REPUBLIC OF BOTSWANA

MINISTRY OF AGRICULTURE
DEPARTMENT OF AGRICULTURAL RESEARCH

ANNUAL REPORT FOR THE DIVISION OF ARABLE CROPS RESEARCH 1936/87

AGRICULTURAL RESEARCH STATION
SEBELE
BOTSWANA
MAY 1988

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Table 2 : <u>MUNGBEAN VARIETY TRIAL NO 2 1986/87 - RESULTS ACROSS 2 LOCATIONS</u>.

Varieties	Plant height (cm)	Pod yield Kg/ha	Seed yield Kg/ha	Pod lenght (cm)	Weight 1000 seed (g)	Seed yield range Duncan test
LOCAL	34.0	170.4	104.2	6.6	48.0	J
VC 3178 A	28.5	630.0	400.5	7.7	70.6	A
VC 2768 A	29.0	597.3	384.3	8.4	66.7	AB
VC 3004 A	27.6	582.1	369.8	8.2	71.3	ABC
VC 3061 A	27.7	587.2	350.3	8.7	72.0	ABCD
V 3726	25.8	489.6	3[illegible]5.4	8.5	78.6	ABCD
VC 2771 A	25.1	526.2	321.9	8.1	75.3	ABCDE
VC 1973 A	28.8	489.5	313.8	8.4	69.3	ABCDE
V 3476	29.7	525.7	312.3	8.0	64.5	ABCDE
VC 3012 B	26.5	483.1	303.7	7.3	61.3	ABCDE
VC 2750 A	28.3	495.8	284.3	7.8	69.5	BCDEFG
VC 2802 A	26.7	394.4	267.3	8.7	70.4	CDEFG
V 2755 A	36.0	385.8	250.4	8.5	78.4	DEFG
V 2984	23.6	362.2	240.2	7.4	55.5	DEFGH
VC 1628 A	26.5	344.1	219.6	7.9	69.3	EFGHI
V 2010	27.1	322.2	203.0	8.2	73.4	FGHIJ
VC 2754	26.7	326.7	190.5	8.0	73.8	CHIJ
VC 3301	24.4	271.4	177.9	8.1	68.6	GHIJ
VC 2764 A	27.2	276.0	174.0	7.8	70.6	GHIJ
VC 2764 B	28.2	227.7	138.4	7.7	67.9	HIJ
VC 3012 A	27.8	233.5	123.2	7.4	54.8	IJ
Trial mean	27.9	415.3	260.7	8.0	68.1	
SEBELE	27.1	429.1	300.9	7.9	67.1	
GOODHOPE	28.6	401.4	220.5	8.0	69.0	
F Locations (L)	0.57	0.16	4.62	0.18	5.49	
F Varieties (V)	3.53**	10.86**	11.55**	6.27**	10.72**	
F (L)*(V)	0.98	8.67**	7.71**	1.07	2.51**	
LSD Locations	n.s	n.s	n.s	n.s	n.s	
LSD Varieties	5.6	154.3	96.4	0.8	8.7	
LSD Interaction	n.s	218.1	136.4	n.s	12.3	
C.V. (%)	15.26	28.39	28.27	7.25	9.74	

Significant level at 5% (*) or 1% (**).
Duncan's test at 1% level.
Varieties ranked in descending order according to seed yield (kg/ha).

MINISTRY OF AGRICULTURE
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Annual Report for the Division of Arable Crops Research

1986/87

AGRICULTURAL RESEARCH STATION
SEBELE
BOTSWANA
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PREFACE

This report covers the dryland cropping and farming systems research activities of the Division of Arable Crops Research for the 1986/87 season. The report is structured to highlight topics of research, to which there are often contributions from several sources. This means that a more integrated presentation is made, avoiding artificial boundries being created between disciplines or between contributions made through external donor sponsored projects.

Included are also reported the trials on winter wheat varieties and summer field crops both grown under irrigation. A report on the new research site at Pandamatenga is given. The seed multiplication and processing refers to that seed needed for the 1986/87 season, being distributed in the latter half of 1986.

There are five projects currently supporting research, these are:

Farming Systems Research

1) Agricultural Development Ngamiland (ADNP based at Gomare)
2) Agricultural Technology Improvement (ATIP based at both Mahalapye and Francistown)

Collaborative research support

3) Cowpea Improvement (Cowpea CRSP based at Sebele)
4) International Sorghum and Millet (INTSORMIL CRSP based at Sebele)

In cooperation with the Department of Agricultural Field Services

5) Melapo Development (MDP based at Maun)

CONTENTS 1986/87

ACKNOWLEDGEMENTS

Management of the Central Research Station at Sebele was provided by the Estate Management Unit, EMU, from which technical backup was extended to the substations.

The Soils and Plants Analytical Research Service, (SPARS), has been supportive of the Division, especially the Plant Nutrition studies.

The British Government provided support of research officers assigned to the Departmental Establishment. The German Government (through GTZ) funded the Melapo Development Project (MDP) in the Shorobe area of the Okavango. The Swedish Agency for Research Cooperation (SAREC) supported the Agricultural Development - Ngamiland Project (ADNP) based at Gomare. SAREC also provided support to start research into strip tillage methods aimed at evolving a workable system incorporating water catchment, reduced draught requirements and extending the land preperation time. USAID financed the Agricultural Technology Improvement Project (ATIP) which continued research activities in the Mahalapye and Francistown regions; they also provided the services of a Seed Technologist. USAID in collaboration with Colorado State and Michigan State University supported the Collaborative Research Support Programme (CRSP) for Cowpea Improvement and a Collaborative Research Support Programme for Sorghum and Millet (INTSORMIL) with the Kansas State University. IRHO (Paris) supported a research officer to develop the groundnut research programme with emphasis on germplasm evaluation and basic seed production.

Germplasm for testing in Botswana was received from the International Centre for Crop Research in the Semi-Arid Tropics (ICRISAT) - India; The International Institute for Tropical Agriculture (IITA) - Nigeria; The Southern African Regional Commission for the Conservation and Utilization of the Soil (SARCCUS); The Asian Vegetable Research and Development Centre (AVRDC) - Taiwan; The Semi-Arid Food Grain Research for Agricultural Development (SAFGRAD) - Upper Volta; The Ministry of Agriculture - Senegal; The Department of Agricultural Technical Services - RSA and from commercial companies in RSA and Zimbabwe.

The Southern African Centre for Cooperation in Agricultural Research (SACCAR) has been instrumental in enlarging both regional and international contacts made by our staff.

The Botswana Development Corporation continued its support of development costs of a research plot on farm Q023 Pandamatenga. Cotton, sunflower, maize, sorghum, mungbean, castor and soybean have been planted this year.

Training of personnel was made possible by allocations of funds from EEC, USAID, FAO/UNDP, ICRISAT, SAREC, The British Council and the Botswana Government. The Institutes responsible for providing the training are shown on page XI . The help and support provided by the Minister, Assistant Minister and office of the Permanent Secretary of the Ministry of Agriculture is acknowledged.

A special note of acknowledgment should go to the substation managers who have been instrumental in implementing components of the research programmes for most officers and have shared in the triumphs and disappointments of all of us under rather difficult conditions.

This report was prepared on the wordprocessor by J.B. Clifford.

ACRONYMS

AD	Agricultural Demonstrator
ADNP	Agriculture Development Ngamiland Project
ALDEP	Arable Lands Development Programme
ARAP	Accelerated Rainfed Arable Programme
ATIP	Agricultural Technology Improvement Project
AVRDC	The Asian Vegetable Research and Development Centre - Taiwan
BAMB	Botswana Agricultural Marketing Board
BCU	Botswana Cooperative Union
CIMMYT	International Maize and Wheat Improvement Centre - Kenya
CRSP	Collaborative Research Support Programme
DAFS	Department of Agricultural Field Services
DAO	District Agricultural Officer
EEC	European Economic Community
EFSAIP	Evaluation of Farming Systems and Agricultural Implements Project
FAO	Food and Agricultural Organization
GTZ	German Agency for Technical Cooperation
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics - India
IITA	International Institute for Tropical Agriculture - Nigeria
INTSORMIL	The Sorghum/Millet Collaborative Research Support Programme
IRHO	Research Institute for Oil crops (France)
LWMRP	Land and Water Management Research Project (ODA/SADCC)
MDP	Molapo Development Project
RAO	Regional Agricultural Officer
RSA	Republic of South Africa
SACCAR	Southern African Centre for Cooperation in Agricultural Research
SAFGRAD	The Semi-Arid Food Grain Research for Agricultural Development
SAREC	Swedish Agency for Research Cooperation
SARCCUS	Southern African Commission for Conservation and Utilization of the Soil
UNDP	United Nations Development Programme
USAID	United States Agency for International Development

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Agronomist	C. Johnson
Seed Technologist	K. Gold

---

1 Seconded from Division of Planning and Statistics
2 Project in Department of Agricultural Field Services

TRAINING

Training was made available to the following officers during the year at the Centres listed:

P. Ditshipi	B.Sc Agriculture	University of Swaziland
P. Gaosegelwe	M.Sc Agronomy	Kansas State University USA
E. Lele	B.Sc Agric.	Univ. of Seale Hayne U.K
J. Luzani	B.Sc Agronomy	Kansas State University USA
D. Machacha	B.Sc Hortic.	Univ. of Bath/U.K
E. Makhwaje	B.Sc. Agric.	Univ. of Seale Hayne U.K
C. Manthe	Ph.D Entomology	Texas A&M Univ./USA/Botswana
N. Mokete	B.Sc Agriculture	Nebraska USA
P. Monyamane	Assoc. Degree Hort.	New Mexico USA
E. Mosarwe	B.Sc Agriculture	University of Swaziland
C. Patrick	M.Sc Mechanization	Silsoe U.K.
T. Mbulawa	Diploma Agric.	B.A.C. - Botswana
M. Moamogwe	Diploma Agric.	B.A.C. - Botswana
M. Rukero	Diploma Agric.	B.A.C. - Botswana

INTRODUCTION

Another very difficult season with generally low rainfall, exceptionally badly distributed in Western Ngamiland where the farmers crops were dried off at the pre-flowering stage, (327 mm. total at Etsha).

The Germplasm office has taken charge of all crop collections guaranteeing their safety into the future. In support of IITA a collection trip was undertaken in the east and north of the country for wild species of vigna (cowpea) and Oryzae (rice). (Section 1). The Department places considerable emphasis on germplasm collection and preservation as the highly variable growing condition that pertains to Botswana has generated local land races of exceptional genetic flexibility of response. Emphasis has been placed upon sorghum and cowpeas, both species commanding an important place in the farming system.

Formal breeding work and selection continues with sorghum, millet, cowpeas and groundnut. The chosen varieties are now being subject to better scrutiny for the characteristics favoured by farmers. For too long plant selection criteria have dismissed consumer preferences in favour of agronomic traits and yield potential. Such a policy has led to the 'establishment' of certain standard varieties of quite unacceptable characteristics, a situation now to be redressed (Section 2).

Parallel to the breeding programmes has been vigorous screening of sorghum varieties for the parasitic weed Striga asiatica and sugarcane aphid resistance and cowpea varieties for the parasitic weed Alectra vogelii and aphid borne mosaic virus (CAMV) resistance. On all four fronts material has been identified with the desired genetic traits and it will be possible to commence breeding there characteristics into agronomically preferred varieties.

Research has been intensified into study of nematodes. It has long been established that there are both crops and wild plant species which act as a host for the root knot nematode. This has lead to a severe nematode build up as a consiquence of intense cropping and inadequate comprehension of nematode population dynamics. On infected land cowpeas and mungbeans have shown spectacular failure but it is believed that the adverse nematode effect is of significance to other crop species as well. (Section 11).

Farmers in the Southern districts have major problems with two dominant weeds; the grass Cynodon dactylon and the broadleaf Datura ferox. Research into their control has provided recommendations on strategy. The Cynodon can be controlled by careful tillage practices while Datura can be controlled by selective herbicides. The herbicide recommended for Datura is particularly suitable as it inhibits post treatment re-germination as well as killing the weed. It also can be safely used on land customarily planted to sorghum (Section 12).

Machinary for weed control still receives attention. In view of the stearage difficulties often encountered with light weight, narrow bladed sweep, cultivators, the machinary development unit is trying to develop weeders based on horizontal blades, cutting just below the soil surface. Chain trailed and pole drawn equipment is now being tested by the farming systems research teams (Section 9).

Of special interest has been development of a practical suit of equipment suitable to achieve a permanent strip, water harvesting, sytem. The experience has not been easy and several fundamental modifications have been required to the equipment. However it now works tolerably well and before any further modification is effected it is thought best to test the system to check whether water concentrated into the riplines is actually available to and exploited by the crop, (Section 9.6).

Any increase in water availability to the plants may soon bring into play nutrient constraints, generally the soils are of low fertility, especially the sandy soils so favoured during low rainfall years, and the value of increasing major nutrients (P & N) can be marked in exploiting the moisture supply, (see Section 8.3).

Heavily cropped, low buffered, sandy soils can also develop quite severe low pH problems, especially aluminium. Remedial treatment of the soil coupled with cultivar testing of known Al tolerant sorghum varieties has also been examined, (Section 2.3).

With the adverse impact of successive drought years on dryland agriculture Government policy has been shifted to improve irrigation capacity.

Irrigated crop trials have been started at Etsha (Section 14) to complement the improved methodology developed for traditional Melapo farming both in the west and south east of the Okavango delta. (Section 15.2).

The hydrological interventions needed to improve water security to the Melapo areas in the South east are described in details (Section 15.3), as are some of the soil and water considerations which should be borne in mind where melapo soils are to be used under irrigation (Section 15.4).

The irrigated wheat variety trials conducted at Etsha during winter of 1987 have been very encouraging requiring some 800 mm of water to raise a crop of up to 8 tons/ha.

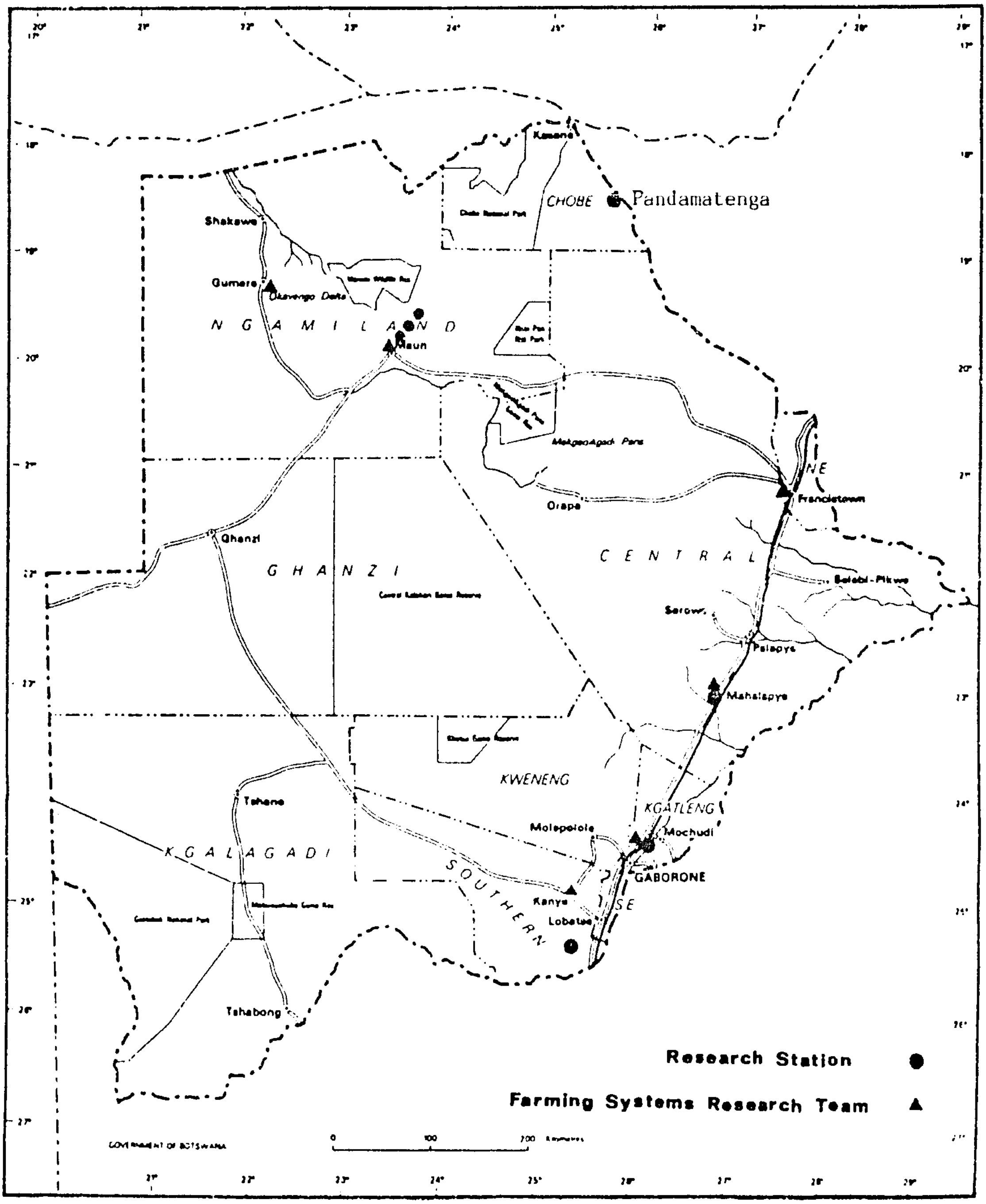
Another big venture being pushed forward by Government policy are the Chobe Commercial Farms at Pandamatenga. There is an obvious role for research to play in support of this scheme and donor funds to generate a research station have been offered from the E.E.C. Until such time that this project can be implemented close collaboration with the BDC have been enabled a modest start to the research (Section 16).

However small holder mixed livestock and arable farming is the way of life for many of the rural people and much effort and resources are channelled into the investigation of ways to improve their farming system. Cognizance of not only the technological but social problems are very important. Attention is also being focused on the perception and aspirations of farmers so that proper interventions in the arable sector can be generated (Section 13).

Finally some 6000 tons (6,000,000 kg) of seed were collected, tested, cleaned and packed by the Seed Multiplication Unit. Over 5 000 tons was sorghum, 80% of which was Segaolane. Maize was in short supply as was cowpea. Very little groundnuts were distributed for sale the bulk of the seed (16 tons) being used for seed multiplication for the 1988/89 season - (Section 17).

Fig. 1 shows Research Stations and deployment of Farming Systems Research teams.

FIG. I



Kasane
CHOBE
Pandamatenga
Shakawe
Gumare
Okavango Delta
N G A M I L A N D
Maun
Makgadikgadi Pans
Orapa
NE
Francistown
Ghanzi
G H A N Z I
C E N T R A L
Selebi-Pikwe
Serowe
Palapye
Mahalapye
KWENENG
Tshane
KGATLENG
Molepolole
Mochudi
K G A L A G A D I
SOUTHERN
GABORONE
Kanye
SE
Lobatse
Tshabong
Research Station
Farming Systems Research Team
GOVERNMENT OF BOTSWANA

Section 1. GENETIC RESOURCES

SUMMARY

A total of 2,138 germplasm lines mostly comprising the main crops grown in Botswana are maintained. More than half of these are cowpeas.

Activities in the year were centred on the description, multiplication and rejuvenation of the germplasm. The exotic sorghums exhibited eliteness in both flowering and maturity. No data was recorded on pearl millet due to the small sample population but a lot of variability was noticed. The variability suggested that a larger plant number is necessary especially to score for qualitative characters. Also no data except for laboratory measurements was recorded for groundnuts and bambara groundnuts. For bambara groundnuts, the following was noted; that characterisation could not be based on seed colour only and that like vegetative characteristics did not mean similar pod and seed characteristics.

1.1 INTRODUCTION

Germplasm is an important natural resource for current and future crop improvement programmes. It provides the building stocks (genes) from which new improved varieties can be created. In Botswana, a lot of genetic diversity (possibly a result of adaptability, gene recombinations and mutations) exists. This is apparent from the local collections of germplasm that are maintained in the research station.

