauhinia macrantha	*G. subspathulata*
Boscia albitrunca	*Lonchocarpus capassa*
B. foetida	*L. nelsii*
Burkea africana	*Maerua angolensis*
Colophospermum mopane	*Ozorea paniculosa*
Combretum apiculatum	*Peltophorum africanum*
C. hereroense	*Piliostigma thonningii*
C. imberbe	*Rhigozum brevispinosum*
C. molle	*Rhus aethiopica*
C. zeheri	*R. lancea*
Eherehia rigida	*R. pyroides*
Grewia avellana	*Ricinodendron rautaninii*
G. bicolor	*Sclerocarya caffra*
G. flava	*Spirostachys africana*

Timberlake (1980a,b). Regarding introduced species, *Atriplex nummularia* seems to have been the most widely tried, with the most promising results (Anonymous, 1985). The use of *A. nummularia* as a hedge, from which animals graze, is reported in the Karakul farms of the extreme southwest corner of Botswana (Arnhold, 1986, personal communication).

Various recommendations have been formulated by the persons consulted, who stressed several consequences of and conditions for shrub cultivation:

1. To utilize the fodder shrubs in a cut-and-carry system rather than by grazing.
2. To design the project so as to interest the small farmer in it, and, in due time, to enlarge work to a series of plots located in selected farms on order to familiarize people with the new forages.
3. To extend the work to additional environments. In particular, Taylor and Chandler stressed the presence of shallow brackish water and of saltpans, which could be utilized for cultivation of salt tolerant plants.
4. To concentrate work on small stock. Goat meat and milk are fundamental for poor people. The improvement of human nutrition will in turn have an impact on the national economy. Goats are easier to raise than other ruminants and would better suit the constraints of environments in which drought periods drastically affect fodder availability.
5. Growing perennial fodder plants poses several problems and requires certain conditions. Introduction, domestication and cultivation of species of high or fair palatability is a risk, since palatability endangers the plant's survival if suitable protective measures are not taken. Perennials imply a dimension of longer time, i.e. a concept of continuity. This implies, in turn, management and total or periodical exclusion of animals from areas planted with fodder species and, hence, changes in the traditional land utilization methods, in which cultivated fields return after harvest to communal exploitation for grazing.
6. Improved fodder supply is only one of the conditions for improved animal

production. For satisfactory results it must be associated with efficient veterinary care.

RESEARCH FACILITIES

The research proposed in this program requires a suitable experimental field. Thusano Lefatsheng has obtained an area near Thusego, the agricultural research center of the organization, SW of Kumakwane. The area is affected by grazing and appears typical of eastern Botswana. The soil is a loose to more compact sand, grading with depth from dark brown to reddish brown. The vegetation includes trees like *Burkea africana, Peltophorum africanum, Terminalia sericea, Securidaca longi-pedunculata, Combretum zeyheri,* bushes like *Ximenia americana* and grasses like *Panicum maximum* and *Eragrostis rigidior*. At the time of the visit, all the area had been fenced and half had been cleared of the native vegetation for fruit tree trials. The second half for fodder shrub research still had to be prepared. A well had been drilled and a pump and pipes were about to be installed. A metal cistern for water storage was already in place, as well as a class A pan for evaporation measurement, and a rain gauge. A quarantine net house, a shelter and other plant introduction and nursery facilities were under construction.

SEED COLLECTION

In November 1986, most of the fodder species recommended by the Botswana specialists were either flowering or had seed that was still ripening. Therefore, very limited amounts of propagation material could be collected for experimental purposes. (Table 4).

SEED SUPPLY TO OUR BOTSWANAN PARTNERS

Seeds of the following species were supplied for trial in Botswana during the visit and in the course of the period surveyed.

Table 4. Seeds collected in Botswana - November 1986

Acacia mellifera	*Combretum apiculatum*
Boscia albitrunca	*C. zeyheri*
B. foetida	*Dichrostachys cinerea*
Cadaba aphylla	*Grewia flava*
Cadaba sp.	*G. flavescens*
Colophospermum mopane	*Peltophorum africanum*

Table 5. Seeds supplied to Thusano Lefatsheng

Acacia ligulata	*Atriplex halimus*
A. pendula	*A. nummularia*
A. salicina	*Cassia eremophila*
A. sclerosperma	*C. sturtii*
Atriplex canescen.	

CONCLUSIONS

1. Animal raising is one of the major economic activities in Botswana
2. Although cattle are numerically the most important livestock, supply of meat and milk from sheep and goats plays a fundamental role in human nutrition, and a very large number of rural household have small stock.
3. Production and survival of livestock are largely dependent on rangeland. Primary production in turn is dependent on weather. The dry season reduces fodder availability and quality, and recurrent droughts have disastrous effects.
4. Efforts are being made to stabilize and improve fodder supply and to ameliorate animal performance by integration of cultivated forages in the production system

and by a more rational utilization of by-products from other crops.

5. Drought-resistant perennial fodder plants can contribute to these improvement efforts by providing a green biomass relatively rich in protein and vitamins, particularly in the periods of major fodder shortage.

6. Among the introduced species, *Atriplex nummularia* seems both relatively better known in Botswana and promising. Native species, however, could be more advantageous and reliable because of their adaptation to the Botswanan conditions; their domestication must be investigated. Non leaf-shedding species appear preferable.

7. The information collected on a number of introduced species suggests that it would be well worth while to investigate their production potential. This can be a first step towards an economic exploitation of shrubs, as suggested in paragraph 8.

8. The cultivation of shrubs in permanent forage gardens by small farmers may be a way to overcome fodder shortages and improve the performance and survival of small ruminants. A "cut and carry" management system could be preferable.

In light of the above conclusions, the original research proposal was discussed with the people of Thusano Lefatsheng at the end of the visit and modified to some extent. The finalized working plan is presented in Chapter 2 of this report.