The main source of this germplasm is the traditional farmer. These farmers are currently benefiting from government assistance by having available improved seed varieties and new technology packages which combined threaten to replace the indigenous genetic material. Improved varieties, although assuring high yields, most often have a narrow genetic base aimed at responding to specific agrometereological conditions and may be very susceptible to extremes in natural conditions, e.g. drought and other adverse climatic conditions, resulting in partial or complete failure of a crop. New technology packages often are designed around the use of improved seed to take full advantage of its potential. It is for these reasons that it is necessary to collect and preserve indigenous germplasm in order to establish a future genetic base.

The objectives of the germplasm section are to collect, describe, store, catalogue and maintain germplasm of sorghum, pearl millet, cowpeas, groundnuts and bambara groundnuts. And lastly to distribute them (germplasm) to the different crop research programmes. It is also planned to maintain forage species as the livestock industry is an intergral part to the farming economy of the country. Genetic erosion of the natural grasslands which is encouraged by overgrazing and the persistent drought, among others, would be a blow to the ecosystem and more to the livestock industry.

1.1.1 COLLECTIONS

Targets for collections are the main cropping areas along the eastern part of the country. In these areas there is the greatest likelihood of genetic variability because the people living there are of different ethnic backgrounds. It is suggested that people of different backgrounds may apply very different selection pressures and as a result, the end products may be far removed morphologically from the original common parent. Also that a large human population, with the associated change in the ecosystem, generates more genetic variability.

Collections have been made in the Southern, Kgatleng, Kweneng, Central, North-east and Ngamiland districts. These have registered about 1,644 accessions (Table 1). Also received have been 494 promising crop varieties from outside Botswana; these are termed as exotic germplasm as indicated in Table 1.

Table 1. NUMBERS OF LOCAL AND EXOTIC GERMPLASM ACCESSIONS.

Crop	No. of local accessions	No. of exotic accessions
Sorghum	166	71
Pearl millet	61	11
Finger millet	6	-
Cowpeas	852	362
Bambara groundnuts	380	-
Groundnuts	179	25
Beans(Phaselous sp.)	-	25
Total	1,644	494

The sorghum, pearl millet, finger millet and some bambara groundnuts collections were made in collaboration with ICRISAT and IBPGR whilst the cowpeas were mostly collected by the Botswana Cowpea Project. The cowpea exotic germplasm was mainly received from IITA-Nigeria and the U.S.A. The exotic groundnuts and beans are from New Zealand. The others were collected by local scientists.

1.1.2 GERMPLASM DISTRIBUTION AND UTILIZATION

Some seed samples(51) of the sorghum germplasm were issued to the Weed Research programme for screening against witchweed (*Striga spp.*). Among the sorghum germplasm of local and foreign origin that were planted for characterisation and preliminary evaluation 30 were selected by the Plant Breeding programme because of their desirable morpho-agronomic traits.

1.2 **Sorghum Germplasm**

BACKGROUND

Sorghum is the main staple diet for large populations in the country. Most of the sorghums maintained from the country collections so far achieved, belong to the durra-kafir race. Almost all of them are reported to be photo-period insensitive and thus rendering them available for use in most parts of the world.

1.2.1 CHARACTERISATION AND PRELIMINARY EVALUATION

A total of 237 accessions, 166 local and 71 of exotic origin were planted on single 5m row plots for characterisation and preliminary evaluation. In order to obtain as much information as possible from each individual accession, a series of characters provided in the ICRISAT/IBPGR Sorghum Descriptor List of 1984 were used. The accessions were grown under favourable conditions so as to obtain an optimal expression of the characters. As the most limiting factor was rain, the plants were irrigated.

There were many significant differences in characters, eg. plant height, days to flowering, inflorescence size, grain number per panicle, etc. Not all the data for characters were observed for all the accessions because of either lack of timing or lack of a representative character.

The exotic germplasm was generally early flowering whilst the local was medium to late flowering. The flowering character ranged from 41 to 125 days. The Durra and Guinea races are late maturing. The minimum and maximum plant height are 65 and 260 cm respectively. It is reported that short maturing varieties have a short stature, therefore, it is common sense to conclude that these type of varieties will flower earlier. In this respect a correlation analysis was done between plant height and days to flowering and this was high (0.65). The number of grains per panicle were also variable, ranging from 379 to 4136. Accession REB 135 had the highest grain number/panicle but a hundred grain weight of 2.17 g, below the average. The accessions belonging to the durra race have the highest 100 grain weights but their grain number/panicle were relatively low.

The grain filling occured under selfing bags with heavy infestation of aphids(Aphis spp.). It is therefore encouraging that most of the accessions showed adequate aphid tolerance. The durra(membranaceum) race lines exhibited high susceptibility to stalkborers (Chilo spp.), either very susceptible to aphids which could have prevented grain formation or have partial self-incompatability. This is probable because the grain filling for this race was generally low. Since the plants were bagged at flowering this obviously did not permit the movement of pollen between the plants and thus the self-incompatability phenomenon is asserted.

1.3 Pearl millet Germplasm

BACKGROUND

Like sorghum, pearl millet is not a new crop. It has been cultivated in the country for a long time now despite its concentration to only a few districts, namely, Kgatleng, North East and Ngamiland. If there is any diversity of this crop these would be the main collecting areas.

1.3.1 CHARACTERISATION, PRELIMINARY EVALUATION AND SEED MULTIPLICATION /REJUVENATION

About 68 accessions were planted for characterisation, preliminary evaluation and seed increase. The establishment was generally poor and those that emerged showed some variation; obvious were the spike shape, bristle length, plant height, tillering attitude and number of days to flowering. The variation was observed within and between the plots. The limited plant numbers of 10 per 5 m row made the characterisation procedure difficult to be carried out. For example, accession REBP 34 showed the following; bristleless lanceolate and bristled oblanceolate spikes. Because of these difficulties, the characterisation and evaluation were postponed until the next cropping season. The variation in a sample could be better assessed by planting a large population and thus more plants to work with. A larger plant population would definitely represent the heterogeneous nature of the accessions without imposing biased data and genetic drifts as concerning seed increase. As it has been mentioned, as pearl millet is heterogeneous in nature or an outbreeder (85%), the variation per accession was not a surprise. Each seed sown could have had a different male parent and thus a different genotype.

To prevent cross-pollination and protect the genetic constitution of the individual accessions, each plant was bagged.

Even though no data was recorded about disease and insect infestations, most of the accessions were heavily infested by spider mites (Tetranychus spp.) and corn crickets (Hetrode papus) at or during the late stages of development. The corn crickets specifically caused a lot of damage to the spikes despite the insecticides that were used which were only temporarily effective.

1.4 Finger millet Germplasm

BACKGROUND

Finger millet is grown in the north-eastern parts of the country. It is traditionally used for brewing beer.

The finger millet accessions (5) that were planted failed to germinate or emerge. This could have been impeded by the hard top-soil crust and/or too deep seeding depth. Therefore, no observations could be made. Shallow sowing will be tried next season.

1.5 Groundnuts Germplasm

BACKGROUND

Groundnuts are not native to Africa, therefore whatever is collected and maintained in the country is an introduced variety, a result of either genetic recombinations or genetic mutations. Groundnut growing is concentrated in the commercial farms of the Barolongs and in small-scale farms in and around the Tati area. Most of the types grown are the spanish erect because of their capability to produce yield under dry conditions and their requirement of less labour as opposed to the spreading types. Figures from samples collected in 1986 show that about 60% were spanish, 32% virginia and 8% valencia types.

1.5.1 CHARACTERISATION, PRELIMINARY EVALUATION AND SEED MULTIPLICATION

All the groundnut germplasm was of local origin. A total of 88 accessions was planted in single row plots 6m long and spacing between plants at 20 cm. The plants were irrigated whenever necessary to supplement the rainfall.

It was evident during the growing season that some accessions were mixtures. Because of this, no representative data could be recorded. Some of the characters that were observed in the field to verify the mixture within an accession were plant pigmentation, days to flowering, growth habit, leaf size, leaf shape, and the branching pattern. Therefore, similar looking plants were harvested together, then classified as a new accession. A single plant was randomly selected from each of this to facilitate the characterisation exercise planned for the next cropping season. In this we are sure that each accession would be genetically homogenous, that is, each plant in an accession having essentially the same genetic constitution. However, the original sample was also kept as a separate accession for future reference. Some patchy necrosis of plants was observed and this could have been caused by termites (Reticulitermes spp.). The maturity ranged from about 105 (erect types) to 150 days (spreading types).

A continuation of characterisation of pod and seed characteristics of all the accessions was carried out. Pod characteristics scored for were reticulation, constriction, size, beak, and number of seeds per pod. Seed characteristics noted were colour, size (length and width). The most common pods were the two-seeded with slight to prominent reticulation, slight to very deep constriction, and slight to very prominent beak. The seeds were generally pink with few having reddish colour.

The accessions producing pods with very deep constrictions proved to be high yielders, that is based on the number of pods and pod weight per plant. Since very deep constriction is an undesirable character it could be changed through breeding probably to a variety with slight or no pod constriction.

1.6 **Bambara groundnuts Germplasm**

BACKGROUND

This is another crop which has always featured among the arable crops across the country. Yields are minimal and apart from a little research done in the late 1940'ies and early 1960'ies, the crop has been largely neglected. Quite a considerable variation of this crop exists and it is credited for its good performance under marginal conditions where other crops will not survive.

1.6.1 CHARACTERISATION, PRELIMINARY EVALUATION AND SEED MULTIPLICATION

At least 56 samples of the bambara groundnuts collected in 1986 were sorted sample by sample. The sorting was based on seed colour of which the colour composition was similar for most of the samples. The following seed colours were common, namely; tan, brown, cream (with a small blackeye), tan (with dark brown specks), cream (with a red/orange eye) cream (with a large extended blackeye), cream (with large extended red eye) and cream (with spreading black dots on the ends). Through the procedure of the seed characterisation a total of about 380 distinctly different morphotypes were separated. These will be treated as accessions for the moment but as each original sample had a limited seed quantity almost all of the accessions ended up with very few seed.

All (380) of the accessions were planted in 6m single row plots. About 103 had enough seed to be characterised and the others which did not have enough seed were specifically planted for seed increase.

No effective data could be recorded from the field as most of the accessions were infested by some type of disease or insects that severely damaged the vegetative parts. In addition, the soil was not suitable for the crop in that it was hard and made it almost impossible for the pods to be set. Because of these problems, very few plant /accessions were able to set pods.

The seeds produced from the few accessions still are not enough, therefore seed increase will be carried on next season.

Variation was noticed on the foliage - most of the accessions had some purple pigmentation (anthocyanin) at the base of the plant, some had complete purple stems whilst others had complete purple stems and leaf veination. Only a few had no purple pigmentation. Leaf variation in size and shape was also obvious, the most obvious difference was between the small and broad lanceolate types.

Some of the accessions showed different plant characteristics despite similar seed colours. For instance, the growth habit showed that there were erect and spreading types and this character was different across accessions with the same seed colour. This indicated that the characterisation could not be based on seed colour only.

It was observed that the colour of the stem was not correlated to the pod colour or even seed colour. Some plants with some pigmentation produced creamish pods with white seeds. One wholly purple pigmented accession (024A) had black pods with speckled brown seeds. This also showed that in spite of the similarities in the vegetative parts between plants there was a big difference in pod and seed characteristics produced by plants.

Section 2. SORGHUM AND MILLET

2.1 Sorghum and millet improvement

The sorghum and millet breeding programme was maintained with breeding materials concentrated at Sebele and Mahalapye.

A common comparative variety trial was used at five locations in Botswana. This trial included local cultivars already released by SMU, local and exotic selections, some commercial hybrids and two selections from breeding populations.

The results of the comparative variety trial is given in Table 1. Further discussion will only be possible when the responsible officer returns from higher degree studies.

Table 1. SORGHUM MILLET IMPROVEMENT TRIALS 1986/87

Cultivar	Yield of Grain (kg/ha)				
	Sebele	Goodhope	Mahalapye	Matsaudi	Pandamatenga
Marupantse	208	752	251	250	70
Town	41	693	64	167	117
65D	922	1553	302	242	242
Segaolane	696	939	420	362	158
Kanye Std	170	565	160	417	120
SDS 2106	884	994	430	280	150
SDS 1785	242	846	227	258	117
SDS 1491	814	756	667	517	283
SDS 381	519	924	359	290	208
SDS 1505	1086	1267	420	571	267
SDS 1506	626	1005	474	267	283
SDS 2729	907	994	638	396	158
SDS 3182	782	773	577	237	233
BOT 79	1143	856	374	321	167
SDS 3953	1069	1038	267	450	210
SDS 2884	684	790	253	533	142
SDS 1591	342	239	352	367	167
SDS 1406	915	866	492	179	280
SDS 1412	593	857	194	461	258
SDS 1998	64	521	272	342	187
SDS 2583	1052	938	389	268	183
SDS 3742	605	1013	143	229	225
Serere 6A	1051	1582	364	204	458
ICTP 8203	998	1551	449	237	383
ICTP 8202	1310	1540	537	188	400
PNR 8311	1432	1339	332	283	408
PNR 8384	1084	1007	541	183	317
PNR 8544	904	1204	452	229	267
PNR 8469	894	1118	354	325	100
SP1BR	520	840	232	554	67
SP2B	762	1475	307	471	110
Mean	720.0	1004.4	364.3	325.7	217.3
SD	351.5	3004.0	144.4	119.2	101.5

* Millet

2.2 Sorghum varietal Acceptability

More attention is being given to the 'quality' of sorghum selections in terms of their acceptability by the food processing industry and consumer. A consumer acceptance trial was conducted using a cross section of employees found at Sebele.

Participants were involved in all aspects of preparation, cooking and sampling sorghum porridge. 15 varieties were used in the test and the following characteristics were graded on a scale from 1 to 3:

a) Endosperm texture
b) Flour colour
c) Porridge colour
d) Porridge appearance
e) Porridge taste

The results of the test are presented in table 2.

Table 2. CONSUMER PREFERENCE FOR DIFFERING SORGHUM VARIETIES

Cultivar type	Cultivar	Endosperm texture	Flour colour	Porridge colour	Porridge appearance	Porridge Taste
Landrace	Segaolane	3	3	3	2+	3+
Landrace	Marupantse	3	2	2	2	2
Landrace	Town	3	1	1	1	1
Exotic selection	BOT 79	3	2	3	2+	3+
Exotic selection	SDS 2106	1	1	1	1	2
Exotic selection	SDS 1491	2	2	2	2	3+
Exotic selection	SDS 1406	2	1	1	1	1
Exotic selection	SDS 1412	2	1	1	1	1
Exotic selection	SDS 2583	2	2	2	1	1
Exotic selection	SDS 1505	1	1	1	1	3
Exotic selection	65D	2	1	2	2+	3
SP1BR*		2	2	1	1	2
SP2B*		2	1	1	2	2
PNR 8311**		2	2	2	2+	3+
PNR 8544**		3	1	1	1	1

Key to table 2

Taste (Porridge)	Appearance (Porridge)	Endosperm texture	Flour colour
1 Very tasty	1 Attractive	1 Chalky	1 White
2 Tasty	2 Not attractive	2 Soft	2 Dull
3 Not tasty	3 Extremely unattractive	3 hard	3 Grey

* Product of current breeding programme, mixed population.
** Commercial hybrid

2.2.1 **Sorghum acceptability to the farmers**

The Sebele sorghum programme has been considering the release of BOT-79, a selected sorghum variety. The objectives of this trial were to: (a) assess the performance of BOT-79 when broadcast planted by farmers, and (b) provide an opportunity for farmers to give feedback to on-station researchers.

Materials and Methods

BOT-79 was compared to three released varieties -- Segaolane, 65-D and Marupantsi. Farmers were given 333.3 grams of each variety and were asked to plant the seed in adjacent plots on the same day. The ordering of the four plots was randomized. All management and implementation was left to the farmers.

Emergence stand counts were taken by ATIP staff. Harvest stand counts were taken on a sub-set of plots. Farmers harvested the plots and threshed the heads. ATIP staff weighed the grain. Approximately six to eight weeks after harvesting was complete, farmers were asked to rank the four varieties with respect to several characteristics.

Results

The trial was correctly implemented by 19 farmers. Eleven farmers obtained some yield. Harvest stand counts were taken on five of the eleven harvested trials. A summary of results is presented in Table 1.

The number of Segaolane plants established was nearly 50 percent higher than for the other varieties. There was no significant difference among the other varieties. All yields were low, due to drought and the abandonment of several sites. Segaolane yielded the best, followed by BOT-79. However, the estimate of BOT-79 yields based on farmers' harvesting may overstate yields relative to the other varieties. At the five sites where harvest counts were taken, only 25 percent of the BOT-79 plants were productive. The heads per productive plant ratio was also lower for BOT-79 compared to either Segaolane or 65-D. On the other hand, BOT-79 did have large heads with large grains.

The farmers reported that Segaolane and Marupantsi were more drought tolerant than the other two varieties. 65-D was noted to have the smallest heads and the smallest grain size, both of which are negative features of 65-D. BOT-79 was viewed as an intermediate variety with respect to most growing and yield features. However, BOT-79 was top ranked with reference to threshing ease, porridge taste, and colour. Segaolane was seen as the easiest to stamp. According to the farmers, 65-D was the most difficult to stamp and had the worst taste. Overall, Segaolane was the top ranked, followed by BOT-79. 65-D was by far the lowest ranked.

Discussion

Based on the results of this limited trial, there would appear to be few reasons why BOT-79 should be released. Overall, Segaolane still is a superior variety. BOT-79 does have some desired consumer characteristics which might be of advantage to the Sebele sorghum program. However, the consumer taste results in this study differ from those of the Sebele programme. The reasons for this need further attention.

Perhaps the clearest conclusion from the trial is than 65-D is not well liked. This confirms results from earlier ATIP surveys. A substitute quick maturing variety, with processing and taste characteristics more approximating Segaolane or BOT-79, would benefit Mahalapye area farmers.

Table 3: 1986-87 SORGHUM VARIETY TRIAL, MAHALAPYE AREA: EMERGENCE AND YIELD RESULTS

	SEGAOLANE	65-D	BOT-79	MARUPANTSI
Plot Size (sq. m.)/a	327	332	338	322
Emergence Stand ('000 plants/ha)	46.5	32.8	28.1	31.2
Yield (kgs/ha):				
All Plots	129	96	100	83
Harvested Plots	224	166	173	143
Harvest Counts:/b				
'000 Plants/ha	60.2	43.6	43.4	40.4
Pct. Productive	53	56	25	35
Height (cms.)	76	68	70	66
'000 Heads	36.2	27.7	11.5	14.2
Heads/Plant	1.13	1.14	1.07	1.00

a. Plots size, emergence stands and yields are based on 19 fields.
b. Harvest counts are based on five fields.

2.3 Variability Among Sorghum Varieties for Uptake of Elements and Yield Under Acid Soil Field Conditions

INTRODUCTION

Soils are limed to neutralize acidity and hopefully enhance plant growth by reducing the availability of toxic levels of aluminium and manganese while increasing the availability of calcium and magnesium. The economic liming may not be the absolute answer to reducing toxic levels of aluminium when production costs are considered. The purpose of the experiment was to ascertain if liming was economical even to the small farmer.

The selection and breeding of plants adapted to acid soils is one approach which can improve crop production on these soils.

The nutritional balance of sorghum plants grown under acid soil stress conditions is one crucial consideration when developing plants which are adapted to these infertile problem soils. (Absorption of elements varies with each variety and ultimately affects plant growth and development). Information on relative uptake of elements for sorghum plants grown in the field on acid soil is lacking.