ACKNOWLEDGEMENTS

We would like to thank all the people of Thusano Lefatsheng, in particular Mrs. F. Horenburg, former manager, and Mr. I. Martin, agronomist, for the hospitality, assistance and information received. Special gratitude is due to Mr. Ian Tolsma, who patiently accompanied the writer throughout the visit and shared his experience and knowledge.

Thanks are extended to all the Botswanan scientists and specialists that we had a chance to consult for their advice and suggestions. Their list in the Appendix is (hopefully) complete.

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Appendix 1

Scientists and specialists consulted in Botswana

Addy B.	Animal Production Research Unit, Agriculture Research Station, Sebele
Arnhold J.	Small Stock and Karakul Sheep, Ministry of Agriculture, Gaborone
Dr. Barhane	Small Scale Dairy Project, Kumakwane
Chandler D.	Farming Systems, Southern Region, Agriculture Research Station, Sebele.
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Dr. Gollifer	Director, Agricultural Research Station, Sebele
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Machacha	Chief, Animal Production, Ministry of Agriculture, Gaborone
Makobo H.	Communal Area Management Unit, Chairman of Fodder Committee, Ministry of Agriculture, Gaborone
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Moyo A.	Plant Introduction and Screening, Agriculture Research Station, Sebele
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2.

OUTLINE OF THE WORK PLAN

A. WORK PLAN IN BOTSWANA

1. Updating the information on the fodder shrubs tested in the Kumakwane and Totatokwame plots

This survey has to verify and complete the data collected during the visit to Botswana, including:

- average rainfall and rainfall amounts during the experimental period
- soil characteristics
- soil preparation. Information as to whether the plots were planted directly after clearing of the bush or had been cultivated previously with other crops
- Planting and cultivation practices, irrigation, if any
- Survival and plant development: height and spread, and estimation of leaf density

Information on other fodder shrub experimental areas or on the use of native or introduced fodder plants would be desirable.

2. Selection and preparation of an experimental area for research on fodder shrubs

This area should be large enough to include the biomass production trials and the introduction tests outlined in the following plan. For details see paragraphs 3d and 5c. The area will be cleared of the natural vegetation, if necessary, and fenced. The soil will be properly cultivated in preparation for the shrub planting.

The species present in the native vegetation will be recorded and listed before bush clearing is carried out, and the soil will be sampled for physical and chemical characteristics. Information on rainfall in the area will be collected and a rain gauge installed.

3. Plant propagation

The facilities necessary for seedling production (greenhouse, shelter, water supply and water storage, watering facilities, propagation materials, containers, etc.) are to be acquired and installed or, if available, inspected and made ready for effective functioning.

4. Fodder production trials

Since the information collected indicates that several introduced perennial fodder species can grow under the conditions prevailing in areas relatively close to Gaborone, where the facilities of Thusano Lefatsheng are located, a major effort will be made to test their production potential there. This seems preferable to initiating a prolonged, largescale introduction program involving many species of unknown and unpredictable behavior and value. Although limited, information is available on the utilization of *Atriplex nummularia* in southern Botswana. The behavior of this and other Chenopods in Kumakwane, Tokatokwane and other sites seems promising. Their performance was found satisfactory under the conditions of Israel, and the considerable experience and documentation accumulated there can help in investigating the shrub under Botswanan conditions. This promising background seems to justify an accelerated process of application of the results.

The main target of this work is to improve the fodder supply to small stock. For this purpose an assessment of the production potential of the shrubs is required. When properly cultivated, the shrubs can represent a source of green, protein-rich fodder produced in forage gardens close to homesteads, for feeding goats and sheep, particularly in critical periods of the pastoral cycle. Possibly a "cut and carry" management system could be applied.

The work will proceed according to the following outline:

a. Three species (*A. nummularia, A. halimus* and *A. lentiformis*) will be tested for their production potential in terms of edible biomass at 4 planting densities: 3x3; 2x2; 1.5x1.5; and 1x1 m (1110, 2500, 4440, and 10.000 plants/ha, respectively). Three to four replicates for each treatment and species will be used. Seeds collected from shrubs grown in Kumakwane will be propagated.

A distance of at least 3 m will separate treatments. Each treatment will consist of a square of 49 shrubs planted in 7 rows of 7 shrubs each. The 9 internal shrubs of each square will be the experimental shrubs. The others (the peripheral shrubs) will serve to prevent border effects and will be used for destructive sampling. It is highly desirable that treatments be planted at random within each replicate.

A double-sampling technique will be used for estimation of the standing shrub biomass. During the first year, survival, growth (height and spread) and canopy density will be determined. Biomass availability measurements will be started at a later stage. The method of measurement of shrub biomass described by Seligman *et al.** will be used. As mentioned, only peripheral shrubs will be used for destructive sampling. Chemical analyses of the plant dry matter will be carried out. Phenological observations will be conducted. They will include records on:

1. Active growth
2. Dormancy
3. Stress conditions and leaf shedding
4. Recovery from stress
5. Floral bud formation
6. Flowering
7. Seed formation
8. Seed ripening
9. Volunteering (natural germination and growth in the field)
10. Other relevant phenomena (Pests, diseases, wildlife browsing, etc.)

*Seligman, N.G., Benjamin, R.W., Lavie, Y., Forti, M. and Mills, D. 1986. Estimation of the standing biomass of fodder shrubs under grazing conditions. In: Dovrat, A., compiler. Fodder production and its utilization by small ruminants in arid regions. Fourth Annual Report BGUN-ARI-61-86, The Institutes for Applied Research, Ben-Gurion University of the Negev, Beer-Sheva, Israel, pp. 46-58.

b. Within the shrub density treatments and in the areas free from shrubs, the process of re-establishment of native species after clearing of the bush will be followed and the effect of the various shrub densities on their cover and on the botanical composition will be recorded. A double-sampling technique involving visual estimates and harvested samples will be used for determining the plant biomass between the planted shrubs. Since the native herbaceous cover is part of the production system, weed control will be carried out only in the initial phase of shrub development, when weed competition could be crucial for their establishment.

c. Planting will be carried out in soil moistened by rain to a reasonable depth, early enough in the season to assume that additional rains will occur and facilitate seedling establishment. Irrigation will be given only under conditions of unusually severe drought.

d. For each replicate including 4 density treatments (3x3, 2x2, 1.5x1.5 and 1 x 1 m, as described in paragraph a) an area of about 1000 m^2 is needed. For 3 species replicated 3 or 4 times a total area of about 1.0 or 1.3 ha. respectively is necessary.
For the same treatments as above, 590 or 785 seedlings/species are needed for 3 or 4 replicates, respectively.