Sorghum varieties differ in their ability to take up elements under stress conditions (Duncan 1981). No single element concentration comparison can be used when evaluating varieties for tolerance or susceptibility to acid soils. The complete nutritional profile of the plant, dry weight production and visual rating scheme can be combined to provide reasonable and reliable comparisons of varieties grown under field conditions of acid soil stress. Field screening for tolerance to stress is complicated by the fact that plant growth is seldom determined solely by the stress factor concerned. Numerous other controlled variables and interactions between these variables and the stress facter study also exert an influence. Performance criteria based on absolute growth may not, therefore, necessarily reflect tolerance or susceptibility to the stress factor of interest particularly if the population under test is genetically diverse. Classification or ratings based on performance, growth in presence of stress, relative to that in the absence of stress are more suitable but are not entirely satisfactory. High yielders regardless of relative performance may be chosen, but the nature of the response is itself affected by uncontrolled climatic effects. Pollination of sorghum is sensitive to heat and moisture stress at flowering and populations of varying maturity are likely to be differentially affected by short duration droughts near flowering.

An experiment was designed to determine the plant yield response of the sorghum varieties grown under different levels of Acid Soil pH (lime and no lime applied), the pattern of leaf nutrient accumulation and their acid soil field tolerance rating.

2.3.1 MATERIALS AND METHODS:

Table 1: SELECTED PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE TRIAL SITE

Site	Particle Size (%)		Exchangeable cations meq/100g					
0-30cm	Sand	Clay	Ca	Mg	K	Al(ppm)	pH($CaCl_2$)	OC%
Sebele (B33)	78.4	14.9	0.94	1.86	0.52	0.9	4.1	0.35
Goodhope	87.7	7.9	0.48	0.51	0.16	32	3.6	0.20
Morwa I	80.3	12.4	1.89	1.01	0.42	10	3.9	0.34
Morwa II	80.1	12.6	3.24	1.39	0.52	12	3.7	0.29

The soil in the four locations chosen was sandy loam, selected properties of the soil are shown in table 1.

During September 1985, two replications of two acidity, regimes (40 x 5 m main plot for Sebele and Goodhope, 20 x 5 m for Morwa I and II) were established using gypsum (Morwa and Sebele) and calcium carbonate in Goodhope at the rate of 0; 2 t/ha Sebele and 0; 3 t/ha Goodhope and Morwa. Later fertilizer 2:3:2 was applied at 120 kg/ha in all the sites. Ten randomly allocated varieties were planted at Goodhope and Sebele on 5 x 3 m subplot, while in Morwa only five varieties were planted. The plant spacing was 0,25 m and the rows were 0,75 m apart.

In Goodhope the experiment failed. More lime was applied on this and left fallow until the following season. In Novembr 1986 the experiment was repeated in all the four sites and the results are reported. The parameters observed were Acid tolerance, dry matter and grain production.

Leaf samples consisted of one leaf (third leaf from the top of the plant) from each plant in the 2-harvest rows. Leaves were collected in 1986/87 season only and were analysed at Sebele.

2.3.2. RESULTS AND DISCUSSION

In Sebele total precipitation during the growing season was not adequate. A period of low rainfall in December and January resulted in moisture stress. The higher evaporative demand of better grown plants and more complete utilization of topsoil moisture led to plants on limed soil being considerably more stressed than those on zero lime soil during the critical flowering period. It's possible, therefore, that yield responses to lime may have been confounded by stress effects at flowering. The other sites did not suffer from moisture stress. Lime had no significant effect on the plant population on all sites. This was also observed in the previous season.

An Acid Soil Field Tolerance Rating scheme,(ASFTR) developed (by Duncan 1981) was used to rate the sorghum varieties.

ASFTR = (Dry plant weight) - (sum of elemental interaction ratios (Ca/Mg, K/Ca, K/Mg, Ca/P, Mg/P, K/P, Al/Fe, Al/Mn, Fe/Mn)) x (Visual stress rating). The results appear on table 2a and 2b.

Table 2. ACID SOIL FIELD TOLERANCE RATING OF SORGHUM

a) Goodhope and Sebele

Variety	Block 33 L	Block 33 NL	Goodhope L	Goodhope NL	Variety	Block 33 L	Block 33 NL	Goodhope L	Goodhope NL
Segaolane	4.60	3.70	2.50	0.40	Sc283	2.95	0.65	-	-
Sc56	2.05	4.90	2.00	1.00	GP1R	2.75	3.30	2.50	2.50
GP140	8.25	3.80	3.50	2.50	65D	4.80	5.30	3.00	1.50
Sc599-6	9.35	3.60	0.75	0.35	Sc599-11E	-	-	2.50	0.60
Marupantse	5.55	5.25	2.00	2.00	8D	3.50	1.70	2.50	0.50
GP142	4.40	3.30	3.00	0.65					

b) in Morwa I and Morwa II

Variety	Morwa I L	Morwa I NL	Morwa II L	Morwa II N
Segaolane	7.80	4.65	3.60	3.45
GP140	8.45	5.05	-	-
Sc 599-6	-	-	5.80	2.45
Sc 56	-	-	5.55	8.50
Marupantse	-	-	6.40	8.45
GP142	4.35	6.25	-	-
Sc 283	1.05	1.90	-	-
GP1R	-	-	4.90	4.70
8D	7.83	4.65	-	-

* Rating below 1.00 indicates poor variety performance under stress conditions.
-- Variety not grown on a site. L = Lime; NL = No lime applied

In Sebele the lime plots Sc 599-6 and GP140 were tolerant to the stress conditions while 65D and Marupantse gave high tolerance in the plots without limo. Marupantse performed well overall in both lime regimes while Sc 283 was susceptible in lime and unlimed plots. Other varieties like Segaolane, GP142 and GP1R ranked the same in both lime treatments.

Goodhope has GP140 as the most tolerant variety in lime and unlimed plots. GP142 and GP1R fall in the second place in the lime and unlimed plots respectively. The susceptible variety is Sc 599-6.

In the Morwa I site GP140 gives an outstanding performance in the lime plots followed by 8D while in the unlimed it takes second position preceeded by GP142. Segaolane's performance is the same in both lime regimes, while Sc283 is still the least tolerant variety.

In Morwa II, Marupantse takes the first position followed by Sc599-6 in the lime plots, while in the unlimed plots it takes the second position out performed by Sc56.

In the trial in Sebele dry mattor production was significantly different among the varieties. The most was produced by Sc 599-6 followed by GP140 in limed plots. Marupantse had the same amount in limed and unlimed plots. In Goodhope varieties gave significant differences at the 5% level. In limed plots Marupantse produced the most dry matter folowed by 65D, GP142, GP1R and GP140 in a descending order. The least production was given by 8D though not significantly different from 65D, GP142, Sc56, Segaolane and Sc599-11e.

Varietal differences were significant at 10% in Morwa I. Variety Sc140 produced the most dry matter in all lime treatments. In the lime plots it is closely followed by Segaolane, 8D and GP142 in a descending order. The least producer in both treatments was Sc283.

In Morwa II varietal differences were not significantly different, though Sc56 and Marupantse produced the most dry matter in the no lime plots. In the limed plots the best producers were Sc299-6 and Sc56 respectively.

The results are summarised in Table 3.

Table 3. <u>DRY MATTER PRODUCTION PATTERNS OF SORGHUM VARIETIES (kg/2 rows)</u>

<u>Block 33</u>							
	Lime:	Sc599-6	GP140	Marupantse	GP142	Segaolane	65D
		7.25	5.25	4.50	4.00	3.75	3.25
	No Lime	Marupantse	65D	GP142	Segaolane	Sc599-6	GP140
		5.00	4.00	2.75	2.50	2.50	2.50
<u>Goodhope</u>							
	Lime	Marupantse	65D	GP142	GP1R	GP140	
		3.39	2.57	2.52	2.12	2.11	
	No Lime	65D	GP142	Sc56	Segaolane	Sc599-11e	8D
		0.94	0.85	0.80	0.80	0.32	0.10
<u>Morwa I</u>							
	Lime	GP140	Segaolane	8D	GP142	Sc 283	
		5.00	4.65	4.05	4.00	0.85	
	No Lime	GP142	GP140	8D	Segaolane	Sc283	
		4.40	3.85	2.90	2.30	1.40	
<u>Morwa II</u>							
	Lime	Sc56	Sc299-6	Marupantse	GP1R	Segaolane	
		4.00	3.90	3.40	3.00	2.45	
	No Lime	Marupantse	Sc56	GP1R	Segaolane	Sc299-6	
		5.15	5.05	3.10	2.00	1.70	

Sebele trial variety 65D produced the most heads in all the lime treatments followed by Segaolane and GP142. In the no lime treatment Sc56 is the second best head producer while in the lime treatment Sc299-6 takes position 3. Marupantse and Sc283 did not head in limed and unlimed plots respectively.

The best producer in Goodhope was in the lime plots GP142, followed by GP1R, Segaolane and GP140 in a descending order. In no lime plots GP1R has the most heads followed by GP140, Marupantse and 65D. The variety with lowest head weight is Sc 599-6 and Sc599-11e in the no lime treatment.

In Morwa I Segaolane and GP142 produced the most heads in the lime plots while GP142 did better than others in the no lime plots also. the poor producer was the variety Sc283. The differences are not significantly different among the varieties in the same lime regime.

Even in Morwa II head production was low. In the lime plots all the varieties produced similar head weights. In no lime plots Sc16 and Marupantsi did well while Sc599-6 did not produce much heads.

Table 4. HEAD WEIGHT OF SORGHUM VARIETIES WITH TWO LIME RATES AND FOUR LOCATIONS

Variety	Block 33 L	Block 33 NL	Goodhope L	Goodhope NL	Morwa I L	Morwa I NL	Morwa II L	Morwa II NL
	(kg/2 rows harvested)							
Segaolane	.147	.120	1.13	0.46	0.79	0.34	0.58	0.44
Sc56	.067	.182	0.76	0.38	-	-	0.55	0.79
GP140	.092	.067	1.09	0.79	0.51	0.31	-	-
Sc599-6	.140	.062	0.36	0.47	-	-	0.39	0.16
Marupantse	0	.047	0.88	0.69	-	-	0.44	0.85
GP142	.120	.100	1.27	0.31	0.75	0.57	-	-
Sc283	.027	0	-	-	0.10	0.04	-	-
GP1R	.007	.067	1.24	0.95	-	-	0.52	0.50
65D	.372	.247	0.97	0.6[illegible]	-	-	-	-
Sc299-11e	-	-	0.54	0.09	-	-	-	-
8D	.090	.040	0.71	0.07	0.58	0.25	-	-

L = Lime; NL = No Lime Applied; - variety not grown in a location

In Sebele 65D produced the most grain in all the lime treatments while Sc56 produced more grain in the lime plots only. Segaolane grain production was the same in the lime and no lime plots. The variety which produced the most grain in Goodhope was GP1R though not significantly different from GP142, Segaolane, 65D and GP140 in the lime plots.

In the no lime plots GP140 produced the most grain followed closely by GP1R, while Sc599-11e had the least grain production in all lime treatments. Grain production in Morwa was low with no significant differences among the varieties in the same lime regime. All the same Sc283 produced the least grain in lime and no lime plots. Similar to Morwa I results, the grain yield in Morwa II was low. There are no varietal differences with the lime treatment, though Sc599-6 had the lowest yield in the no lime plots.

Table 5. GRAIN WEIGHT OF SORGHUM VARIETIES IN DIFFERENT LOCATIONS (kg/3 rows)

Variety	Block 33 L	Block 33 NL	Goodhope L	Goodhope NL	Morwa I L	Morwa I NL	Morwa II L	Morwa II NL
Segaolane	.09	.08	0.36	0.87	0.60	0.28	0.45	0.33
Sc56	.03	.11	0.30	0.59	-	-	0.43	0.54
GP140	.06	.05	0.85	0.72	0.38	0.24	-	-
Sc599-6	.07	.03	0.41	0.28	-	-	0.28	0.15
Marupantse	0	.02	0.51	0.67	-	-	0.23	0.51
GP142	.08	.05	0.34	0.[illegible]	0.60	0.44	-	-
Sc283	.01	0	-	-	0.09	0.04	-	-
GP1R	.02	.03	0.66	1.08	-	-	0.40	0.38
65D	.19	.15	0.48	0.81	-	-	-	-
Sc599-11e	-	-	0.48	0.81	-	-	-	-
8D	.05	0.08	0.54	0.29	0.17	-	-	-

L = Lime applied; NL = No Lime; variety not grown on a location

Table 6. EFFECT OF LIME ON SELECTED CHEMICAL PROPERTIES

Lime Applied t/ha	Exchangeable cations meq/100 g soil Ca	Mg	K	pH	OC %	P (ppm)	Al (ppm)	Mn (ppm)
Block 33				$CaCl^2$				
0	3.51	0.95	0.19	4.6	0.52	25.25	24.3	23.85
2	3.77	0.91	0.24	5.00	0.25	15.25	13.9	20.92
Goodhope				H^2O				
0	9.98	1.23	1.58	4.3	-	50.1	599	21.5
6	18,01	6.41	2.27	6.5	-	28.9	495	52.2
Morwa I				$CaCl^2$				
0	1.32	0.80	-	4.1	-	560.4	-	-
3	2.38	0.62	-	4.0		129.7	-	-
Morwa II								
0	1.99	0.38	-	4.1	-	210.3	-	-
3	0.85	0.60	-	4.2	-	89.8	-	-

- Data not available

Looking at the pH of the four sites taken after the experiment was harvested. Goodhope is the only site which had a higher pH on the limed plots, due to the second application of lime, when the trial failed in '85/'86. Probably the results on the other sites did not show the effect of lime because 2t/ha and 3t/ha was not enough to raise the pH significantly.

Table 7. VARIETAL PERFORMANCE FOR VARIOUS TRAITS IN DIFFERENT LOCATIONS

		Block 33	Goodhope	Morwa I	Morwa II
Plant stand:	1)	Marupantse	Marupantse	Segaolane	Marupantse
	2)	Sc599-6	GP140	8D	Sc56/Segaolane
	3)	Sc283	Sc599-11E/8D	Sc283	Sc 599-6
Acid Tolerance:	1)	Marupantse/65D	GP140	GP140	Marupantse
	2)	GP140/Sc299-6	65D	8D/GP142	Sc56
	3)	Sc283	Sc 599-6	Sc283	Segaolane
Dry Matter:	1)	Marupantse	Marupantse	GP140/GP142	Sc56
	2)	Sc599-6	GP140/65D	Segaolane/8D	Marupantse
	3)	Sc283	Sc599-6	Sc283	Segaolane
Grain prod:	1)	65D	GP1R/GP140	GP142	Sc56
	2)	Sc56/Segaolane	GP142/65D	Segaolane	Segaolane/GP1R
	3)	Sc283/ Marupantse	Sc599-11e	Sc283	Sc599-6

1 = best 2 = Medium 3 = Poorest

Remarks:

1. Marupantse produces a good plant stand, it's acid tolerant and produces a lot of dry matter but does not produce much grain.

2. Segaolane is not good in many traits but is a good grain yielder

3. Introduced varieties GP140, GP142 and Sc56 are good grain and dry matter producers, also they are acid tolerant.

2.3.3. CONCLUSIONS

The reported findings are encouraging though not conclusive yet. Two levels of lime are not enough to show the effect of lime in comparison with the acid tolerance of the varieties. Drought and heat stress confound the effect of low pH making it difficult to single out the acid soil stress. The trial sites in Goodhope and Lebele will be maintained for long term experiments while another experiment with several rates of lime will be designed and laid out.

2.4 Sorghum Variety Response to Population

INTRODUCTION

Sorghum variety selection has traditionally relied upon cross seasonal and cross locational comparisons to determine which varieties exhibit the desired characteristics. Though highly efficient in screening out large numbers of unsuited varieties it is limited in its application to identify which genetic traits confer the most suitable characteristics to cope with the yield potential extremes pertaining to arable production in Botswana. Although this will require a collaborative programme between Breeders, Agronomists and the crop protection staff the present limitation may prove to be a constraint to developing the most appropriate parameters to apply for the breeding programme.

Of paramount importance to yield production is the availability of water and in the case of Botswana the conservative husbandry of this moisture so as to optimize the successful fruiting, of the plant. One of the most powerful tools available to both farmer and researcher is the manipulation of interplant competition through plant population, the effects of which can be so dominant as to mask all other potential yield influencing factors. In their conclusions on sorghum spacing studies the Dryland Farming Research Scheme (DLFRS) recommend "that" comparisons of promising new varieties be conducted routinely at more than one population (at say 20,000, 50,000 and 120,000 plants/ha) (DLFRS, 1985).

The information reported here is an extract from a more elaborate nutrition/population/variety/moisture use study but helps to contribute to this approach.

METHODS

At two sites, Sebele and Goodhope, four sorghum varieties were hand planted at five populations (3,10,30,60 and 120+ thousand plants per hectare). Over six combinations of N and P fertilizer. For economy of space and minimizing border effects, variety is a split plot of population (adjusted by equidistance between plants and row) and a systematic design adopted for the layout of population blocks. Disregarding the fertilizer treatments this offered 18 replicates for the population variety interaction at each site.

The sorghum varieties were chosen in consultation with the sorghum breeder for their qualities as representatives of differing growth habits. They were:

Segaolane	-	Medium season, purpose tillering
65D	-	Short season, short height
BOT 79	-	Medium to long season, reduced tillering
PNR 8311	-	Very well adapted commercial hybrid

The results have yet to be subjected to a complete analysis as raw data on aspects of nutrient uptake have still to be completed by the laboratory.

RESULTS AND DISCUSSION

The main effects of variety on total dry matter production and grain yield are presented in table 1.

This shows the general superiority of conditions for production at Goodhope over those at Sebele and the superiority of the commercial hybrid PNR 8311 over the other three varieties tested.

Table 1. MAIN EFFECTS OF VARIETY COMPARISONS ON DRY MATTER PRODUCTION AND GRAIN YIELDS

	Goodhope				Sebele (D46)			
	Total DM	Grain Yield (Kg/ha)			Total DM	Grain Yield (Kg/ha)		
Variety	Kg/ha	Total	Main hd	Tillers	Kg/ha	Total	Main hd	Tillers
BOT 79	2573	433	238	195	1342	246	156	90
65D	2569	629	277	352	1334	320	192	128
Segaolane	3130	793	343	439	1656	429	237	191
PNR 3811	3781	1043	508	531	1767	438	296	144
LSD(1%)	743	295	145	194				

The population ranges tested (3-120,000 (+) plants/ha) exerted a strongly significant effect on drymatter, total yield, yield from the manheads, tillers and their number. However the variety by phosphorous interaction was far less pronounced, producing significant effects (at the 1% level) on the number and yields of both mainheads and tiller heads. The interaction on the total yield just failed to reach the 5% level of significance. This implied that the different varieties did not all respond to the same degree with changes in population but the overall trend was comparable.

Table 2 gives the tabulated means of the interaction between variety and population for Goodhope. This shows the overall peak grain yield/ha occurred below 30,000 plant/ha and dropped off extremely rapidly with higher plant competition. It is of note that up to 10,000 plants/ha only a modest drop in harvest index was recorded.

TABLE 2. EFFECT OF PLANT POPULATION ON TOTAL GRAIN YIELD AND HARVEST INDEX OF FOUR SORGHUM VARIETIES AT GOODHOPE (kg/ha)

	Sorghum populations (X 1000/ha)				
Variety	3	10	30	60	120(+)
BOT 79	579(31.7)*	1032(27.1)	471(14.4)	82 (3.9)	0(0)
65D	613(37.9)	1330(37.1)	950(26.3)	250(12.1)	2(.1)
Segaolane	863(34.5)	1553(34.7)	1230(30.6)	307(11.2)	9(.5)
PNR8311	1142(44.7)	1947(41.4)	1426(28.0)	511(12.8)	42(1.6)

* % Harvest index in brackets

Examining the Goodhope data showed that with the exception of BOT 79 all varieties gave a maximum main mainhead yield production at 30,000 but maximum tiller head yield from tillers exceeded that achieved from mainheads. The variety BOT 79 exhibited a dual disadvantage of having a maximum mainhead yield at only 10,000 plants/ha coupled with a very sharp drop in tiller yields at 30,000 and above.

In conclusion the outstanding variety was the hybrid PNR8311 which performed very well over all population ranges. As all varieties showed similar yield patterns it would appear to be valid to continue to make meaningful selections based upon multilocation, cross seasonal uniform population comparisons. A population of 20-30,000 plants/ha appears to be appropriate.