5. <u>Propagation and domestication of native and exotic fodder plants</u>

a. *Species*

In the meetings held in Botswana, the following native species were particularly recommended as worthy of attention:

Grewia spp.
Boscia foetida
Boscia albitrunca
Bahuinia macrantha
Colophospermum mopane

Seeds of these species have yet to be collected.

Hendzel (1981) mentions a number of native species having a good forage desirability. The list is given in Table 3 of Chapter 1. In our opinion, preference should be given to species that do not shed their leaves during the dry season. Their suitability to the conditions of the experimental area must be evaluated.

Among the exotic species, the following displayed good performance in Israel and elsewhere and are proposed for trial in Botswana:

1. *Acacia ligulata*
2. *A. saligna*
3. *A. victoriae*
4. *Atriplex barclayana*
5. *A. breweri*
6. *A. canescens*
7. *A. halimus* (Israeli type)
8. *A. lentiformis* (Israeli type)
9. *A. linearis*
10. *A. nummularia* (Israeli type)
11. *Cassia nemophila*, var. *coriacea*
12. *Cassia sturtii*

Their seed will be supplied from Israel as soon as they become available.

b. *Propagation*

Germination procedures for the species supplied from Israel are fairly well established. While *Atriplex* spp. do not need any treatment, seeds of the legumes have to be soaked in boiling water for 24 hours. It is possible that some of the species native to Botswana will need some kind of treatment. Information, if available, must be collected. Particular problems will be investigated in parallel in Botswana and Israel. In this initial phase, material and containers as in the current practice in Botswana nurseries will be used, possibly black plastic bags approximately 0.20x0.10 cm in size. About 50 seedlings or (preferably) more have to be prepared per species in order to enable selection for planting material of good, uniform quality.

c. *Planting scheme and practices and follow- up*

After soil preparation as described in paragraph 2, planting will be carried out in the same season as for the fodder production trial. Irrigation will not be applied or will be kept to a minimum. Species will be planted at random in 3 replicates, in blocks of 4x4 plants each. Spacing will be 3x3 m. Development and phenology will be recorded as described in paragraph 4a, but no destructive sampling will be carried out.

6. Improvement of plant propagation techniques

Planting of large areas of fodder shrubs implies the use of a large number of plants and in turn high costs for seedling supply and planting operations. In Israel, the propagation of plantlets in speedling trays has recently been extended to fodder shrubs, with satisfactory results. Trials with this technique will be carried out in Botswana to determine specific practices, materials and conditions needed to produce plantlets of good quality and at low cost.

7. Seed suply to the Israel team

According to the original plan, seeds of Botswanan species listed in Paragraph 5a and in Table 3 of Chapter 1 will be collected and shipped to Israel for introduction trials. Information on the problems and results of the propagation program will be exchanged between the Botswanan and the Israeli teams.

B. WORK PLAN IN ISRAEL

1. Training

Trainees from Botswana will join the Israel team and participate in its activities in the field of pasture improvement through the use of fodder plants (trials on the role of fodder plants in animal production systems; establishing fodder plants in marginal areas; response of shrubs to various planting densities; methods of biomass determination; chemical analyses; propagation techniques, etc.). Particular attention will be paid to investigation of Botswanan species of potential pastoral value.

2. Improvement of propagation techniques

Since 1982 the propagation of plantlets in speedling trays instead of in plastic bags has been tested at the Institute in Beer-Sheva. This is an adaptation of a technique developed for propagation of irrigated vegetables to species to be grown under poor rainfed conditions. The drastic difference in the final growth environment and the deficiencies observed in plantlet quality in the past call for further investigation of the new propagation techniques with regard to the substrate, fertilization, watering, light intensity, etc. Various combinations of these factors will be tested in different seasons.

3. Introduction of Botswanan species of pastoral value

A list of recommended species is presented in part A of this program. In parallel with work in Botswana, they will be propagated in Israel. The species propagated successfully will be planted in the experimental fields of the Institute for follow up and measurements as detailed in paragraphs 4a, 5b and 5c of part A.

4. Cultivation of shrubs under saline conditions

During the visit to Botswana the presence of brackish water in several locations in the country and its potential for more intensive cultivation of salinity tolerant species was stressed. The existence of salt pans that could serve for shrub cultivation was also pointed out. An effort will be made to test one or more species known for their suitable characteristics (in particular *Atriplex nummularia*) in a saline environment and to establish the agricultural practices for satisfactory establishment and development. The effect of salinity on growth, fodder quality and animal intake will be investigated. The results will be of importance for applications in Botswana.

TRAINING

In mid-April 1987 Mr. Benjamin Mpho Walter Moruakgomo was selected by Thusano Lefatsheng and arrived at the Institute for a training period on subjects related to the use of perennial fodder plants. During almost 10 months he was involved in the activities of the pertinent research team in order to become familiar with various aspects of the work. In particular he was in charge of trials for the improvement of the shrub propagation methods; preliminary propagation tests with Botswanan species; and trials for the vegetative propagation of fodder shrub types sent from Botswana and worth cloning in view of their particular traits. Details on these activities are presented in separate chapters elsewhere in this report. In addition, Mr. Moruakgomo participated in:

1. The grazing experiments carried out in the Migda Farm to study the role of perennial fodder shrubs in animal production. He familiarized himself with principles and background of this research as well as with methods of determination of shrub and native vegetation standing biomass and biomass consumed by sheep during grazing periods.
2. Surveys in a 20 ha plot of shrubs planted in the winter of 1986-87 on the hillsides of the Bedouin Demonstration Farm north-east of Beer-Sheva, in which the microcatchment technique is used.
3. Surveys in a preliminary trial with fodder shrubs planted in 1987 in the Neot Ha-Kikar farm south of the Dead Sea in soils of extremely high salinity. The methods of establishment tested in this work can be relevant to saline conditions in Botswana.