The vigour of tillering producing large heads, nearly synchronizing in maturity with the main head must be a very valuable trait by which varieties should be classified.

Section 3. WHEAT

SUMMARY

Wheat variety trials were conducted at four sites in Botswana, using a selection of 12 varieties from South Africa and 6 from Zimbabwe.

The crop was grown without trouble at only one site, Etsha, where yields were very encouraging, above 7.5 t/ha, requiring between 700 - 900 mm of irrigation over 120 days.

The varieties Inia and Zaragoza again performed reliably as did the new variety Loerie. The short season variety SST 25 was suprisingly poor at Etsha. The Zimbabwe varieties were not adequatly tested this season due to the late arrival of seed, compounded by some technical problems.

Biological control of the greenbug aphid was noted to be very effective in Botswana.

INTRODUCTION

Thirty five to thirty six thousand tons of wheat were used at Bolux, Ramotswa during the year 1987. 325 tons were received from BDC farm at Talana - the rest was imported from Saudi Arabia, Australia and Argentina. About 80% is milled for flour the rest going to produce stock feed. Exports do occur but have been limited to a few hundreds of tons this year.

Irrigated wheat variety trials were conducted at four locations in Botswana Sebele, Kasane, Maun and Etsha. Seed for the trials was obtained from South Africa (12 varieties) and Zimbabwe (6 varieties).

The trials followed the format of the SARWEIN regional wheat trials from South Africa. Seed rate was 70 kg/ha, row spacing 30 cm, 6 rows of 5 m per entry (with the exception of Sebele), and four replicates. A randomized complete block design was used for the full 18 entries at all sites except at Etsha.

The objective of the Kasane, Maun and Etsha trials was to compare varietal performance and obtain data on yield expectation should commercial production be developed in the future. No trial was planted at Talana Farms as planting took place took place before seed for the trials arrived. However following last years experience (Anon 1987 page 17) a pre-production planting of the variety Palmiet was made, giving a yield of 5.29 t/ha. The principal varieties employed for production were Elize and SST 25 giving 3.8 and 5.6 t/ha. the Elize was badly raided by elephants. Elephants particularly liked a .2 ha trial planting of the Zimbabwean variety Sengwa reducing it to yield less than 2t/ha.

The trial at Sebele was sown so as to be available to the departmental entomologist and pathologist should any of the entries develop plant protection problems.

3.1 SITE FEATURES

As always there were site specific features detailed below:-

Etsha:-

The trial was planted on the Agricultural Development Ngamiland Project (ADNP irrigated sand veldt plot adjacent to Etsha 6. Water is drawn 1 km from one of the small permanent Lagoons on the Western fringe of the Okavango Delta. The plot was developed in January 1987, the wheat following maize as the second crop off that soil. Two separate trials had to be planted due to the late arrival of the Zimbabwean entries. Each trial was set in the middle of a 0.7 ha irrigable unit sown to the wheat variety SST 44 (broadcast planted) and served by 32 sprinklers delivering almost 6 mm/hr.

The 12 entries supplied by SARWEIN were planted on 23rd May, harvested on maturity, which occurred 109-132 days later. The 6 entries from Zimbabwe were planted on the 29th of May, harvested on maturity, which occurred 112-123 days later.

The irrigation schedule was determined to meet the actual demand. Free surface water evaporation, Epan, (read daily) was given a pan factor, K pan, set at 0.6. The crop factor, K crop, estimating the crop water demand as influenced by stage of growth was started at 0.46 from planting, rising to 1.05 at 38 days and then declined after flowering (89 days) to a value of 0.25 at maturity. Using these factors on assessment of the daily evapotranspiration (ETa) is possible with the equation ETa = Epan x Kpan x K crop in mm water/day. (For more detail see Section 12).

The SARWEIN trial was very well irrigated. Assuming an irrigation efficiency of 0.7 the 1082 mm delivered would have provided 700-900 mm dependent upon location under the sprinklers. During the same period the Epan was 881 and the calculated ETa only 364 mm. Taking a' allowance for preplanting irrigation, this still implies a net gain of approximately 400 mm water/m of soil. The soil has an available water holding capacity of 100 mm/m.

Clearly the ETa is grossly under estimated and one source of error will probably be the K pan set at 0.6. A value of 0.8 brings Eta up to 485, which though more reasonable is still too low to fit the facts.

The Zimbabwean varieties were established after a pre irrigation of 74 mm but there after were very lightly irrigated, on a greater than weekly schedule, at an average of 31 mm/week up to flowering (76 days). This was an inadequate rate and left the crop severely water stressed with a theoretical negative soil moisture deficit. From the commencement of flowering an additional 543 mm of water was applied and strong recovery achieved. Including the preplanting irrigation a total of 887 mm was applied equating to 620 mm applied water during a period when the E pan was 835 mm. Yield data for the SARWEIN trial was trial collected on reps 1, 2 and 4; plant height, flowering date and maturity on rep 2 and the grain moisture content and density on representative samples.

An error at planting the SARWEIN trial resulted in each block being planted with the same randomizination. Fortunately the major plot effect was compensated by block layout.

Kasane:-

The trial was planted in the North Western corner of the main arable block at BDC's Chobe Farm. The trial was attacked by subterranian termites which devoured the plant root systems and severely damaged the trial. On a visit to the site, 26th August, it was decided to abandon the trial as full grown flowering plants were dieing from termite attack and the cummulative damage was in excess of 70%, despite two applications of a termaticide.

The termite species responsible is thought to have been the fungus cultivating Hodontoternes transvaalensis and the presence of numerous large nests adjacent to the site (on the outside of the fence) the reason for the severity of attack.

Maun (Irrigation Management Plot):-

The trial is sited within the sandy - sandy clay Molapo adjacent to the Rice Project. Water is drawn from the Boro river which, this year, fell dry in February until mid June when the rising flood finally discharged into the south eastern fringe of the delta. The lateness of the flood delayed planting to the he beginning of July which is about six weeks later than thought desirable.

Irrigation was in raised basins each holding 3 entries. Water was delivered by a 5 hp centrifugal pump into earth distribution ditches, the flow being controlled to each basin by spade. By timing pumping times and monitoring discharge rates irrigation application can be estimated. Allowances had to be made for those basins with slow water infiltration rates and in some cases excess water had to be drained from the basin to prevent waterlogging.

The trial consisted of 18 entries, with four replicates, requiring 24 basins. Each basin was equipped with a neutron probe tube, monitored weekly.

Planting was on the 2nd July and emergence started on the 10th. Irrigation was scheduled for weekly intervals, harvesting starting by 20th October by which time these had been a total of 755 mm applied in 16 separate irrigations with a mean application of 47 mm.

Sebele:-

A two ha block was prepared for winter irrigation of wheat, variety SST44, using domestic effluent applied in furrows of 100 m length, 75 cms apart. One corner of the plot was reserved for the variety trial which was hand planted with twin rows on each ridge, giving three paired rows per entry. The variety trial was planted on the 16th June while the main field was a single row/ridge.

The only fertilizer applied was 56 kg/ha N/ha applied as LAN on day 59.

The mainfield of SST44 was cut for hay at the milk doe stage. The variety trial was kept on till maturity with limited water. Observations on pests, diseases and flowering time were made, yield data from only 45% of the plots was collected due to bird pest problems.

3.1.2 RESULTS AND DISCUSSION

Etsha:-

The differential planting dates, irrigation frequencies and ammounts makes any direct comparison of the SARWEIN and Zimbabwean varieties impossible. The yield obtained from the SARWEIN trial are very impressive, Table 1. This is all the more marked when the low moisture content of the seed is considered (mean value of 8.7) which would have raised the mean yield to over 11 tons/ha if harvest had been possible at 14% MC, the maximum value permitted for milling. The yields were so high that a second field check was made to ensure that only the 4 centre rows of each plot were harvested. This was confirmed, the yields recorded are correct and through accurate weighing are potentially within 2 kg/ha of the true/ha yield assessment (dependent upon threshing accuracy).

Inia and SST25 were amongst the first to flower, with SST25 maturing first. However the very short % of grain fill, (17%), implies a rather belated interpretation of flowering. Nonetheless there is a surprising difference in yield perforance between the two varieties with Inia significantly out yielding SST25 as well as Gamtoos, SST66 and Palmiet.

Table 1. SARWEIN WHEAT VARIETY TRIAL RESULTS FROM ETSHA

Variety	Entry No.	Plant height	Days to flowering	Days to maturity	GFP* %	Yield kg/ha	Grain MC %	Grain density kg/hl
Inia	1	93	90	110	18.2	8670	8.4	77
Loerie	9	92	103	124	16.9	8390	8.9	79
13SP 83/5	5	92	96	132	27.3	8220	8.6	78
BSP 84/7	12		90	124	27.4	8182	8.7	79
BSP 84/2	11		90	126	25.4	7900	8.8	79
Zaragoza	6		103	132	22.0	7700	8.5	79
W83/10	10	89	101	126	24.8	7320	8.3	76
SST44	3	97	96	131	26.7	7260	8.5	78
Gamtoos	8	93	103	124	16.9	6840	9.1	80
SST 66	4		92	124	25.8	6830	8.7	78
Palmiet	7	89	94	117	24.5	5950	8.6	80
SST 25	2	92	90	109	17.4	4700	9.5	80
Mean			95.7	123	22.8	7285	8.7	78.6
LSD 5%						2318		
CV.						15.3		

* GFP = % of growth as the grain fill period.

The markedly poor performance of SST25 was not anti pated from yield appearance and is a worrying result as SST25 would be the ecommended short season variety based upon previous trials at Kasane and Ta na when Inia had been disappointing (Anon 1987 pages 17 & 18). However i 's of note that

Inia was the top performer at Maun in 1986 as well as in the present trial so has good potential.

The uniformity of stand was excellent and none of the varieties suffered from lodging or shatter. Mild frost was recorded between days 47 to 57 without causing any damage. The crop was virtually free of pests and diseases, occassional plants suffered from head smut or stalk borer. Leaf rust was at a lower incidence than stem rust being at about 10 and 50%, respectively at the beginning of maturity. There were no major bird problem and damage is assessed as having been uniform and below 10%.

The Zimbabwean varieties were considerably disadvantaged by a poor irrigation schedule prior to flowering. This held back the commencement of flowering and in part explains the very brief period between flowering and maturity. (Field interpretation probably adding to this problem).

Table 2: ZIMBABWEAN WHEAT VARIETY TRIAL RESULTS FROM ETSHA

Variety	Entry No.	Plant height cm	Days to flowering	Days to maturity	GF* %	Yield kg/ha	Grain MC %	Grain density kg/hl
Angwa	17	54	102	118	13.5	4810	8.8	78
Gwebe	18	48	103	112	8.0	4610	8.8	79
Chiwore	13	59	99	115	13.9	4200	8.7	79
Rusape	14	61	51	115	20.0	3810	8.9	79
Sengwa	15	91	103	123	16.3	3580	8.5	78
Torim 78	16	53	104	119	12.6	3350	8.7	80.5
Mean		54	101	117	14.1	3888	8.7	78.9
LSD 5%						1721		
CV%						20.8		

However it was very impressive how the crop recovered and though the yields are low, remains encouraging. The potential advantage of the Zimbabwean short straw varieties will be in their ability to cope with high fertilization rates. At Etsha the phosphates, potassium and some nitrogen were applied with seedbed. Small and frequent top dressings of nitrogen being applied through the irrigation system. This probably can be raised from the 120 kg N/ha recommended for this trial.

All Zimbabwean entries were recorded as having a heavy incidence of stem rust at the beginning of maturity. This point should be checked in subsequent trials and the nature of the pustule type so obtaining an assessment of intensity. Again leaf rusts were low, less than 10%.

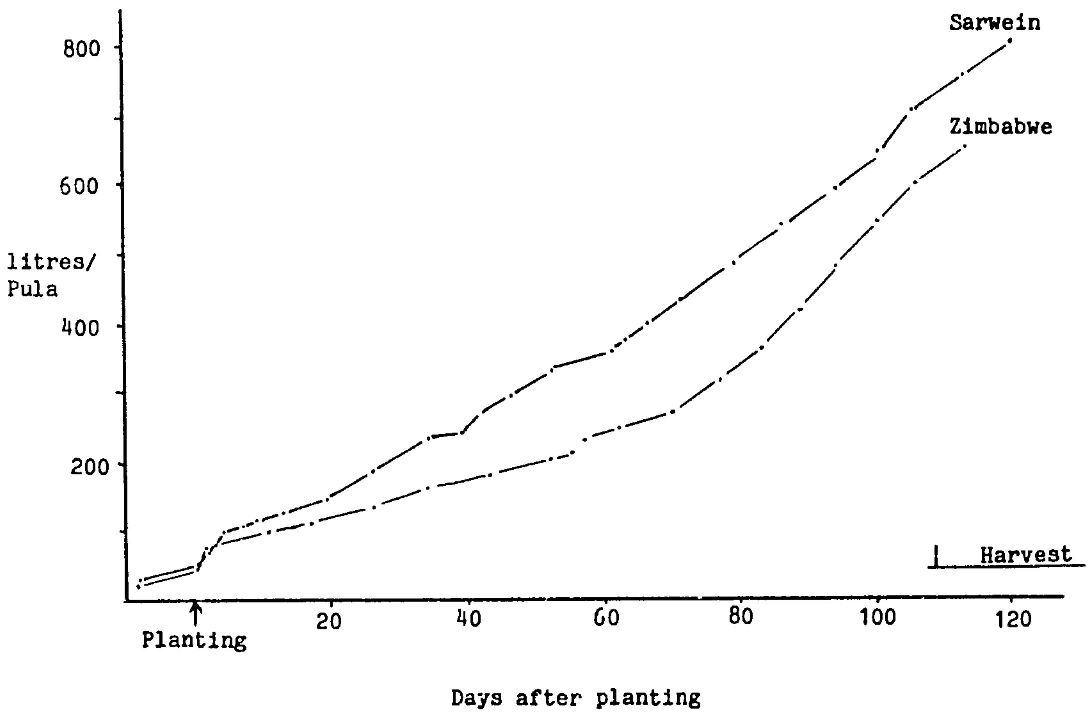
It is strongly recommended to irrigate wheat right up to maturity, rather than allow the maturing crop to dry down the soil profile. This will be especially important in these warm locations where the grain fill period is short. Taking the mean fuel consumption rate of 1 litre per 14 m^3 of water an assessment of fuel requirements for both variety trials is given in Fig 1. Of particular interest is the impact of using long (135) or short (110) season varieties on fuel requirements for irrigation. From the figure it can be seen that a maximum advantage of only 100 litres/ha can be expected which will not warrant the exclusion of longer season varieties if they show superior agronomic features. The analysis of irrigation production costs are

Illustration 1. BRINGING IN THE WHEAT AT ETSHA

Illustration 2. THE THAOGE PROJECT, TO RESTORE WATER AVAILABILITY TO THE NOKANENG
(Molapo and irrigation)

more fully explored in section 15, Agricultural Development Ngamiland Project.

Figure 1. FUEL CONSUMPTION SUPPLYING WATER TO THE SARWEIN AND ZIMBABWE TRIALS AT ETSHA IRRIGATION PLOT. *



*14m3 water pumped per litre of diesel, 1l set at 1 Pula.

Maun:-

The crop had a difficult start owing to problems of establishing a uniform irrigation regime. Water flow within blocks caused some disruption of the planted rows with 'rogue' seeds being washed out of place. Young seedlings attracted the attention of chickens and maturing plants were prayed upon by monkeys. These adversely affected the yields which were again well below potential, (See table 3).

The late planting and warm winter encouraged the crop to flower early on rather short stems, however maturity did not take place till 110 - 125 days from planting. The early varieties, Inia SST25 matured in 112 days, followed shortly by Palmiet and Gamtoos (113 days), however surprisingly the entry Loerie flowered and matured earlier at 56 and 110 days respectively.

Table 3. WHEAT VARIETY PERFORMANCE AT MAUN 1987

Variety	Entry No.	Plant Height cm	Days to Anthesis	Days to Maturity	GFP* %	Yield kg/ha
Zaragoza	6	69	74	125	59	3460
Rusape	14	56	65	118	55	2880
Angwa	17	55	62	114	54	2670
BSP 83/5	5	69	68	119	57	2670
Gamtoos	8	64	65	113	58	2630
SST 44	3	63	67	120	56	2630
W 83/10	10	62	71	117	61	2580
Loerie	9	66	56	110	51	2540
Inia	1	70	62	112	55	2330
SST 25	2	71	59	112	53	2250
Chiwore	13	57	65	116	56	2250
Gwebe	18	59	65	116	56	2240
Palmiet	7	67	62	113	55	2210
BSP 84/7	12	74	71	124	57	2040
Sengwa	15	54	62	115	54	1960
BSP 84/2	11	71	67	118	57	1920
SST 66	4	72	65	117	56	1920
Torim 78	18	52	62	114	54	1710
Mean	-	63.7	64.9	116.1		2440
LSD 5%		8.0	7.3	6.6		1273
CV%		6.3	5.6	2.8		26.0

* GFP = Grain fill period as a % of the total growing period of the variety.

The long season variety Zaragoza flowered only at 74 days, matured at 125 days and was the top yielder. In the Melapo Zaragoza has previously been the top yielder, with 6300 kg/ha, in 1983 (Anon 1984) and second highest yielder, with 4792 kg/ha, in 1986 (Anon 1987).

The Zimbabwean varieties (entry numbers 13-18) were readily recognisable by their very short straw, however, flowering and maturity dates as well as yield was not dissimilar to the SARWEIN entries. On no varieties was there any appreciable disease incidence.

Much better irrigation and agronomic management is needed to test varietal yield potential. Attention must be given to improved fertilization including micro nutrients, (Cu, Zn and B). With water available, heat response after planting will also be examined for irrigated wheat in the melapo.

Sebele:-

The trial at Sebele emerged very well a week after planting, however, as it was some four days behind the rest of the field, and in the corner of the field closest to the boundary of the arable lands it suffered intense damage from guinea fowl during days 10-13 after planting. No plot escaped with less than 40% damage. On some plots the distruction was almost total. The plot was maintained for disease and insect observations, flowering dates and yield from only those plots which had a stand of at least 40%.

As can be seen from table 4 the low grain yields reflect the low plant stand. However flowering data is very reliable, Inia and SST 25 are the first to flower at 80 days with Torim 78 and Gwebe shortly after. Inia showed excellent head exertion and uniformity, an attractive feature if considering the crop for combining. The short straw Zimbabwean varieties would be less attractive in this respect, especially in the case of Angwa having a lot of leaf close to the head. Despite the apparently greater leaf mass produced by the Zimbabwean varieties they showed no greater propensity to wilt than the varieties from SARWEIN. Symptoms of water stress appeared on the variety Palmiet long in advance of any other entry tested.

Disease and insect attack did not develop to any damaging level. In respect to the greenbug aphid, Schizaphis graminum (Rondam.), the situation was potentially damaging but for the efficieny desplayed by natural predation.

Throughout the development of the crop close examination of the leaf canopy revealed the presence of a low incidence of the greenbug aphid. Usually clusters of aphids could be found with a few adults and several juveniles present. Invariabally there was present either the egg or the lavae of Xanthogramma aegyptiium.

This larvae exclusively feeds on aphids and predated preferentially on the greenbug keeping its populations very tightly under control.

Table 4. WHEAT VARIETY TRIAL GROWN WITH DOMESTIC EFFLUENT WATER AT SEBELE

	Entry No.	Height cm	Days to * flowering	Yield kg/ha	Grain MC %	Grain Density	No. of Plot harvested
Inia	1	78	79.5	1580	9.3	76	1
SST 25	2	71	80.5	1780	9.8	77.5	2
SST 44	3	63	92.3	1220	8.7	68	1
SST 66	4	77	86.0	1680	9.1	74.5	2
BSP 83/5	5	59	93.0	1350	8.5	68.5	2
Zaragoza	6	63	96.8	1540	8.9	65.5	2
Palmiet	7	69	85.3	1630	9.5	75.5	1
Gamtoos	8	70	91.0	1490	9.1	70.2	3
Loerie	9	69	92.0	1350	8.9	69.5	1
W83/10	10	59	92.5	1130	9.2	73.0	1
BSP 84/2	11	77	91.3	1000	9.0	67.5	1
BSP 84/7	12	77	90.5	950	8.8	65.8	2
Chiwore	13	49	90.0	1230	9.0	69.0	3
Rusape	14	47	87.3	1500	8.7	70.0	1
Sengwa	15	57	88.8	NA	NA	NA	0
Torim 78	16	57	82.0	1520	9.3	71.8	2
Angwa	17	53	88.3	1560	9.2	70.7	3
Gwebe	18	56	83.3	1510	9.5	72.0	2
Mean		64.0	88.3	1600			
LSD 5%		7.3	5.2	-			
CV.		5.7	2.9	-			

* Days to flowering is recorded at the peak of flower production.