Access to the library services and to the publications and reports issued by our group permitted Mr. Moruakgomo to extend and deepen his knowledge on the subjects relevant to his work. The information was enlarged by visits to other libraries and by meetings with people of other laboratories and institutes.

During a stay with the Bedouins at the Demonstration Farm he learned their methods of preparing cheese and other milk products as well as small stock management practices.

Visits to experimental fields in which other research relevant to Botswana is being carried out (e.g. trials on novel fruit trees) completed the activities of this stage. Mr. Moruakgomo was of good assistance and contributed well to the work of the group. Unfortunately, his late arrival and departure early in the winter did not enable him to participate in the series of operations involved in planting shrub areas in rainfed arid regions.

4.

IMPROVEMENT OF SHRUB PROPAGATION TECHNIQUES

INTRODUCTION

Seedling preparation and planting represent a considerable portion of the costs involved in the establishment of perennial fodder shrub areas. Since 1983, the Beer-Sheva team has been striving to reduce these costs by adapting the speedling tray technique to the special requirements of rainfed agriculture under semi-arid conditions. This technique is applied widely in Israel in intensive irrigated agriculture, especially of vegetables, and offers numerous advantages. Compared with the conventional growth in bags, considerably less nursery area is required (more than 200 seedlings can be grown per square meter). The volume of soil mixture is much smaller, filling the trays is very rapid, shipping by truck requires much less space, transport in the field can be done by hand even in the worst terrain (one worker can easily carry 200 seedlings), and planting is simple and fast (since a very small hole is necessary).

Despite these advantages, the technique has not been exempt from deficiencies and uncertainties when applied for propagation of plantlets for dryland conditions. Besides the small volume, the substrate had a poor water holding capacity because of the components of its mixture. Plantlets were often weak, tender and etiolated with long, thin stems. Thus they were easily attacked by pests and diseases in the nursery and hardly suitable for the harsh conditions of natural environments. By modifying the substrate and by fertilizing, improvements were obtained and encouraging results achieved not only in terms of reduced production costs and higher planting performance, but also in terms of survival of plantlets in the field (Benjamin and Levi, 1984; Benjamin *et al.*, 1985; Forti *et al.* 1987; Forti *et al.*, 1988).

To further improve the technique, more information is required. In the present trials the interaction of four factors affecting speedling quality was tested: light intensity, irrigation level, substrate composition and fertilization.

MATERIALS AND METHODS

Location and facilities

The trial was conducted in the nursery of The Institutes for Applied Research in Beer-Sheva, in a shelter covered by a black plastic net reducing light intensity by about 30%. In the shelter, metal frames about 110 cm high permitting free water drainage from the containers and root air pruning were installed. An automatically regulated overhead mist irrigation system enabled watering at the desired levels and intervals.

Containers

Speedling trays containing 104 cells (4x4 cm each) were used. After being filled with the various soil mixtures, they were placed on the metal frames and sown. One hundred and eight trays were placed in parallel rows of 6 trays each. Each pair of rows was separated from the next one by an access path.

Plant material and sowing procedure

Untreated seed of *Atriplex nummularia* collected in 1985 in the Omer experimental area near Beer-Sheva were used. At least three seeds per cell were sown. Sowing was carried out on June 11, 1987, in the high shade section and on June 14-15, 1987 in the medium and low shade section.

Experimental plan

The following treatments were applied:

1. *Shading*. The effects of three light intensities were compared: that usual in the net shelter vs. two weaker ones obtained by adding one or two layers of a plastic net to the original layer. Care was taken to locate the trial so as to avoid shading from nearby trees. Each shading treatment included 36 speedling trays (3744 cells), arranged in 6 rows.

2. *Irrigation regimes*. In each shading treatment three water regimes were applied at random, one to each pair of tray rows. The treatments consisted of misting during the daylight hours at 30-minute intervals for different durations (30, 45 and 60 seconds). Plastic curtains separated the treatments and prevented intrusion of water from near-by sections. Each irrigation regime was applied to 12 trays in each shading treatment.

3. *Substrates*. Three substrates were compared. All contained (by volume) 30% peat moss, 10% compost produced from cotton waste of the Ofakim Gin, and 40% vermiculite 101-10 enriched with nutrients (1.5:3:1 N-P-K, microelements and iron). The remaining 20% varied and consisted either of sand (S), or of local loess soil (L) or of 10% sand plus 10% loess (S+L). Each substrate was used to fill 4 trays in each irrigation regime of each shading treatment. The composition of the substrates is summarized in Table 1.

Table 1. Substrate composition (% by volume)

Components	Substrates		
	S	L	S+L
Loess	0	20	10
Sand	20	0	10
Vermiculite	40	40	40
Peatmoss	30	30	30
Compost	10	10	10

4. *Fertilization.* To the basic fertilization treatment (control) given to all plantlets through the nutrients incorporated in the vermiculite, a treatment was added consisting of a solution of 20:20:20 N-P-K fertilizer, supplied individually to seedlings once every two weeks, starting approximately from the sixth week after beginning the trial. Each treatment consisted of two trays (208 cells) per substrate in each irrigation and shading treatment. The first additional fertilization on July 26, 1987, had a 1% concentration and was the equivalent of 10 mg fertilizer/seedling, while the following ones, on August 19 and September 10, and the last on September 24 had a 2% concentration, or the equivalent of 20 mg fertilizer/seedling.