Section 4. GROUNDNUTS AND SUNFLOWER

SUMMARY

Very comprehensive variety trials were conducted involving material from both within and outside the region. The hash cropping condition of the season universally produced low yields with very fews varieties showing greater promise than the selection already made.

The benefit of maintaining high groundnut stands without depressing yield quality is presented and crop establishment improvements through seeddressing demonstrated at farmer level.

Groundnut of the Spanish type are well adapted to the conditions found in Botswana but having a predominance to produce harvestable pods from the first flowers and an absence of seed dormancy at maturity makes it not advisable to mound up the plants.

Sunflower variety trial involving seven varieties across four locations showed the excellent potential of the crop to use accumulated soil moisture. The argument is presented for post christmas planting of the crop especially on heavier soil.

GROUNDNUT (*Arachis hypogaea* L.)

4.1 INTRODUCTION.

Groundnut is an important oil crop of high protein value which can provide a useful cash income to the rural community.

Groundnut is well adapted to dry countries,approximatly 67% of the production comes from the seasonally-dry, rainfed areas of the semi-arid tropics.

Following factors are frequently cited as constraints to production :

Environmental

- -Yield losses due to drought (low rainfall compounded by high temperature).
- -foliage insect.
- -root,stem and pod insects.

Agronomic

- -low yield potential of cultivars from lack of resistance/tolerance of drought,diseases and insects.
- -short-cycle cultivars not available for drought escape.
- -low yields due to cropping systems (inadequate mineral nutrition,improper sowing technique,competition from weeds).

Socioeconomic

- -Groundnut often are not regarded as a major food source with high nutritional value.
- -Prices,markets and farmer and consumer interests limit production.

Agricultural Research has established an oil seed programme with the objective to address the different aspects of groundnut production. This will be more successful if it is complimented by good industrial development in oil processing and confectionnery, encouraging commercial groundnut production.

4.1.1 OBJECTIVES AND METHODS.

Groundnut production in Botswana is still at a subsistence level, mostly grown by traditional farmers for home consumption. If demand stimulated by price and market,then research must provide the means to enable reasonable yields.

The core of the research programme is based on :

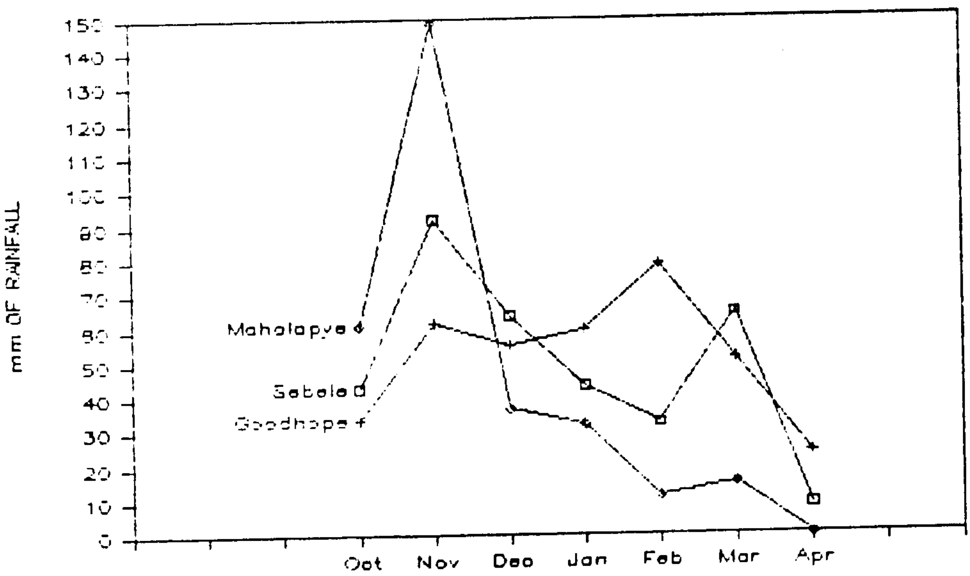
- Variety improvement, screening of local and imported varieties.
- Agronomic aspects associated with groundnut cultivation, such as fertilization, cultural practices, sowing densities.
- Plant protection.

This programme includes a seed production of gene-pool and first level of seed multiplication to supplied SMU (Seed Multiplication Unit) with good quality seeds.

Advanced trial was conducted under rainfed conditions across Botswana from Goodhope in the South-East to Ethsa in the North-West, other variety trials and agronomic trials were set up at Sebele.

This lead to significant variations in pod yields dependent upon total rainfall and rainfall distribution. Although the total rainfall registered in 1986/87 was almost identical at all experimental stations, at Sebele and Goodnope a good distribution occured in February and March which helped pod filling, whilst a poor rainfall pattern at Mahalapye during this period prevented pod filling -Figure 1.

Figure 1 : RAINFALL DISTRIBUTION ACROSS STATIONS.



Generally when new cultivars are introduced they are placed in t germplasm collection to be evaluated, conserved and multiplied if necessar This work is assigned to the Germplasm Officer.

Variety trials with less than 10 varieties are sown on complete randomis block design with four or six replications. Each plot containing three 6-met rows with a spacing of 0.75m between rows and 0.15m between plants. 100 kg/ of single superphosphate (10.5% P) are applied before sowing. Trials a planted with double row planter at Sebele and by hand on other stations.

For over 10 varieties an incomplete block design or lattice design used.

4.2 Groundnut improvement trials.

Cultivated groundnuts can be classif'ed in three plant types :
Spanish - Valencia - Virginia.

The two first types are characterized by an erect growth habit,a shor growing period and have no seed dormancy factor,non-dormant seeds ca germinate after they are morphologically mature.Spanish type produce pods wit 1 or 2 seeds, Valencia type produce longer pods with 2 to 5 seeds.

The third group have an erect or spreading growth habit, a long growin period and a seed dormancy factor for about on month.

The Spanish type seems best adapted to Botswana rainfall conditions.

Five different variety trials including advanced trial,adaptation trial local variety trial regional and international trial were planted in 1986/87.

4.2.1 ADVANCED TRIAL.

This trial was conducted in four different locations (Sebele,Goodhope Matsaudi and Ethsa). Four Spanish type varieties and one Virginia typ (selected for dormant seed factor) were grouped together, Sellie was used a control.

The Ethsa trial is not included in the results,as half of it was destroye by termite attacks.

Results are given in table 1. A combined variance analysis across loca tions shows a significant difference for pod yield due to the location, bu there is no significant difference between varieties. It is likewise for th other characteristics between Sebele and Goodhope. At Goodhope pod yields ar better, but with poorer harvest values than those at Sebele. This is no dou due to better soil management at Sebele. Generally speaking, it is impossibl to make a judgement concerning the performance of these varieties, as yield were levelled off by rainfall well below the usual mean.

Table 1 ADVANCED VARIETY TRIAL,RESULTS ACROSS LOCATIONS.

VARIETIES	3 LOCATIONS SEBELE,GOODHOPE,MATSAUDI 202.2 210.8 150.8 g.r POD YIELD kg/ha	g/plant	2 LOCATIONS SEBELE,GOODHOPE SHEL. %	WT.100 PODS	WT.100 SEEDS	POPS %	OIL CONTENT
SELLIE	261.0	3.7	61.5	60.9	23.8	12.9	49.4
55-437	291.0	3.8	62.1	59.5	24.5	16.5	49.7
STARR	305.0	4.1	64.7	61.7	25.2	10.8	49.5
CN 115 B	291.0	3.9	64.1	66.5	27.0	11.6	49.4
ELNA	295.0	4.0	63.1	62.6	26.0	14.8	50.2
73-33	216.0	2.7	59.9	65.8	25.7	15.6	49.8
Trial means	277.0	3.7	62.6	62.8	25.4	13.7	49.7
Mean Sebele	232	3.3	66.6	68.0	28.2	12.5	49.6
Mean Goodhope	476	6.5	58.6	57.6	22.5	14.9	49.7
Mean Matsaudi	122	1.3	-	-	-	-	-
F locations (L)	5.2*	4.6*	7.9*	6.0*	12.4**	1.0	-
F varieties (V)	1.3	1.6	0.7	1.5	1.0	0.7	-
F (L) * (V)	1.0	0.8	0.6	2.9	1.9	1.3	-
C.V. (%)	44.7	46.5	12.0	12.6	15.8	68.2	-
L.S.D. 5% (L)	223	3.5	5.6	8.6	3.2	n.s.	-

g.r. Growth period rainfall in mm.

At Sebele special attention was given to the varieties Sellie and 55-437, which which are recommanded for release by SMU.

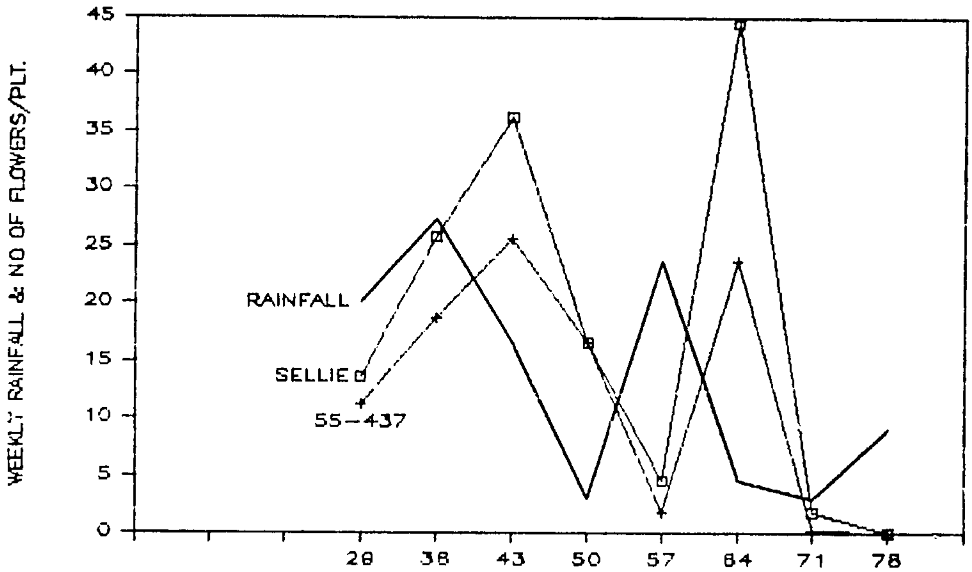
If subjected to drought stress the variety 55-437 is subject to faster defoliation on the lower parts of the branches than Sellie,which could be one of the characteristics confirming superior drought resistance.

Flowering is also in direct relation to rainfall and under irregular distribution, each period of rainfall is followed by a peak in flowering figure 2. As 90% of harvestable pods will be derived from flowers emitted during the three first weeks, it is very important to have good rain at this growing stage. Variety 55-437 has a better flowering coefficient, meaning it needs less flowers 11.5, for the production of one harvestable pod as compared to sellie 18.3 ,Table 2.

Table 2 FLOWERING, PEGGING AND POD FORMATION.

Observation from 10 plants	SELLIE	55-437
Mature pods	78	83
Total Flowers	1429	980
% fertile "pegs"	11.4	13.6
% fertile flowers	5.5	8.5

Figure 2 RELATIONSHIP FLOWERING/RAINFALL. (mm & No. flower)



TIME---- DAYS AFTER SOWING.

4.2.2 ADAPTATION TRIAL.

Eleven varieties selected for their performance over the previous two seasons were grouped together in the same trial, for comparison with the two controls (Sellie and 55-437) with respect to yields and technological characteristics. This trial was sown at Sebele and Goodhope.

The Results are given in tables 3 and 4. Due to a serious lack of rainfall, the analysis of variance reveals no significant difference between the varieties for pod yield or yield by location interaction.

The analysis of variance shows significant differences for the weight of 100 pods and notably in the two Valencia varieties,Boal and 79 H 1. Nontheless these are the two varieties with the lowest shelling percentages, due to greater water needs for these two large seed varieties.

The Harts variety, which is destinated to replaced Sellie in South Africa because of its resistance to pod rot),is earlier to flower but seems more sensitive to drought than Sellie , having 25% of harvested pods empty.

ICGM 21, an ICRISAT cultivar gave the best yield between the 2 sites.

Table 3 ADAPTATION VARIETY TRIAL,SEBELE 1986/87 RESULTS.

VARIETIES	POD kg/ha	YIELD g/plant	SHEL. %	SEED YIELD kg/ha	WT. 100 PODS	WT. 100 SEEDS	OIL CONTENT %
SELLIE (ctl)	295.9	3.6	62.8	185.8	65.9	25.5	47.8
55-437	374.1	5.2	65.3	244.3	62.5	25.6	49.9
CN 94C	286.3	3.7	67.7	193.8	81.1	31.0	49.8
ICGM 21	344.9	5.1	64.7	223.2	67.5	34.7	51.2
PRONTO	374.7	5.0	71.9	204.5	68.3	31.9	47.3
HARTS	272.0	4.8	63.1	171.6	66.3	32.2	52.6
ICGM 01	264.4	3.8	70.4	206.5	67.6	28.4	48.8
ICGM 22	299.7	4.0	64.4	193.0	66.8	25.8	50.2
BOAL	114.1	1.4	54.9	62.6	95.1	27.7	48.9
ICGM 27	237.6	3.4	68.6	163.0	64.3	25.9	51.7
NATAL C.	298.9	3.5	66.7	199.4	57.6	22.9	50.5
SELECTION 5	339.9	4.8	66.4	225.7	66.5	26.8	49.2
79 H 1	141.5	2.4	50.8	61.0	102.1	31.8	48.9
Trial means	280.3	3.9	64.4	180.0	71.7	28.1	49.8
F varities	1.33	1.49	3.08	-	8.2**	3.7*	-
L.S.D. 5%	n.s.	n.s.	n.s.	-	26.0	4.4	-
L.S.D. 1%	n.s.	n.s.	n.s.	-	35.1	n.s.	-
C.V. (%)	39.7	37.8	7.9	-	11.7	9.9	-

Table No. 4 ADAPTATION VARIETY TRIAL,GOODHOPE 1986/87 RESULTS.

VARIETIES	POD kg/ha	YIELD g/plant	SHEL. %	SEED YIELD kg/ha	WT. 100 PODS	WT. 100 SEEDS	OIL CONTENT %
SELLIE (ctl)	475.0	5.0	60.1	285.5	44.1	17.1	45.5
55-437	349.0	3.7	60.1	209.7	43.5	20.7	45.5
CN 94C	370.0	4.4	59.1	218.7	61.6	22.3	48.0
ICGM 21	598.4	5.5	65.2	390.2	48.6	20.7	-
PRONTO	517.6	5.0	62.5	323.5	45.7	20.4	46.9
HARTS	358.6	4.8	53.0	190.1	56.1	27.8	46.4
ICGM 01	490.3	5.0	63.8	312.8	48.8	19.1	-
ICGM 22	468.2	5.0	65.4	306.2	47.3	19.8	47.1
BOAL	451.0	4.4	54.4	245.3	81.2	23.0	46.9
ICGM 27	619.8	5.7	57.3	355.1	44.0	18.8	47.8
NATAL C.	493.2	4.6	59.3	292.5	45.4	18.4	45.2
SELECTION 5	416.0	4.2	57.1	237.5	45.8	16.6	46.1
ICGS 74	514.9	4.7	65.2	335.7	50.6	23.7	47.1
Trial means	467.0	4.8	60.2	280.6	51.0	20.7	47.1
F varities	1.17	0.5	1.43	-	18.6**	3.5*	-
L.S.D. 5%	n.s.	n.s.	n.s.	-	6.8	4.5	-
L.S.D. 1%	n.s.	n.s.	n.s.	-	9.2	n.s.	-
C.V. (%)	33.3	32.4	10.2	-	10.0	16.0	-

F significant at 5% (*) or 1% (**) level.

4.2.3 LOCAL GERMPLASM EVALUATION

Under the aegis of the IBPGR (International Board for Plant Genetic Resources), local germplasm collection succeeded in adding 9 varieties of groundnut cultivated in Botswana. These varieties were grouped together in the same trial, for comparison of their performance with that of the two varieties Sellie and 55-437.

Results are given in Table 5. The 2 control varieties performed better than the other varieties,but the analysis of variance indicates no significant difference between the varieties as far as pod yield per hectare is concerned.

All the varieties belong to the Spanish type,apart from MA 47,which is of the Virginia type and FCT/Tan,MA 23 which are of the Valencia type.

Table 5 LOCAL GERMPLASM EVALUATION,SEBELE RESULTS 1986/87.

VARIETIES	POD kg/ha	YIELD g/plant	SHEL. %	SEED YIELD kg/ha	WT. 100 PODS	WT. 100 SEEDS	OIL CONTENT %
SELLIE	467.6	6.3	63.1	295.1	60.0	24.8	50.5
55-437	417.6	6.0	67.3	281.0	61.1	25.7	51.6
MA 13	382.6	5.2	61.1	233.8	67.7	31.5	50.3
MA 22	203.0	2.6	63.5	128.9	72.0	29.2	49.9
MA 23	427.2	5.6	57.0	243.5	79.3	25.4	50.5
MA 32	368.5	5.2	65.9	242.8	59.7	26.9	52.0
MA 47	484.6	6.7	45.4	220.0	64.2	24.1	51.2
MA 59	423.0	5.3	58.4	247.0	75.8	32.5	51.9
MA 71	349.6	5.0	60.3	210.8	54.1	23.2	49.7
FCT/Tan	326.5	5.0	52.6	171.7	61.5	25.4	52.9
FCT/Red	341.1	4.5	66.5	226.8	70.2	30.3	51.6
Trial means	381.0	5.2	60.1	227.4	66.0	27.2	51.1
F treatments	1.82	2.3*	7.8**	-	4.9**	6.7**	-
L.S.D. 5%	n.s.	2.06	6.77	-	10.1	3.54	-
L.S.D. 1%	n.s.	n.s.	9.11	-	13.6	4.77	-
C.V. (%)	30.4	27.4	7.80	-	10.6	9.03	-

Significant at 5% (*) or 1% (**) level in comparison with the control Sellie.

4.2.4 REGIONAL TESTING TRIAL.

This variety trial includes 34 varieties supplied by the Regional Groundnut Programme base in Malawi. Its aim is to assist national programmes in their variety investigation. This regional trial is conducted by any SADCC member country requesting to do so. The trial was sown at Sebele on 10th Nov., harvested from 6th March,for earliest varieties,to 25th April for latter ones.

The results are given in Table 6. The bad climatic conditions of this season seriously effected this trial. As for the previous season, these varieties imported from Malawi, are not very well adapted to Botswana. In the future, it would be preferable to orientate this cooperation towards more specific objectives, especially at breeding and selection level.