Measurements

1. *Germination rate* was recorded by counting all the seedlings emerging in each tray every five days from the 5th until the 30th day after sowing. At the end of this period, seedlings were thinned to one per cell. Where necessary, thinned seedlings were transplanted into empty cells.

2. *Seedling growth* was determined by measuring height and weighing. The first dry weight determination was done when superfluous seedlings were thinned, 30 days after sowing; the second was done 9 weeks later and the last after 17 weeks, at the end of the experiment. The aerial portion and the roots of the seedlings were separated, oven-dried for 36-48 hours at 70°C, and weighed.

Height measurements were done every two weeks, each time on the same plants. These consisted of the 16 seedlings growing in the third rows from both sides of each tray.

3. *Light intensity* was measured in the middle section of each of the three shading treatments with a Li-Cor model LI-185B light meter. Light measurements were made four times during the experimental period, from 8.00 to 18.00 at 2 hour intervals.

4. *Air temperature* was recorded daily by min. - max. thermometers placed above the trays in the center of each shading section.

5. *Amounts and distribution of mist water*. To measure the values of these parameters over 24 h or in a single spray, jars or petri dishes were placed on trays at random, one container per tray in each of the three irrigation regime sections. A few drops of paraffin oil were added to the containers to prevent evaporation.

The experiment was terminated in mid-October, 1987, when the last measurements were made.

RESULTS AND DISCUSSION

Table 2 summarizes the data on germination of *Atriplex nummularia*. Ten days after sowing germination was between 20 and 50% (data not shown). After 25 days no further germination occurred. In evaluating the results it must be remembered that

the percent germination was calculated on the basis of at least 312 seeds sown in each

Table 2. Germination of *Atriplex nummularia* under various shading, irrigation and substrate conditions

Mean % germination per tray 30 days after sowing*

Substrate	Misting			
	30 s	45 s	60 s	Mean
Low shading				
Sand	39±14	34±14	35±13	36±12
Loess	56±19	41±10	69±24	55±21
Sand + Loess	72±12	41± 7	3±22	54±19
Mean	52±19	38±11	52±23	48±19
Medium shading				
Sand	46±10	54±12	59±13	53±12
Loess	70±27	37±13	62±30	57±26
Sand + Loess	36± 9	30± 8	50±18	38±14
Mean	50±22	40±15	55±24	49±20
High Shading				
Sand	67±20	59±16	57±16	61±17
Loess	40±12	41±18	49±15	43±14
Sand + Loess	30± 6	33±10	56± 3	40±14
Mean	43±24	44±18	54±12	48±17
All shading treatments				
Sand	51±19	49±17	50±17	50±17
Loess	55±22	40±13	60±23	52±21
Sand + Loess	40±18	33± 9	53±15	43±17
Mean	49±20	41±15	54±19	48±19

*Germination% was calculated on the basis of 312 seeds per tray

tray. This means that even when germination was relatively low, most of the 104 cells had at least one seedling, a satisfactory result from a practical point of view. The overall mean germination was 48%, and so was the mean germination in each shading treatment. However, considerable differences were recorded among individual treatments. Highest values were registered in the three shading treatments when misting was maintained for 30 s. In each, however, the best substrate differed (72% in loess and sand, 70% in loess, 67% in sand for low, medium and high shading, respectively). Second-best results (56-69%) were registered with the 60 s misting and the poorest with the 45 s misting. From these data it would appear that in summer a low-level irrigation regime at a low shading level would suffice or would be preferable for good germination, provided a uniform mist distribution is ensured. In the initial phase of this experiment distribution was, however, deficient and resulted in large germination differences between trays of the same treatment, as indicated by the large standard deviations presented in the Table.

The effect of the subtrate, on germination, if any, is not clear. However, while possibly of minor importance in the germination phase, its characteristics can be as important as irrigation in the growth phase. The results of this second phase and complementary data are still being summarized and analysed and will be presented in the next report.

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5.

PROPAGATION OF BOTSWANAN FODDER SPECIES: PRELIMINARY TRIALS

INTRODUCTION

Various perennial species native to Botswana are reported to have potential as fodder plants. A list is presented in Chapter 1 of this report. Their domestication and utilization could contribute to pasture and feeding improvement programs in the country. Since they are well adapted to the Botswanan conditions, they could offer certain advantages in comparison with introduced species. On the other hand, they are also of potential value to other countries, whose animal production systems face similar problems of fodder shortage.

Seeds of several species were collected in Botswana by M. Forti during his visit in November 1986. Unfortunately at that time many species were still flowering and others had seeds in the ripening stage. Thus, very limited quantities of desirable propagation material could be harvested. The small amounts collected were nonetheless sufficient for a small-scale propagation trial. The results are summarized below.

MATERIALS AND METHODS

The seeds of the following species were tested:

Species	Family
Boscia albitrunca	Capparidaceae
Boscia foetida	"
Cadaba aphylla	"
Cadaba sp.	"
Colophospermum mopane	Leguminosae
Grewia flava	Tiliaceae
Grewia flavescens	"

Trials were conducted at room temperature. Sowing was carried out on September 22, 1986 in parallel on filter paper in petri dishes and in small pots filled with vermiculite. Five seeds per container were used, each treatment being replicated 5 times for each species. Seed were not treated. Water was applied every second day. Germination rates were recorded every 3 days during 3 weeks.

RESULTS AND DISCUSSION

The germination rates of the 7 species under trial are presented in Table 1.

Grewia flavescens and *Colophospermum mopane* displayed the highest germination percent (100 and 95%, respectively), followed by *Cadaba* sp. Mopane also started germinating much sooner (3 days after sowing) than any other species. *Boscia foetida* and *Grewia flava* had very low germination, while *Boscia albitrunca* and *Cadaba aphylla* did not germinate at all.

Generally germination was higher in pots with vermiculite than in petri dishes (e.g. 100% vs. 44% in *Grewia flavescens).* This does not appear to be an accidental result, since the same phenomenon was observed in germination tests of other species, and a study might be worthwhile.

Table 1. Propagation of Botswanan species
Germination Rate (%) - Mean of 5 replicates of 5 seeds each

Days from sowing	Boscia albitrunca		Boscia foetida		Cadaba aphylla		Cadaba sp.		Colophosp. mopane		Grewia flava		Grewia flavescens	
	P	V	P	V	P	V	P	V	P	V	P	V	P	V
3	-	-	-	-	-	-	-	-	-	40	-	-	-	-
6		-	-	-	-	-	-	-	60	80	-	-	-	-
9	-	-	-	-	-	-	4	30	65	90	-	-	-	-
12	-	-	-	-	-	-	20	50	70	95	4	4	36	80
15	-	-	4	8	-	-	30	50	76	95	8	4	44	95
18	-	-	4	8	-	-	40	52	76	95	8	4	44	100
24	-	-	4	8	-	-	40	52	76	95	8	4	44	100

Low or no germination does not necessarily indicate special problems in the germination of certain species (such as the need for chemical treatments, for particular environmental conditions, etc.), and in our case may depend on seed quality. Fruits of *Boscia albitrunca* and *B. foetida*, for instance, were still very fresh when collected and their seeds were probably not ripe. For *Cadaba aphylla* and *Grewia flava*, treatments with hot water also did not result in any germination. In view of the limitations in seed amounts and of the suspected seed deficiencies, the experiment will be repeated as soon as mature seeds in larger amounts will be available, so as to enable the use of more seeds per replicate and, if necessary, several treatments

At the conclusion of the germination trial, seedlings were transplanted into plastic bags. In due time they will be transferred to the field for follow-up of their growth, phenology, and adaptation to Negev conditions.

6.

VEGETATIVE PROPAGATION OF SELECTED TYPES OF CHENOPODS

INTRODUCTION

During the visit to the Kumakwane introduction area, it was found that the leaves of *Atriplex nummularia, A. lentiformis* and *A. halimus* had a less salty taste (or not at all) than the plant material commonly cultivated in Israel. In addition, *A. halimus* was morphologically different from the type native to Israel and currently grown there (see Chapter 1 in this Report). Since the three species all displayed the same trait, it appears doubtful that their different taste is genetically controlled, and it seems probable that both the absence of a salty taste and the different chemical composition, if proved, are environmentally determined. It was shown in our previous trials that environmental conditions do affect the chemical composition (including the ash content) and consequently the intake of *Atriplex* spp. by grazing animals (Benjamin and Barkai, 1984; Yaron *et al.* 1984 and 1985; Benjamin and Oren, 1987) whether induced by environmental or by genetic characteristics; increased acceptability by animals could result in a destructive, barely controllable grazing pressure on palatable shrubs. This could be prevented by adopting, as suggested, a "cut and carry" management system, in which grazing is replaced by harvesting.

To verify whether the traits of the Chenopod species growing at Kumakwane are genetically controlled or environmentally or even age affected and to introduce the particular type of *A. halimus* observed there, vegetative methods of propagation must be applied. The rooted plantlets must then be tested under uniform conditions and compared with types currently grown in Israel. The initial results of this work are presented in this report.

MATERIAL AND METHODS

Chemical analyses

Leaves of *A. halimus, A. lentiformis* and *A. nummularia* were collected in the Kumakwane plot on November 24, 1986. Additional samples, including also *Monochlamys albicans,* were collected later, on March 30, 1987. All were dried and sent to our laboratory in Beer-Sheva, where they were ground and tested. Samples were analyzed for crude protein (Kjeldahl), ash (burning organic matter at 500°C), Na, K, Ca and Mg (all with a flame photometer), and Cl (with a chloridometer). Dry matter digestibility was determined in an artificial rumen.

Vegetative propagation

The stems for the vegetative propagation of *Atriplex halimus, A. lentiformis, A. nummularia* and *Monochlamys albicans* were collected by Thusano Lefatsheng in the Kumakwane plot on August 21, 1987, and shipped to Beer-Sheva. On August 28, 1987 two types of cuttings were prepared: cuttings from which all the leaves were removed, and cuttings on which a few leaves were left in their terminal portion. All were treated with a commercial IBA growth regulator powder (Stimuritz 2), inserted in a vermiculite rooting medium and grown in a quarantine plastic house. An automatic overhead misting system was used for watering.

On October 30, 1987, cuttings were removed from the rooting medium and checked for root formation. Rooted plantlets were transplanted into 2 kg plastic bags filled with vermiculite.

Table 1. Chemical composition of Chenopods leaves collected in the Kumakwane Experimental Plot (% DM)

Species	Date collected	Crude protein	Fiber	Ash	Na	K	Mg	Ca	Cl	P	DM digestibility
A. nummularia	24.11.86	29.97		19.80	2.15	5.74	0.10	0.09	2.63	0.17	84
	30.03.87	25.40	13.53	23.14							
A. halimus	24.11.86	27.06		25.20	2.02	8.36	0.09	0.12	3.30	0.15	83
	30.03.87	22.48	16.58	24.87							
A. lentiformis	24.11.86	23.89		17.52	2.10	2.86	0.11	0.19	2.37	0.15	84
	30.03.87	20.18	14.24	23.53							
Monochlamys albicans	30.03.87	26.06	14.78	21.62							

Table 2. Vegetative propagation of four Chenopod species. Rooting % - October 30, 1987

Species	With leaves			Leafless			Total				
	Cutting No.	Rooted No.	Rooted %	Cutting No.	Rooted No.	Rooted %	Cutting No	Rooted No.	Rooted %No.	Alive unrooted No.	Alive unrooted %
A. halimus	52	8	15.4	48	2	4.2	100	10	10.0	1	1.0
A. nummularia	66	26	39.4	48	1	2.1	114	27	23.7	5	4.4
A. lentiformis							100	22	22.0	2	2.0
Monochlamys albicans							100	5	5.0	1	1.0