Table 6 : REGIONAL YIELD TRIAL, SEBELE 1986/87 RESULTS. (Ranked according to seed yield/ha)

VARIETIES	Cycle of growth	Emergence stand (000/Ha)	Final stand (000/Ha)	Mortality (%)	Pod yield (Kg/Ha)	Pod yield (g/plant)	Shelling perct. (%)	Seed yield (Kg/Ha)	Weight 100 pods (g)	Weight 100 good seeds (g)	"pops" (%)	Oil content (%)
SELLIE(1st ctl)	3	96.3	72.8	24.4	308.8	4.1	57.6	177.9	54.3	28.8	17.7	46.5
55-437(2nd ctl)	2	97.6	66.8	31.6	398.5	6.1	62.1	247.5	51.6	26.1	19.4	48.3
ICGM 721	2	100.5	69.2	31.1	337.0	5.1	68.7	231.5	61.0	31.3	21.4	48.7
ICGMS 9	3	94.5	89.0	5.8	371.7	4.5	60.1	223.4	58.3	25.1	13.6	44.8
ICGM 734	2	92.9	67.4	27.4	329.1	5.0	63.5	209.0	59.4	29.7	21.9	48.7
ICGMS 68	2	100.8	68.4	32.1	322.5	4.5	60.0	193.5	59.0	35.4	30.0	51.7
ICGMS 60	2	92.4	75.8	18.0	380.6	5.4	50.0	190.3	71.5	43.7	32.8	47.3
ICGMS 11	3	96.0	77.4	19.4	394.0	5.5	47.0	185.2	62.6	38.7	33.8	47.9
ICGMS 66	2	95.3	74.0	22.4	302.6	4.1	57.6	174.3	53.1	32.6	18.5	50.4
ICGMS 64	2	97.3	77.4	20.5	278.6	4.0	61.8	172.2	59.7	35.3	19.4	51.4
ICGMS 2	2	96.7	59.9	38.1	245.9	4.6	69.5	170.9	75.6	24.9	1.5	45.6
ICGM 522	1	93.7	72.9	22.2	308.7	4.5	53.2	164.2	65.9	37.2	31.6	47.4
ICGMS 67	2	100.6	69.7	30.7	260.7	3.6	57.6	150.2	86.8	38.9	6.2	47.2
ICGMS 1	2	101.3	74.0	26.9	255.1	4.5	58.5	149.2	43.1	22.8	24.2	46.4
ICGMS 70	1	99.2	68.3	31.1	242.0	4.1	60.3	145.9	73.6	37.0	20.4	49.5
ICGMS 59	2	96.3	64.6	32.9	265.5	3.9	54.1	143.6	84.4	35.8	32.8	45.1
ICGMS 12	3	93.2	48.0	48.5	274.4	6.4	51.3	140.8	75.8	49.7	35.5	-
ICGMS 31	2	97.9	79.0	19.3	244.8	3.4	57.3	140.3	85.9	36.7	16.1	45.6
ICGM 437	2	97.9	89.2	8.9	212.2	2.4	60.1	127.5	68.4	35.1	23.0	48.4
ICGMS 29	2	89.1	72.1	19.1	218.7	2.9	58.0	125.8	52.6	28.5	10.2	46.6
ICGMS 65	2	98.6	74.0	24.9	272.8	3.8	46.2	126.0	47.4	38.4	46.5	49.6
ICGMS 69	3	101.7	68.9	32.3	248.1	4.0	49.9	123.8	35.7	32.7	54.3	47.2
ICGMS 21	2	95.6	63.5	33.6	229.4	4.1	52.2	119.7	54.4	34.1	14.9	47.2
ICGMS 58	3	105.9	95.9	9.4	364.2	3.9	29.2	106.3	68.8	40.0	51.7	48.6
ICGMS 13	3	101.9	68.5	32.8	243.4	3.7	41.4	100.8	45.9	37.2	52.3	48.3
ICGMS 56	3	94.7	69.4	26.7	313.2	4.8	29.9	93.6	63.5	30.5	57.2	50.0
ICGMS 72	3	97.2	54.7	43.7	225.8	4.2	40.5	91.4	52.6	32.7	42.3	51.0
ICGMS 63	2	102.8	78.7	23.4	206.8	3.3	42.0	86.9	93.9	46.2	20.9	50.0
ICGMS 5	2	95.2	78.6	17.4	255.6	3.4	33.1	84.6	84.0	48.5	26.5	49.9
ICGM 473	3	96.4	71.0	26.3	278.5	5.2	30.3	84.4	71.2	26.1	4.4	47.6
ICGMS 62	2	96.2	76.9	20.1	266.4	3.1	31.3	83.4	49.4	27.2	44.9	48.8
ICGMS 57	2	91.7	91.6	0.1	177.2	2.3	44.5	78.9	58.5	48.2	40.5	50.9
ICGMS 71	3	103.4	65.4	36.8	218.8	3.5	30.6	67.0	62.8	36.7	43.7	49.3
ICGMS 30	3	95.6	54.0	43.5	338.9	6.4	17.5	59.3	61.6	30.6	70.7	46.9
ICGMS 55	3	91.3	86.9	4.8	138.2	1.6	36.5	50.4	123.1	54.5	56.1	47.0
ICGMS 61	3	92.3	90.0	2.5	96.8	1.0	42.3	40.9	55.1	35.0	25.7	50.5
Trial means		96.9	73.0	22.0	272.9	4.1	49.0	133.9	65.0	35.3	30.1	47.0
F treatments		1.17*	2.45**	-	1.31*	5.57**	-	-	-	-	-	-
L.S.D. (5%)		9.54	18.10	-	161.20	2.16	-	-	-	-	-	-
L.S.D. (1%)		n.s	23.56	-	n.s	2.80	-	-	-	-	-	-
C.V (%)		6.96	17.56	-	41.76	37.44	-	-	-	-	-	-

Significant at 5%(*) or 1%(**) level, in comparison with the control SELLIE

Cycle growth: (1) 113 days, (2) 128 days, (3) 153 days.

Rainfall during growth: (1) 217.2mm (2) 248.9mm (3) 285.4mm.

4.2.5 INTERNATIONAL GROUNDNUT EVALUATION TRIAL

41 cultivars from ICRISAT (Hyderabad - India) were recommanded for their early maturity and drought resistance. After two seasons of tests, 13 cultivars were selected for their good characteristics and grouped togehter in a single trial. The trial was sown at Sebele on 10th November and harvested on 9th March.

The yield results are given in Table 7. There is no significant difference between varieties for pod yield. The shelling percentages and weight of 100 seeds are significantly different. The variety ICGS 60, which is slightly earlier than Sellie (-8 days) and which was superior to the control in the previous seasons,confirms this tendency.

Table 7 INTERNATIONAL GROUNDNUT EVALUATION TRIAL.

VARIETIES	POD	YIELD	SHEL.	SEED YIELD	WT. 100	WT. 100	OIL
	kg/ha	g/plant	%	kg/ha	PODS	SEEDS	CONTENT %
SELLIE	418.9	4.8	66.3	277.7	61.4	27.5	49.7
55-437	381.8	3.8	71.8	274.1	63.9	30.6	50.2
ICGS 04	385.0	4.0	51.8	199.4	60.8	21.3	49.2
ICGS 22	386.8	4.0	68.7	265.7	76.7	30.5	49.8
ICGS 23	400.0	4.2	63.9	255.6	62.8	26.6	47.7
ICGS 26	371.8	3.9	66.6	247.6	71.2	28.7	49.7
ICGS 28	351.8	3.6	66.5	233.9	65.3	29.8	51.7
ICGS 31	432.0	4.6	64.6	279.1	75.9	31.3	50.7
ICGS 36	412.4	4.2	65.0	268.1	63.8	26.7	50.4
ICGS 49	417.4	4.5	67.4	281.3	68.8	29.2	50.5
ICGS 50	453.1	4.7	64.5	292.2	72.3	25.4	52.6
ICGS 55	395.3	4.3	67.9	268.4	61.1	29.1	48.8
ICGS 60	650.7	6.6	63.6	413.8	77.5	29.9	47.9
ICGS 74	389.7	3.8	71.0	276.7	75.6	33.7	49.9
ICGS 85	308.1	3.2	70.5	217.2	73.1	31.2	51.4
Trial Means	414.5	4.3	66.0	270.1	68.9	28.8	50.0
F Varieties	1.8	1.9	4.0**	-	2.9	5.8**	-
L.S.D. 5%	n.s.	n.s.	6.2	-	n.s.	3.1	-
L.S.D. 1%	n.s.	n.s.	8.4	-	n.s.	4.3	-
C.V. (%)	25.3	23.7	6.5	-	10.2	12.3	-

4.3 Agronomy.

4.3.1 PLANT POPULATION STUDY.

The purpose of this trial, conducted at Sebele, was to determine the spacing best adapted to rainfall conditions, so as to ensure the optimum yield of good quality nuts.

Variation in spacing, between rows and between plants were studied for stands going from 4 plants per sq.m to 17 plants per sq.m.

Material and method.

The trial was organized in a split-plot with 4 replications.The split-plot contained 3 different spacings between rows : 60 , 75 and 90cm (main plots) and 3 different spacings between plant in the row :10 ,20 and 30cm (sub-plots)

Each main plot contained five 18-metre rows and was divided into 3 sub-plots.

Each plot was sown by hand at the inter-row spacings studied respectively, but with a single spacing of 10cm between the plants on the row. Each sub-plot was thinned out to the desired spacing 20 days after sowing.

Results and discussion.

The different yields and production characteristics are given in Tables 8 to 11.

The trial suffered from the drought. The situation was comparable to that in 1985/86,for both rainfall and results. Yields are between 420 and 663 kg/ha of pods.

As regards pod yields per hectare, the analysis of variance shows a significant difference for spacing along the row, favouring the tightest spacing, i.e. 10cm. The positive yield/stand correlation is significant $P < .05$ with a value of $r = 0.705$.

For pod yield per plant, the analysis of variance is significant but for largest spacing between rows and between plants in the row (90cm x 60cm). Interaction is not significant (F value = 0.47).

Yields were limited by a lack of rainfall. Under these conditions,the groundnut was unable to develop all its production potential, which despite a significant increase in pod yield per plant from lowest density (37,000 plants per ha), the highest pod yield per hectare is obtained with highest population (110,000 plants/ha as final stand). However lowest and medium populations gave best seed quality as indicated by 100 pod and seed weights.

In economic terms and based on Botswana Agricultural Marketing Board (BAMB) prices (1986/87) as follows :

groundnut shelled		
grade 1	66.1	Thebe/kg
grade 2	60.1	"
grade 4	44.5	"

farmers can obtain better returns with production from medium population, which can be classified as grade 1 or 2 than from highest populations which can easily fall to grade 4, thus income from :

(1) medium populations (75cm * 20cm) 259 kg shelled x 66.1 = P 171.2
or 259 kg " x 60.1 = P 155.7
(2) high populations (60cm * 10cm) 326 Kg " x 44.5 = P 145.1

Table 8 POD YIELD PER HECTARE. (kg)

		SPACING BETWEEN PLANTS						
		10cm	20cm	30cm	MEANS	INDEX	L.S.D.	C.V
SPACING BETWEEN ROWS	60cm	560.4	464.1	418.3	481.0	100		
	75cm	493.7	421.5	353.1	422.8	87.9	n.s.	32.2
	90cm	463.7	427.5	421.6	435.9			
	MEANS	505.9	437.7	397.7				
	INDEX	100	86.5	78.6				
	L.S.D.	5%	64.0					
	C.V.		15.9					

Table 9 POD YIELD G/PLANT.

		SPACING BETWEEN PLANTS						
		10cm	20cm	30cm	MEANS	INDEX	L.S.D.	C.V
SPACING BETWEEN ROWS	60cm	5.5	7.8	14.0	9.1	100	5%	
	75cm	6.8	7.9	14.0	9.6	106	3.5	33.1
	90cm	9.0	11.5	19.2	13.9	153		
	MEANS	7.1	9.1	15.7				
	INDEX	100	128	221				
	L.S.D.	5% 1.98		1% 2.72				
	C.V.		21.8					

Table 10 WEIGHT OF 100 PODS. (g)

		SPACING BETWEEN PLANTS						
		10cm	20cm	30cm	MEANS	INDEX	L.S.D.	C.V
SPACING BETWEEN ROWS	60cm	35.9	40.2	40.5	38.9	100		
	75cm	42.1	45.3	46.1	44.9	115	n.s.	12.2
	90cm	44.0	44.1	46.0	44.2	114		
	MEANS	40.7	43.2	44.2				
	INDEX	100	106	109				
	L.S.D.		n.s.					
	C.V.		10.2					

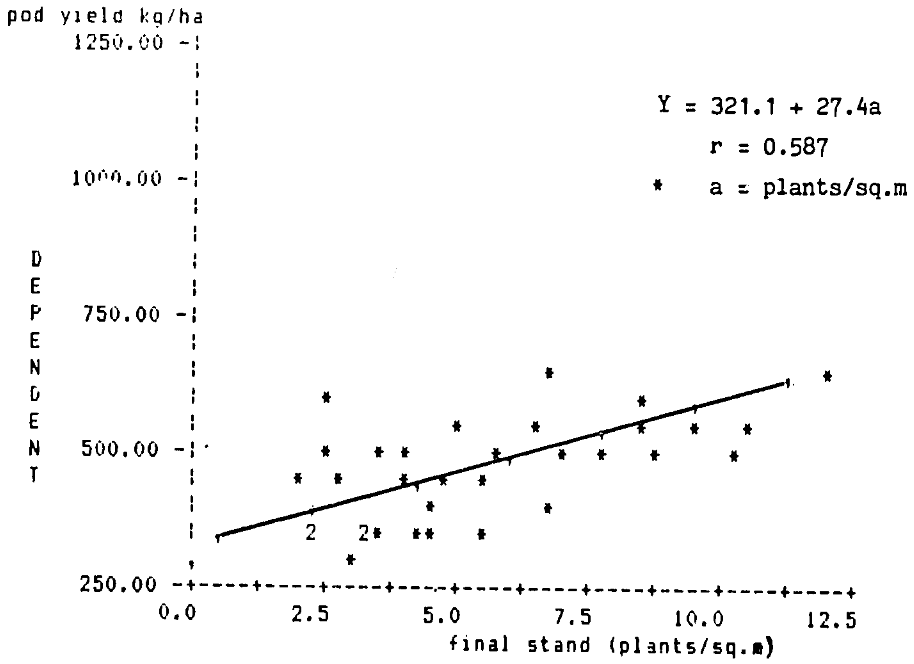
Table 11 WEIGHT 100 GOOD SEEDS. (g)

		SPACING BETWEEN PLANTS						
		10cm	20cm	30cm	MEANS	INDEX	L.S.D.	C.V
SPACING	60cm	20.4	23.1	21.9	21.8	100	5%	
BETWEEN	75cm	23.1	23.0	23.3	23.1	106	2.7	11.3
ROWS	90cm	25.2	25.1	26.3	25.5	117		
	MEANS	22.9	23.7	23.8				
	INDEX	100	104	104				
	L.S.D.		n.s.					
	C.V.		9.7					

Groundnut proves that it is a drought resistant plant and that it is ofte possible to obtain both good pod yields and seed quality,in spite of drought, with stand around 70,000 plants/ha (75cm x 20cm), compared to stands of 20 to 30,000 plants/ha often adopted by farmers.

Figure 3 shows linear correlation between pod yields and populations.

Figure 3 RELATIONSHIP BETWEEN POD YIELDS AND POPULATIONS.



4.3.2 FERTILIZER STUDY.

As for other crops, groundnut requires nutrients for it to develop correctly. Howerver, groundnut response to fertilizer is often unpredictable.

Phosphorus is a very important element and works in direct relation with nitrogen and sulphur. Excess phosphorus limits nitrogen uptake, which is an indispensable element for plant growth. A phosphorus deficit gives similar symptoms to those obtained under nitrogen stress (McVicker and Walker 1978).

Calcium is also an important element as it improves pod filling and increases flower fertility. In the form of gypsium, the released sulphur also stimulates nodulation and favours better shell structure.

A phosphate fertilizer trial, with and without calcium, was set up at Goodhope and Matsaudi to determine the most beneficial fertilizer rate for pod yield and seed quality.

Material and method.

Four phosphate fertilizer (single superphosphate - 10.5% P) rates were tested :0 - 50 - 100 and 150 kg/ha, with or without calcium (gypsum) at a rate of 1,000 kg/ha

A split-plot design and 4 replications were used with the calcium treatment as main plot and the phosphorus fertilizer rates as sub-plots.
Each sub-plot measured 4.5m x 6m and contained 7 rows of Sellie variety planted at a spacing of 75cm x 12cm (i.e a stand of 110,000 plants/ha).

The gypsum was spread by hand and shallowly incorporated, one month before sowing whereas the phosphate was broadcasted and worked into the surface the day before sowing.

A soil analysis was carried out before the fertilizers were applied. Table 12 shows the different characteristics.

Table 12 :CHEMICAL ANALYSIS OF THE SOIL.(1)

ANALYSIS	Value (0 - 20cm)	
	Goodhope	Matsaudi
Soil type	loamy sand	sandy
Soil pH (CaCl2)	4.5	7.2
Phosphorus (ppm - Brays No 2)	4.3	27.9
K (meg/100 g soil)	0.35	0.16
Ca (meg/100 g soil)	1.47	3.84
Mg (meg/100 g soil)	1.12	0.37

(1) Soil Laboratory -Sebele.

Results and discussion.

The large data bank of groundnut leaf composition held by the IRHO* made it possible to establish a relationship between the mineral composition of the groundnut leaves and soil fertility (sandy soil,loamy sand). These analyses also showed that the response of groundnut to mineral fertilization was often low once a minimum critical mineral content was reached in the leaves. Table 13 summerize these reference contents and shows the results for samples taken at the Goodhope and Matsaudi trials.

Table 13 FERTLIZER ELEMENT CONTENTS.

	Contents above which response to fertilizer is weak	Goodhope	Matsaudi
N	3.5%	3.78%	3.60%
P	0.225%	0.16%	0.23%
K	0.8 - 1.0%	2.50%	1.98%
Ca	1.2%	2.05%	3.18%
Mg	0.5%	0.60%	0.65%
S	0.25%	0.28%	0.25%

It turns out that in both cases the initial fertility was quite well balanced. This may explain the non-significant differences between the effects of the different fertilizer rates on yields and production characteristics (Table 14). The drought, which reduced plant development indirectly limited the assimilation of fertilizing elements. It was noted that phosphate increased pod numbers, but due to drought stress these pods could not reach complete maturity, and this minimised treatment yield differences.

At Goodhope leaf analyses shows a significant interaction between phosphorus and gypsum on Ca content. At Matsaudi leaf analyses shows a significant interaction between phosphorus and gypsum on S content, figures 3 and 4,with :

		Ca	S
Goodhope :	F gypsum	15.34*	4.07
	F phosphorus	2.58	1.71
	F interaction	5.88**	4.50*
Matsaudi :	F gypsum	0.14	60.31**
	F phosphorus	0.76	8.51**
	F interaction	0.53	6.08**

Significant at 5% (*) or 1%(**) level.

Soil analysis after cropping season at Goodhope shows a steep increase in P and Ca (Table 15).

As a general rule, mineral fertilization has often been found to be more cost-effective when applied directly on a cereal preceding groundnut.

*Institut de Recherches pour les Huiles et Oleagineux - Paris

Table 14 FERTILIZER TRIAL ,GOODHOPE 1986/87 RESULTS.

1- POD YIELD (kg/ha)	DOSES OF P (Single superphosphate) 0	50	100	150	MEANS	L.S.D.	C.V.
WITHOUT GYPSUM	603	678	520	867	667		
WITH GYPSUM	660	690	566	530	611	n.s.	54.0
2- SHELLING %							
WITHOUT GYPSUM	57.7	65.6	60.8	66.6	62.7		
WITH GYPSUM	64.8	63.0	61.3	64.8	63.5	n.s.	4.5

Table 15 FERTILIZER TRIAL GOODHOPE 1986/87.
SOIL ANALYSIS AFTER CROPPING SEASON (0 -20cm).

	pH	P	K	Ca	Mg	ex Cat. + CEC
Soil analysis before treatment.	4.5	4.3	0.35	1.47	1.12	-
WITHOUT GYPSUM						
CONTROL	5.0	6.9	0.48	1.68	0.26	4.83
50 kg/ha S.S.	4.7	8.8	0.38	1.33	0.21	3.83
100 kg/ha S.S.	5.0	6.9	0.52	4.43	0.79	5.28
150 kg/ha S.S.	4.7	6.7	0.31	1.14	1.02	4.28
Treatment means	4.8	7.3	0.42	2.15	0.57	4.55
WITH GYPSUM						
CONTROL	5.2	8.2	0.46	2.83	0.22	3.92
50 kg/ha S.S.	5.0	6.1	0.49	8.42	1.25	7.05
100 kg/ha S.S.	4.7	9.4	0.58	4.61	0.73	5.75
150 kg/ha S.S.	5.1	11.1	0.29	2.29	0.79	4.53
Treatment means	5.0	8.7	0.45	4.53	0.75	5.31
INTERACTION						
Trial means	4.9	8.0	0.44	3.34	0.70	4.93
F GYPSUM	0.56	4.08	1.55	5.61	1.07	5.10
F PHOSPHORUS LEVELS	1.99	0.20	14.5**	2.51	2.20	1.03
F INTERACTION	2.42	1.10	1.33	2.49	2.23	1.99
L.S.D. INTERACTION	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
C.V. (%)	4.9	50.5	17.7	85.0	83.7	35.5

pH : CaCl2 - P : ppm - Cat. : meq/100g soil.