RESULTS AND DISCUSSION

Chemical composition

Table 1 presents data on the chemical composition of the leaves of the fodder species collected in Kumakwane. (The mineral content of the leaves of the second shipment is being analyzed). The crude protein content appears high, particularly in *A. nummularia* (25-30%), as compared with data from material collected in Israel (Benjamin *et al.*, 1984; Yaron *et al.*, 1984 and 1985). However, its nutritional value will be determined by the content of protein N, which is usually low in the *Atriplex* species. The ash content appears lower than the values usually found in Israel, but still too high for a good quality feed. The Na and Cl contents are lower than in the analyses carried out on the *A. nummularia* grown in Israel, where their percent on a DM basis has ranged between 4.5-7.9 and 7.7-10.4 for Na and Cl, respectively, depending on growth conditions, season and plant age. In contrast, the K content was higher in the Botswanan than in the Israeli material: for *A. nummularia* 5.7% vs. values ranging between 1.1 and 3.3% in Israel. The practical implications of these results are not yet clear, and further analysis and testing to establish their consistency are called for. On the whole, the nutritional value of *A. nummularia* and of the other shrubs grown in Botswana does not appear substantially higher than that of the plant grown in Israel, because of the high ash content. However if the different mineral composition and a different taste will improve palatability, the fodder intake might increase, while the water intake (usually very high when *Atriplex* species are consumed) might decrease. While higher palatability would represent a danger for shrub survival in a grazing system, it could suit a cut and carry management. In both systems reduced water consumption would be an advantage, wherever, as in arid areas, drinking water supply is a crucial problem.

Rooting of cuttings

Table 2 presents the rooting percentage of the four species. A separate record for cuttings with and without leaves was not kept for *A. lentiformis* and *Monoclamys albicans*, and only total rooting is presented. At the end of the experiment a few

cuttings were found still alive, although unrooted. Their data are presented separately.

Rooting was generally poor and, according to the data for *A. halimus* and *A. nummularia*, better when the terminal leaves were not removed.

In due time the rooted plantlets will be transplanted in the field and tested for chemical composition and other traits. If results will indicate special characteristics, they will serve as a stock for supply of selected propagation material.

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7.

CULTIVATION OF *ATRIPLEX NUMMULARIA* UNDER HIGHLY SALINE CONDITIONS

INTRODUCTION

Botswana, Israel and many other arid regions have large tracts heavily affected by salinity. Agricultural exploitation of these areas is possible provided halophytic plant species can be selected which combine high salt resistance with the ability to produce a yield of economic value. Species with a fodder and/or forage potential are frequently regarded as promising candidates for such environments.

The distribution area of *Atriplex halimus* in Israel includes highly saline environments (Zohary, 1966; Waisel and Agami, 1982). Other species of *Atriplex* are also well known halophytes. Several of the latter, introduced into Israel and irrigated with 100% seawater (EC 54 $dS.m^{-1}$), both grew and produced, although their feed quality deteriorated (Pasternak *et al.*, 1985). In view of the fact that it had performed well under dryland conditions in non-saline environments displaying large edible biomass production, relatively high crude protein content, and ability to recover after grazing (Benjamin *et al*, 1987; Forti *et al.*, 1987), *A. nummularia* was chosen for the initial cultivation experiments without irrigation under saline conditions.

MATERIALS AND METHODS

The plot selected for the experiment (0.5 ha) is located at the margins of the fields of the Neot Hakikar farm south of the Dead Sea. Because of the high water table and of drainage problems, it was excluded from the areas suited for intensive, irrigated agriculture (mostly out-of-season vegetables). The site is about 400 m below sea level and is characterized by hot dry summers and mild winters, low relative air

humidity, and low and erratic rainfall (mean annual average ~50 mm) in the cold season. Soils are often coarse, the groundwater is saline, and the water table, as mentioned, is high, and lies at seasonally variable depths. The ecological conditions enable the growth of a relatively dense and tall vegetation which stays green throughout the year.

Soil preparation

The vegetation of the experimental plot consisted chiefly of *Suaeda monoica, Tamarix* sp. and *Phragmites communis*. They were mechanically cleared and furrows 25-30 cm deep and spaced about 3 m from each other were opened to remove the uppermost soil layer which was affected by highest salinity (Table 1). A drip irrigation pipe was laid along 14 of the 17 furrows prepared. Drippers spaced 0.5 m and releasing 2 L water per hour were used. Three rows served as controls and were not irrigated.

Soil tests

Before planting, soil tests in the SE and the NW corners of the plot as well as in its center were carried out. Along the profile samples were generally taken from each 30 cm sections down to 120 cm, except when relevant changes in texture were observed in intermediate layers. Samples were tested for texture, water content and electroconductivity. The same procedure was used in later tests.

Species

Sixteen of the seventeen rows were planted with *Atriplex nummularia* and row 10 with *A. barclayana*. A few available seedlings of *A. canescens* were also planted. All plantlets were grown in the Institute's Nursery in Beer-Sheva in speedling trays and were one year old at time of planting.

Planting

Planting was done on July 15, 1987. Speedlings spaced about 1.5 m apart were planted in the bottom of the furrows. Except for the control (rows 2, 9 and 16), all were irrigated with fresh water soon after planting and then at intervals in the following 10 days. In total, the equivalent of 80 mm water was applied. No additional irrigations were given later. A replacement planting in the control rows was carried out on December 22, 1987 in rain moistened soil. No water was applied.

Establishment and growth

A first establishment survey was carried out on August 16, 1988, one month after planting, and an additional one on December 12, 1988. In the first, only survival was recorded; in the second, plants were also estimated for development, using a relative growth index scale (1= very weak; 6 = excellent). The mean sizes for each development class were determined by measuring height and spread of sample plants.

RESULTS AND DISCUSSION

Soil characteristics

The soil characteristics (texture, water content and salinity) are presented in Table 1. Salinity was always high reaching the highest values in the upper soil layers and decreasing with depth. Soil moisture increased with depth, up to saturation. Texture was generally sandy, often with heavier layers at variable depths along the profile. In particular the soil of bore 3 showed hydromorphic characteristics in the lowest layers where it was heavy, plastic, water-saturated and of a grey-bluish color (gley).

Plant survival and growth

In Tables 2 and 3 the survival percent one month after planting and an estimate of plant growth after 5 months, respectively, are summarized. In Table 4 the mean sizes of plants according to growth indexes are presented.

Table 1.
Soil texture, water content and electroconductivity. Neot Hakikar, July 8, 1987

Bore No	Depth cm	Texture	Moisture %	EC dSm
1	Surface	Sand	6.1	156
	5-30	Sand	5.6	29
	30-50	Sand	10.1	46
	50-60	Loamy sand	15.0	57
	60-75	Loam + clayey loam	19.0	57
	75-90	Silty clayey loam (~30% clay)	NM*	63
	90-105	Loamy sand	NM	40
	105-120	Sand	NM	34
2	Surface	Sandy loam	3.0	147
	5-30	Sandy loam	10.8	111
	30-60	Sand	14.9	47
	60-90	Sand	NM	36
	90-110	Loamy sand	NM	33
	110-120	Sand	NM	33
3	Surface	Sand	2.0	131
	5-30	Silty loam	21.8	88
	30-50	Sandy loam	NM	89
	50-80	Sand	NM	67
	80-90	Sandy loam	NM	48
	90-120	Silty loam (~30% clay)	NM	26

NM = Not measured, since moisture was high (~ to water saturation %), EC in these cases was measured with no need to add distilled water to the soil paste.

No plants survived in the non-irrigated control rows. Survival in the other rows varied according to species and location. The few *A. canescens* planted cannot be

regarded as a reliable sample. They were still alive in the second survey, but their performance (growth and health) was very poor. *A. nummularia* displayed fair survival (37.5%) and a largely variable development over short distances. Most of the plants (about 58%) were confined to the small size range (1-2) and 42% to class 3-6, with a few plants reaching remarkable dimensions. After the period of establishment, mortality stopped and survivors are in excellent shape as to color, health and vigor. Mortality and large growth variability can be related to soil characteristics, but more tests are to be carried out to verify this hypothesis. *A. barclayana* displayed the best performance (61.9% survival) and fair development, with 46% of the survivors in the 3-4 classes; it should be stressed, however, that the sample was relatively small and not distributed evenly over the plot. Because of the different habit the mean sizes of *A. nummularia* presented in Table 4 are not appropriate for *A. barclayana*.

Table 2.
Plant survival one month after planting. Neot Hakikar, August 16, 1987

	Total survival							Survival, controls excluded			
Species	Planted	Fair		Weak		Total		Planted	Fair	Weak	Total
	No.	No	%	No	%	No.	%	No.	%	%	%
A. nummularia	1058	170	16.1	200	18.9	370	35.0	858	19.8	23.3	43.1
A. barclayana	63	22	34.9	17	27.0	39	61.9	63	34.9	27.0	61.9
A. canescens	5	3	60.0	1	20.0	4	80.0	4	75.0	25.0	100.0
Total	1126	195	17.3	218	19.4	413	36.7	925	21.0	23.6	44.5

Table 3.
Plant survival and growth 5 months after planting. Neot Hakikar, December 12, 1987*

Species	Total planted	Dead		Survival and Growth**													
				1		2		3		4		5		6		Total	
	No.	No.	%	No	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
A. nummularia	858	536	62.5	101	11.8	85	9.9	103	12.0	28	3.3	4	0.5	1	0.1	322	37.5
A. barclayana	63	24	38.1	11	17.5	10	15.9	15	23.8	3	4.8	0		0		39	61.9
A. canescens	4	0	0	3	75.0	1	25.0	0		0		0		0		4	100.0
Total	925	560	60.5	115	12.4	96	10.4	118	12.8	31	3.4	4	0.4	1	0.1	365	39.5

*Data do not include the three control rows, where no survival occurred
**Growth according to an index scale from 1 (very small) to 6 (excellent). For the corresponding mean sizes, see Table 4.

Table 4. Mean dimensions of Atriplex nummularia according to growth indexes. Neot Hakikar, December 12, 1987.

Index	Mean height cm ± SD	Mean width cm± SD	Index	Mean height cm± SD	Mean width cm ± SD
1	14.0 ± 2.24	5.0 ± 0.0	4	48.7 ± 2.3	34.4 ± 6.2
2	29.0 ± 2.24	14.0 ± 4.2	5	65.0 ± 5.8	43.7 ± 7.5
3	39.4 ± 3.20	21.0 ± 3.7	6 (one plant only)	80.0	70.0

CONCLUSIONS

The preliminary trials conducted in 1987 show that plant material with potential for growth under the highly saline conditions of the region south of the Dead Sea is available. However, it is necessary to develop agrotechniques which can yield better results and if possible do away with irrigation altogether.

It is surmised that the wide variations observed in the survival and growth of plants are due to changes in soil characteristics over small distances; the factors responsible for the variability need to be investigated further.

After establishment, both *A. nummularia* and *A. barclayana* developed fairly well. Establishment appears a major problem. Irrigation with fresh water immediately after planting improved results. No later additional irrigation has so far proved to be necessary. The irrigation methods could be improved by a water application before and not only after planting to wash salt into deeper layers. However water, if available, is a rare and precious commodity in arid areas and even if brackish instead of fresh water could be used, its application requires equipment and work, whose costs could be not justified for a few applications to a crop of low economic value. An alternative method for improved establishment could be the physiological adjustment of plantlets in the nursery to gradually increasing salinity levels and their subsequent transplanting without watering. If applied in the naturally moist salty soils that are frequent in desert areas, this method, if successful, could contribute significantly to the utilization of salt affected areas, for which no alternative uses other than cultivation of halophytic fodder plants appear possible. This method will be tested next year.

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