Figure 4 INTERACTION OF P AND GYPSUM ON Ca.(Groundnut leaves picked at 50th day at Goodhope).

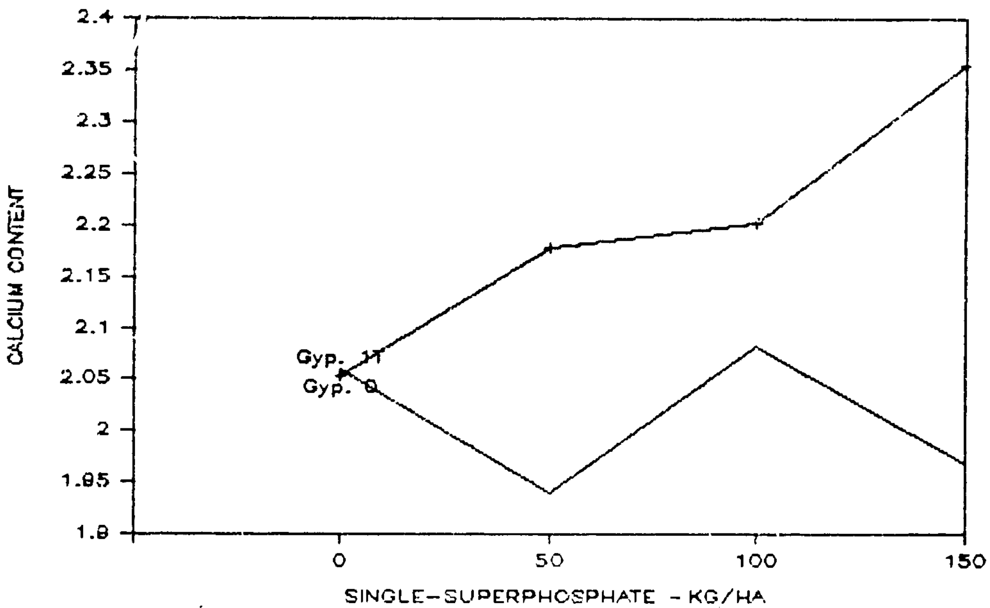
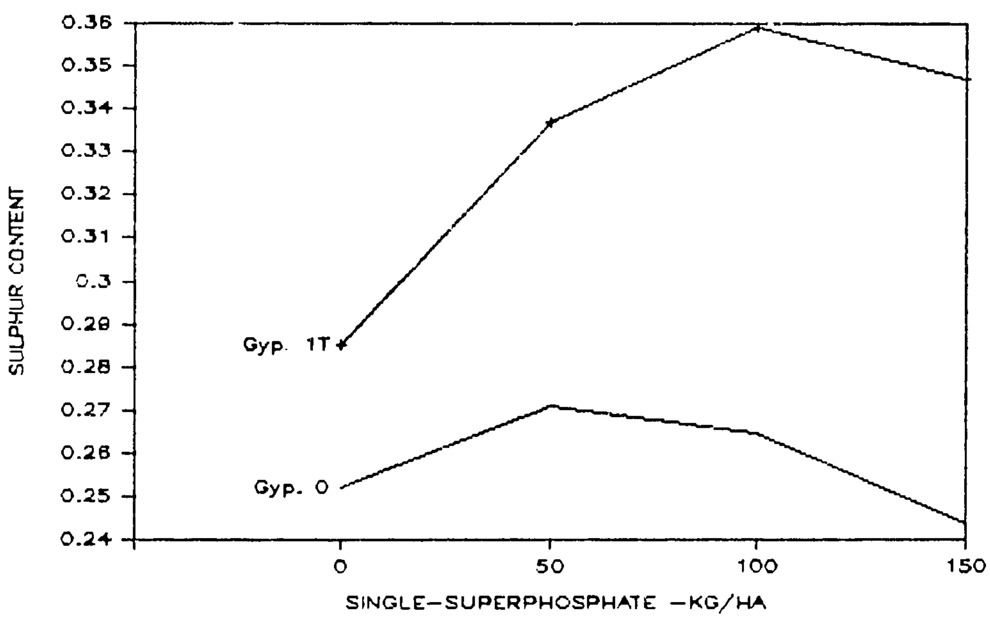


Figure 5 INTERACTION OF P AND GYPSUM ON S.(Groundnut leaves picked at 50th day at Matsaudi).



4.3.3 CULTURAL PRACTICES.

On small groundnut plots sowing is carried out by broadcasting prior to shallow tillage to cover the seed or by hand after cultivation, sometimes using a harrow to cover seed.

In both cases, farmers often adopt the practice of mounding up groundnut during the first weeding operations, either by hand or using a ridge-plough on the commercial farms.

A trial simulating both these techniques was set up at Sebele to measure the effect on both groundnut yields and on water conservation.

Material and method.

3 treatments were tested at Sebele (Blk 8)

1. Flat sowing
2. Flat sowing with hand mounding at the start of flowering
3. Flat sowing with mechanical mounding at the start of flowering.

The trial was in randomized complete blocks with 6 replications. Each plot comprised six 6-metre rows with a spacing of 75cm between rows. 100 kg/ha of single superphosphate was spread before sowing. The trial was sown with the Sellie variety.

Results and discussion.

Yields

The different yields are given in table 16. Under this year's drought conditions, mounding led to high plant mortality due to drying out. The analysis of variance shows a highly significant difference ($P < .01$) for mechanical treatment,which was much deeper and which favoured evaporation of the water stored at root system level.

The significant difference ($P <.01$) for single-seed percentage in the case of manual mounding can be explained by the fact that hand mounding was better carried out than mechanical mounding, which favoured the fruiting of part of the upper pegs. This fruiting is characterized by the production of a majority of pods with only one seed, which is an inconvenience in mechanical shelling.

In addition, the Spanish group varieties, recommended for their precocity and drought resistance, have the characteristic of having a very concentrated fruiting, basically arising from the first flowers. Although mounding favours the fruiting of later flowers, it causes a staggering of maturity; as Spanish group varieties have non-dormant seed after physiological maturity, this leads to a situation where the first pods are regerminating whilst the last ones are not yet mature. The result is a drop in production quality (or even in shelling percentage,100-pod weight and 100-seed weight).

Table 16 CULTURAL PRACTICES (mounding),SEBELE 1986/87 RESULTS.

TREATMENTS	MORTALITY (%)	POD kg/ha	YIELD g/plt	SCHEL. %	Wt. 100 PODS (g)	Wt.100 SEEDS (g)	PCT. PODS WITH 1 SEED
Without mounding	23.0	361.0	3.1	63.8	65.1	25.0	7.2
Hand mounding 2.2	30.3	244.0	2.3	59.5	59.4	23.4	12.2
Mechanised mounding	54.0	189.0	2.9	61.2	64.3	24.0	7.5
Trial means	35.8	265.0	2.8	61.5	62.9	24.1	9.0
F treatments	-	2.71	1.1	0.9	0.65	0.47	8.45**
L.S.D. (1%)	-	n.s	n.s	n.s	n.s	n.s	4.30
C.V (%)	-	49.6	36.9	9.2	14.8	12.0	26.1

** significant at 1% level

Rainfall during growth : 202.2 mm

Water use

Mounding could have beneficial effects as far as rainwater capture is concerned,but the lack of rainfall this season made it impossible to measure these effects. Nonetheless,using a neutron moisture probe it was possible to measure soil moisture at 25cm ,50cm ,75cm and 100cm.

Root system

Under the drought conditions of this season,it should also be noted that plant development was quite limited and that the greatest root system density was to be found in the 30-50cm zone (soil profile).

Soil moisture

Water consumption was studied taking into account soil moisture at different depths and different periods of plant growth. Table 17 shows this consumption (mean of treatments).

Table 17 WATER BALANCE IN SOIL PROFILE FROM 0 TO 107.5CM (in mm)

Days	0-20	20-40	40-60	60-90	Total
	+10	-33	-8	-5	-36
Rainfall	49	42	24	41	156

Data were calculated taking a soil density of 1.72 g/cm3.

Figure 6 shows the changes in soil water content during the growth cycle. The following remarks can be made :

10th - 17th day : good rainfall, young plants with low water requirements, hence an accumulation of water percolating downwards (a).

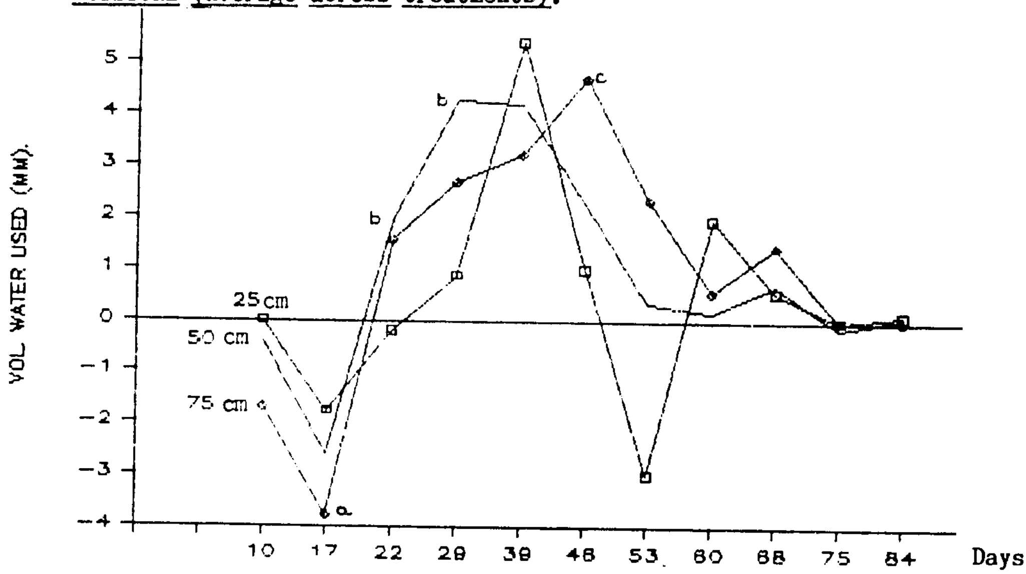
22nd -39th day : rapid moisture consumption, particularly in the 50cm zone where the majority of the root system is developing (b). Consumption also increasing in the 75cm zone where the root system is beginning to develop.

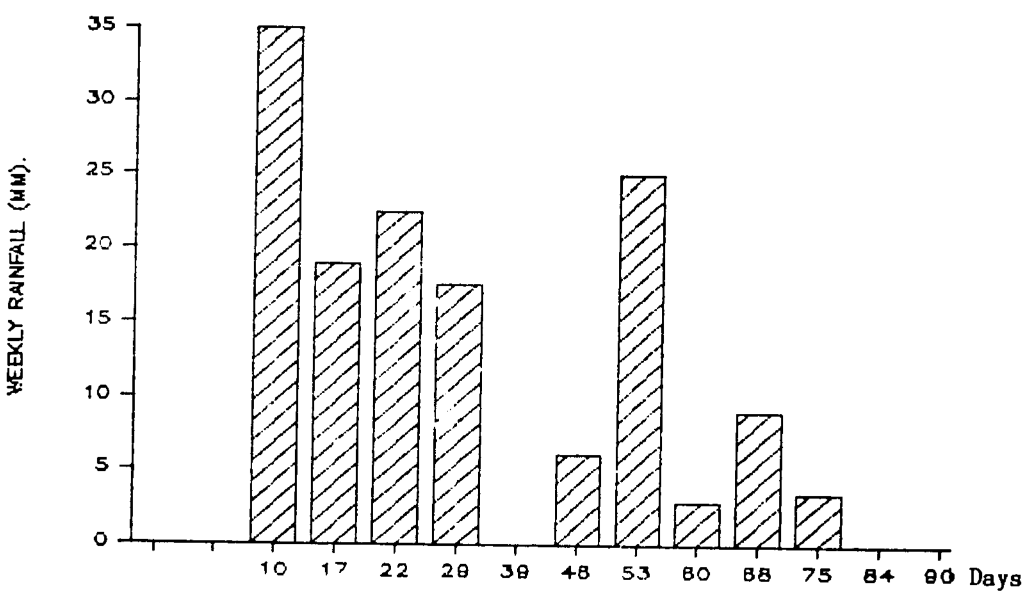
40th -90th day : substantial consumption threshold on 50th day (c) at 75cm where the root system is now to be found.

Serious lack of rainfall,rapid drop in soil water reserves and beginning of water stress causing plants to dry out.

Water consumption for the production of 1 kg of unshelled groundnut was 0.7 mm under this season's climatic conditions.

Figure 6 <u>MOISTURE USE (mm) ESTIMATED BY WEEKLY CHANGES IN SOIL VOLUMETRIC MOISTURE (Average across treatments).</u>





4.4 Plant protection.

4.4.1 INSECTICIDE TRIAL.

Several species of termite are known to attack groundnut,but the most common are Microtermes and Odontotermes.

Attacks occur at all stages of the growth cycle and are usually expressed in terms of mortality rate. In Botswana, this rate is generally between 20 and 30% of the plants emerging.

After consultation with Dr. J. Wightman (ICRISAT Principal Groundnut Entomologist) a trial was set up at Sebele in the aim of controlling these attacks through the use of insecticides.

Marerial and method.

Traditionally, groundnut seeds are not treated and current recommendations only concern fungicide, in the form of seed dressing, to ensure seed protection during emergence.

The trial consisted of one insecticide to measure its effect on termite attacks.

Captan (fungicide at 83% a.i.) and Carbaryl (insecticide at 85% a.i) were used, either alone or together,in the form of seed dressing.

One trial comprising two 20m x 10m plots was set up at Sebele on two different sites.

Results and discussion.

Mortality observations were carried out during the growth cycle and physical appearance was cheked on harvesting. The results are given in Table 18.

In comparison with the other groundnut trials set up at this station, the first groundnut plant deaths were recorded later for seeds insecticide treated than non treated seeds. Throughout for the rest of the growth cycle there is no different between the treatments. However, plant growth from insecticide treatment was retarded during the first month.

As far as pod appearance is concerned,there appears to be no difference between the two treatments,with 30 to 35% of the pods damaged by termites.

Mortality is due to attacks which mostly occur on root system (typical of Microtermes attacks). The termites penetrate into the main root around 1 to 5 cm underground and move upwards inside the plant. The leaves dry out and the plant gradually dies.

Pod damage occurs at the end of the growth cycle. The termites perforate the pods just below the beack;this opening provides access for pathogens which may contaminate the seeds.

The results indicate that use of an insecticide seed dressing only has a temporary effect on termite attacks and cannot therefore be recommended. For effective chemical protection, it is recommended to use insecticides in bait form, with regular applications during the growth cycle. Traditional groundnut yields make this technique uneconomical.

Varieties likely to be resistant (from ICRISAT) will be tested starting next season.

Table No. 18 TERMITE DAMAGE TO GROUNDNUT,SEBELE 1986/87 RESULTS.

	Pod damages				Plant
	good pods %	perforated pods	scarified pods	destroyed pods(+25%)	mortality %
Site 1					
Fungicide	62.8	14.1	16.7	6.3	16.5
Fungi. + Insect.	66.3	14.5	13.3	5.9	17.0
Trial means	64.6	14.3	15.0	6.1	16.8
Site 2					
Fungicide	65.5	16.9	6.7	10.9	21.0
Fungi. + Insect.	70.5	15.6	11.0	2.9*	22.0
Trial means	68.0	16.3	8.9	6.9	21.5
Analyse of variance					
F sites (S)	0.55	0.72	3.22	0.18	-
F treatments (T)	0.67	0.02	0.02	5.18*	-
F interaction S*T	0.02	0.06	1.35	4.24	-
L.S.D. (5%)	n.s	n.s	n.s	2.75	-
C.V. (%)	24.7	70.7	88.5	90.1	-

* Significant at 5% level.

4.5 Farmer's field test

4.5.1 SEED PROTECTION

The experimental trials conducted at stations have shown the effectiveness of seed fungicide treatment for their protection during emergence. In order to check these results and,at the same time,prove to those farmers who do not apply fungicide to their seeds, how important this practice is,several tests were carried out in collaboration with farmers.

In certain trials,mineral fertilization was given in conjunction with the fungicide.

Material and method.

Test 1: Fungicide + Fertilizer

A 40m x 20m groundnut field,divided into 4 plots with the following treatments:

- Untreated seed
- Treated seed
- Untreated seed + single superphosphate
- Treated seed + single superphosphate

Test 2: Fungicide

Test carried out in collaboration with ATIP project at Mahalapye.

667 g of untreated seeds and 667g of treated seeds were distributed to each farmer (17 in all). Each farmer cultivated them in his own way, but sowed all treatments on the same day.

For the two types of test,the seeds received a fungicide application - Captan - at the rate of 0.2% (20g/10 Kg of seed).

For the plots with fertilizer, 75Kg of single superphosphate was spread before sowing.

The Sellie variety was used in all the tests.

Results and discussion.

Table 19 shows the results of test No. 1. Only the results of 2 locations were recorded, which prevents any statistical analysis. Nontheless, these results show the effectiveness of the fungicide with +27.7% of the plants emerging at Kgapamadi and +12.3% at Goodhope. Given that the aim is to have the same stand as with the untreated seed, but with treated seed, it would have been necessary in the case studied to have 2.6kg less on average per hectare, i.e. at the local price for seed, P 5.20. Gains could be double for a normal stand of 75,000 plants per hectare, with only P 1.20 of fungicide.

Table 20 takes the same approach and shows the mean results for the 17 trials. To obtain the same stand, with treated seed, an average of 4.0 Kg less of seed are required per hectare.

Table 19 FIELD TEST No.1 ,RESULTS.

Kgapamadi farm. Rainfall 293.3mm. Planting date 19/11. Harvesting 24/4/87.

	untreated seed	treated seed	untreated seed + fert.	treated seed + fert.
Final stand (000/ha)	30.0	41.7	38.5	45.9
Pod yield kg/ha	545	575	595	595
Pod yield g/plant	18.2	13.8	15.4	13.0
Shelling %	65.2	63.3	61.4	61.5
Seed yield kg/ha	355	364	365	366
100 pod weight	54.6	57.5	59.5	59.5
100 seed weight	26.7	27.3	26.0	31.4

Goodhope farm. Rainfall 267.8mm. Planting date 3/12. Harvesting 21/5/87.

Final stand (000/ha)	28.7	32.1	29.0	32.8
Pod yield kg/ha	245	260	210	230
Pod yield g/plant	4.9	5.2	4.2	4.6

Table No.20 FIELD TEST No.2 ,RESULTS (ATIP Mahalapye)

Based on paired t-test with 16 df (17 paired observations).

	Untreated	Treated	t	Significance
Plants per hectare	12,025 (10,048)	14,306 (10,280)	1.795	.975
Plot size (sq. m)	441.7 (222.8)	505.[illegible] (292.5)	1.44	.95
Seeding rate (kg/ha)	18.64 (8.74)	17.02 (8.70)	1.42	.95
Seed/ha (a)	66,368 (31,141)	60,614 (30,967)		
Percent field emergence (b)	19.4 (14.8)	25.3 (14.3)	3.66	.99

(a) Based on an average of 28.08 grams per 100 seeds.
(b) Not adjusted for in vitro seed viability estimated at 95.5%

4.6 **Seed multiplication**

The purpose of seed multiplication is to ensure regular supplies to the selected seed distribution services, so that they can meet the farmers' requirements.

Based on the sowing of 5,000 hectares of groundnut per year, i.e. a seed requirement of 500 unshelled tonnes, and assuming that is necessary to renew seed every four years (maintenance of crop value), 125 tonnes of unshelled groundnut have to be produced every year.

Given this objective, the following production scheme was adopted :

SEED PRODUCTION SCHEME

Levels	Objective	Achievement
Sebele under irrigation		
Collection	5 single selected plants	5 single sel. plants : Sellie 5 single sel. plants : 55-437
G 0	250 selected plants	250 selected plants : Sellie 250 selected plants : 55-437
G 1	100 selected families	100 selected families: Sellie 100 selected families: 55-437
G 2	250 kg of pods	100 kg unshelled : Sellie 150 kg unshelled : 55-437
Sebele under dryland		
M 1	2,300 kg of pods	1,450 kg unshelled : Sellie 400 kg unshelled : 55-437
Contract growers		
M 2	18,000 kg unshelled (23 Ha)	18,000 kg unshelled : Sellie (10,900 Kg shelled)

=========================

1987/88 expectation
M 3 180 Ha ------------------------125 tonnes unshelled
SEED DISTRIBUTION
1988-1989

For this year, the target was not completely reached for level M1, because of a considerable lack of rainfall. To ensure the production of this M1 level, the necessary means should quickly be made available to the Sebele station, which is currently being equipped with an irrigated periphery.

4.7 SUNFLOWER (Helianthus annuus)

Introduction

The sunflower variety trial was conducted on four sites throughout Botswana : Sebele, Goodhope, Matsaudi and Shorobe.

As far as the hectarage planted is concerned, this crop is at the same level as groundnut;it is very well accepted by farmers and the hectarage could be considerably increased if Botswana had the processing equipement for this crop.

Six hybrids were tested and compared to the local variety Russian No.4 (open pollinated variety).

Seed yields range from 165 kg/ha at Matsaudi to 677 Kg/ha at Goodhope. Under the climatic conditions of this season and on average for the 4 sites, no variety is significantly better than the control, though the hybrids have a tendency to be superior to the local variety Russian No. 4 .

4.7.1 MATERIAL AND METHOD.

Six hybrids imported from South Africa were tested at 4 different sites. These were :

1. Russian No. 4 (control)
2. CAR 1006
3. SO 323
4. PNR 7225
5. SNK 22
6. AS 504
7. SO 242

For each site,the trial was planted in randomized complete blocks with 4 replications. The plots contained 3 10-metre rows and were adjacent to each other. Spacing at the time of sowing was 75cm x 50cm. 150 kg/ha of 2-3-2 compound fertilizer (6.6% N, 9.9% P, 6.6% K) + 0.5% Zn was applied before sowing. Table 1 shows the composition of the trial for each site.

Table 1 LIST OF LOCATIONS AND SOWING/HARVESTING DATES

Site	Sowing date	Harvesting date	Rainfall
Sebele	24/11/86	06/03/87	179.2 mm
Goodhope	30/12/86	13/04/87	189.2 mm
Matsaudi	04/12/86	18/03/87	167.8 mm
Shorobe	05/12/86	23/03/87	159.1 mm

4.7.2 RESULTS AND DISCUSSION.

A combined analysis of variance for the 4 sites, in table 2, reveals no significant difference between the varieties and no variety/site interaction.

At Sebele, yields in seeds/ha for variety SNK 22 are significantly higher than those of the control, which is undoubtedly due to a larger SNK 22 stand.

The hybrids reached maturity after a growth cycle of 105-110 days as opposed to 120 days for the control. For all varieties as a whole, 50% of flowering occurred around the 60th day after sowing.

In view of the rainfall recorded during the growth cycle, yields at Sebele and Goodhope are remarkable. These results are definitely linked to the accumulation of water at the beginning of November and to early sowing. In a year of normal rainfall, charactrized by more abundant rainfall in January and February, it is recommended to sow at the beginning of January, for two reasons:

1) In clayey soils (Pandamatenga,Okavango),where sunflower performs very well, it is important to have good water reserves in the soil,hence accumulation of the November and December rainfall.

2) To avoid the drying out of seeds during their formation which begins 80 days after sowing,it is preferable that this seed formation take place at the moment the temperature begins to fall,i.e. from March onwards in Botswana.

Yields were very low at Matsaudi (sandy soil) and Shorobe(Sandy clay loam). In the case of the latter site, which is in a normally floodable low-lying area, but which has not been flooded for the last two seasons, rainfall has not been enough to build up water reserves in the soil, hence the low yields.

Table 1 <u>SUNFLOWER VARIETY TRIAL 1986/87, RESULTS ACROSS 4 LOCATIONS</u>.

VARIETIES	PLANT HEIGHT (cm)		HEAD DIAMETER (cm)		SEED YIELD (kg/ha)		Wt. 1000 SEEDS (g)		OIL CONTENT (%)
RUSSIAN No. 4	115.7		17.0		354.1		65.1		49.1
CAR 1006	103.3		14.7		347.5		53.3		49.7
SO 323	97.3		15.7		385.0		53.2		50.4
PNR 7225	108.0		15.0		372.7		56.9		50.4
SNK 22	101.7		15.9		383.5		56.9		50.3
AS 504	104.1		15.8		326.7		52.9		48.5
SO 242	97.6		17.8		430.8		61.2		49.1
Trial means	104.0		16.0		371.5		57.1		49.6
Sebele	110.8		15.0		432.4		47.6		50.6
Goodhope	105.0		16.4		677.3		54.8		47.5
Matsaudi	102.6		15.8		165.3		57.6		48.6
Shorobe	97.4		16.6		210.9		68.3		52.0
		LSD*		LSD		LSD		LSD	
F Locations (L)	0.88	n.s.	0.77	n.s.	21.1	144	8.2	8.4	-
F Varieties (V)	5.82	5.3	4.29	1.5	0.67	n.s.	7.4	4.7	-
F Inertaction L*V	2.66	n.s.	0.90	n.s.	1.31	n.s.	2.14	n.s.	-
C.V. (%)	10.2		13.2		44.1		11.9		

*L.S.D. at 5% level.

Section 5. COWPEAS AND MUNGBEANS

SUMMARY

A summary of the research trials conducted on Cowpeas during the 1986/87 season are presented. The major emphasis was on screening indigenous and exotic cowpea lines for drought and disease resistance, and desirable agronomic traits. Ten varieties were identified (TVX 3236, TVX 3236-01G, TVX 3405-01E, TVX 4262-09D, B057, B044, IT82D-641, IT82D-785, IT82E-9 and PI 471521). The yield ranged from 0.3t/ha to 1.4t/ha, with average rainfall of 300 mm. New varieties from IITA were also evaluated and no conclusions could be made from these evaluations. Bulked and single plant selections were made on F2, F4, and F5 breeding material from Botswana, IITA and SAFGRAD respectively. The CAMV screening trial identified four sources of resistance; TVU 410, UCR 237, B027 and Blackeye. The ER7 evaluation survey showed a general acceptance of the variety by farmers.

Mungbeans variety selection has identified several very promising lines.

5.1 OBJECTIVES

The general objective is to identify and minimize those constraints in cowpea production which cause traditionally low yield levels.

The objectives for 1986/87 called for continuation of those shown the previous year. These included the following topics:

1. to continue the program of local germplasm characterization.
2. to continue variety evaluation involving local and exotic lines.
3. to evaluate breeding material at various stages of cultural practices under special conditions.
4. to undertake field research for improvement of cultural practices under special conditions.
5. to continue disease resistance screening of cowpea lines.
6. to conduct a collaborative prgramme with the DAFS to test research findings on varieties and insect control on farmers' fields with and without subsidized inputs.

5.2 RESULTS

Objective 1 (Germplasm Characterization)

Fifty accessions were planted at Sebele on January 10, 1987 for field evaluation. However, one accession failed after germination leaving forty-nine lines for evaluation. The lines were planted on four-row plots of 5 m length, spaced 75 cm between rows and 20 cm within rows. Forty-one millimeters of irrigation water was applied at planting and 10 mm three days after planting to ensure good germination. Spraying for insect pests began at flowering and continued throughout the pod-filing period.

The characteristics evaluated were plant architecture, plant physiology and pigmentation, leaf and pod characteristics, seed characteristics, and yield components. Disease incidence was also evaluated. This evaluation brings the total number screened to 440, leaving another 400 to be characterized. The data collected this season will be summarized in Volume 4 of the Botswana Cowpea Germplasm Catalogue.

Objective 2 (Variety Evaluation)

Great emphasis is placed on variety evaluation as shown by a high number of experiments conducted on this subject. The varieties evaluated are from both local collection and imported lines (mainly from IITA). Trails were carried out at Sebele, Goodhope and Mahalapye. However, the experiment at Goodhope failed owing to the unrelenting drought which caused serious flower drop and bold heads.

Thirty-five local and imported cowpea cultivars were evaluated for yield and disease resistance in four-row plots replicated three times at Block-8 in Sebele. Supplimentary irrigation water was applied at planting and at flowering. The outstanding cultivar was TVX 3236 which remained free from mosaic virus and ashy stem blight (Macrophomina phaseolina), and produced the highest yield (Tables 1 and 2). The check variety ER7 performed poorly. The total rainfall at Block-8 was 305.3 mm.

A similar trial with thirty-four varieties at Mahalapye resulted in nine varieties yielding higher than TVX 3236. The variety ER7 ranked fourth (Table 3). The total precipitation at Mahalapye was 315.3 mm.

The last trial was carried out at the Labfield in Sebele. Ninety-four varieties were planted in four-row plots, 5 m long in a randomized complete block design with three replications. The variety TVX 3236 with a low disease score for mosaic virus and bacterial blight, produced the highest yield.

Ten cultivars yielded consistently higher (among the top ten) at all the three sites. These were TVX 3236, TVX 3236-01G, TVX 3405-01E, TVX 4262-09D, B057, B044, IT82D-641, IT82D-785, IT82E-9 and PI 471521.
Testing will be continued with 30 varieties selected for high yield and/or disease resistance.

Table 1: VARIETY ADAPTATION, BLOCK-8. 1986/87
MEAN DISEASE SCORE (1)

VARIETY NAME	MOSAIC VIRUS	BACTERIAL BLIGHT	MACROPHOMONA PHASEOLINA 47 DAP	60 DAP	68 DAP	96 DAP
B009-B	0.7	4.3	0	1.0	3.3	5.0
B032-A	0.0	5.0	0	0.3	2.7	-
B044	1.4	3.7	0	0.0	3.0	5.0
B052-A	0.3	3.0	0	0.0	0.7	4.7
B057	0.1	2.7	0	0.0	1.7	-
B097	0.7	0.7	0	4.7	5.0	-
B123	1.1	4.3	0	0.0	1.3	2.3
B171	0.8	4.3	0	0.0	2.3	-
B245-B	1.0	4.2	0	0.0	0.0	3.7
ER7	1.3	3.0	0	3.0	5.0	-
IT81D-1137	2.0	3.3	0	0.7	2.0	5.0
IT82D-640	2.0	2.0	0	1.0	4.3	-
IT82D-641	0.7	1.7	0	0.0	2.7	5.0
IT82D-709	1.7	2.0	0	0.3	4.0	5.0
IT82D-716	1.3	1.0	0	1.0	0.3	5.0
IT82D-755	1.1	1.7	0	0.0	0.0	3.0
IT82D-785	1.0	5.0	0	0.3	3.3	-
IT82D-881	1.7	4.0	0	1.0	2.7	4.5
IT82D-885	0.3	4.3	0	1.7	4.0	-
IT82D-889	1.3	5.0	0	3.7	4.3	5.0
IT82D-952	2.3	3.0	0	0.7	3.0	5.0
IT82E-9	2.1	3.7	0	3.3	4.0	-
PI 293505	0.0	5.0	0	3.3	4.7	-
PI 293570	0.0	4.3	0	0.7	2.0	4.0
PI 471521	1.7	4.0	0	0.0	1.0	-
TVU 98"	0.0	4.0	0	0.0	0.0	5.0
TVU 1185	0.0	5.0	0	0.0	0.0	3.7
TVX 1999-01F	0.3	5.0	0	0.0	0.7	-
TVX 3236	0.3	2.7	0	0.0	1.0	-
TVX 3236-01G	0.3	1.3	0	0.0	2.7	-
TVX 3405-01E	1.3	4.0	0	0.3	3.7	5.0
TVX 4262-09D	0.7	0.7	0	0.0	2.7	-
UCR 237	0.0	4.0	0	0.0	0.0	3.0
VITA 9	1.3	2.7	0	0.0	0.0	1.3
7964	0.0	4.3	0	2.0	4.3	-

(1) Scale: 0-5 where 0 is no disease and 5 is very severe disease.

DAP: Days After Planting

Table 2: VARIETY ADAPTATION, BLOCK-8. 1986/87. DAYS TO FLOWER, POD MATURITY AND YIELD.

VARIETY NAME	95 % DAYS TO FIRST FLOWER*	DAYS TO POD MATURITY*	YIELD (kg/ha)*
TVX 3236	45.7	70.7	1401.91 a (1)
TVX 4262-09D	45.0	68.0	1171.91 ab
B009-B	40.0	64.7	1102.13 ab
PI 471521	48.7	69.3	1074.58 ab
IT82D-785	41.3	66.0	1010.09 ab
TVX 3236-01G	45.7	69.0	990.00 ab
IT82E-9	38.0	56.3	960.22 ab
B044	44.3	69.3	959.69 ab
IT82D-641	42.7	68.0	928.27 ab
B171	42.7	68.7	897.02 ab
7964	40.3	60.0	870.04 ab
IT82D-716	46.3	72.0	854.89 ab
B057	50.3	73.0	833.07 ab
TVX 3405-01E	42.7	64.3	811.60 ab
IT81D-1137	44.3	70.7	763.60 ab
TVX 1999-01F	51.7	72.7	758.93 ab
PI 293505	40.7	64.0	750.44 ab
TVU 984	48.7	69.7	749.38 ab
IT82D-640	43.0	69.3	700.67 ab
B032-A	42.3	64.7	696.36 ab
IT82D-709	42.0	68.7	685.69 ab
TVU 1185	47.7	67.3	665.11 ab
B052-A	42.0	70.0	655.56 ab
PI 293570	42.0	66.3	653.38 ab
IT82D-755	46.3	69.7	641.82 ab
B123	53.3	77.7	636.98 ab
IT82D-881	42.3	65.0	624.76 ab
B097	39.0	57.7	586.89 ab
VITA 9	49.3	76.0	586.76 ab
IT82D-889	39.7	61.7	537.87 ab
IT82D-885	42.0	63.3	524.31 ab
ER7	40.7	58.7	511.11 ab
B245-B	47.7	72.3	481.78 ab
UCR 237	55.3	75.3	261.69 ab
IT82D-952	45.7	73.0	251.24 ab
CV (%)	2.53	4.71	37.99

* Significant at 0.01 probability level

(1) Means followed by the same letter are notr significantly different at 0.01 probability level using the Student-Newman-Keuls' test.

Table 3: VARIETY ADAPTATION, MAHALAPYE, 1986/87.
PRODUCTION AND DISEASE SCORE.

VARIETY NAME	DFF	DAYS TO POD MATURITY *	MOSAIC VIRUS	BACTERIAL BLIGHT	PLANT POPUL	YIELD (kg/ha)*
IT82D-709	37	58	2	2	60	689.0 a
IT82D-641	39	57	2	2	61	624.3 ab
IT82D-640	38	59	3	3	57	612.9 ab
ER7	35	55	2	2	60	500.1 ab
IT82D-785	37	54	3	3	59	463.4 ab
IT82D-885	37	59	3	3	57	453.4 ab
TVX3405-01E	39	58	2	2	60	408.3 ab
B097	33	47	2	2	56	394.9 ab
IT82D-881	42	60	3	3	56	392.3 ab
TVX 3236	49	65	3	3	56	376.1 ab
IT82E-9	34	52	3	3	60	375.7 ab
PI 471521	55	70	4	4	65	356.8 ab
B044	45	65	3	3	63	350.4 ab
PI 293505	38	54	3	3	55	346.9 ab
TVX3236-01G	43	57	2	2	57	340.0 ab
IT82D-952	50	69	3	3	63	323.1 ab
IT82D-716	49	63	2	2	63	322.8 ab
7964	35	51	3	3	60	284.5 ab
IT81D-1137	48	64	2	2	59	272.0 ab
TVX1999-01F	56	71	2	2	59	271.0 ab
B009-B	39	58	3	4	55	250.8 ab
B171	36	59	2	2	55	228.4 ab
IT82D-889	35	50	2	2	57	218.0 ab
B032-A	36	53	2	3	57	196.6 ab
TVU 984	54	66	2	2	57	195.2 ab
PI 293570	45	60	2	2	59	149.1 ab
B052-A	36	56	2	2	57	142.9 ab
TVU 1185	54	68	2	2	60	138.2 ab
B057	51	64	2	2	64	127.7 ab
IT82D-755	52	72	2	2	59	88.4 ab
VITA 9	49	63	2	2	65	66.3 ab
B123	57	71	2	2	55	66.2 ab
B245-B	55	66	2	2	51	35.6 b
UCR 237	65	79	3	3	59	24.3 b
CV (%)	10.93	10.60	38.54	39.92		58.29

Plant Population is in thousand plants/hectare ('000 plants/ha)
Disease score was recorded 66 days after planting
* Significant at 0.01 probability level

Means followed by the same letter are not significantly different at 0.01 probability level using the Student-Newman-Keuls' test.

Table 4: VARIETY ADAPTATION, LABFIELD. 1986/87.
PRODUCTION AND DISEASE SCORE.

VARIETY NAME	DFF	DAYS TO POD MATURITY	MOSAIC VIRUS	BACTERIAL BLIGHT	PLANT POPUL	YIELD (kg/ha)
TVX 3236	46	71	1.0	1.7	48	601.3
TVU 1185	46	61	1.3	3.0	51	508.1
TVX 3405-01E	43	67	1.0	2.7	47	471.3
B057	52	76	1.7	3.0	46	410.4
TVX 4262-09D	43	62	0.7	1.3	52	400.0
IT82D-952	44	67	1.3	2.7	57	390.4
B165	47	71	1.0	2.3	56	378.7
TVX 3236-01G	45	69	0.0	0.7	47	373.6
B047-A	70	-	1.3	3.0	53	361.4
B242-A	61	-	1.7	2.7	51	344.8
UCR 237	38	59	0.7	0.0	51	340.7
IT82D-641	41	67	0.7	3.0	49	334.7
IT81D-1137	45	70	3.0	3.0	59	333.5
IT82D-716	43	68	1.0	2.0	47	331.5
IT82D-709	41	68	1.0	2.3	46	330.7
B029-A	46	66	1.7	3.3	53	318.8
B171	47	71	1.3	2.7	45	317.0
B127	68	70	1.0	2.7	57	312.8
UCR 274	38	60	1.3	2.0	59	300.7
IT82E-9	37	62	2.0	4.0	46	299.3
B098-A	40	67	1.7	3.7	46	299.1
IT82D-880	41	65	2.3	3.3	56	283.2
B013-D	58	66	1.3	3.0	51	282.2
B122	52	76	1.7	2.7	48	279.1
MAGNOLIA B/E	38	62	0.7	4.0	52	270.4
TVU 408	62	73	0.7	3.0	56	262.1
B055	38	62	1.3	4.0	40	258.4
B028-A	45	67	0.3	2.7	55	242.3
B163	43	65	0.7	4.0	55	241.4
B007-F	38	62	1.0	2.3	52	237.6
IT82D-755	43	62	1.0	3.0	45	236.8
IT81D-1039	49	73	1.0	3.0	48	235.3
ER7	38	60	1.3	2.0	56	234.3
IT82E-60	43	61	1.3	2.0	61	232.9
IT82D-785	39	64	1.0	3.3	51	229.7
B044	42	64	2.3	2.0	49	222.3
MISSI WHITE	42	66	1.0	3.7	55	216.5
PI 250238	41	60	2.3	3.3	50	208.7
TVU 2755	53	78	0.7	3.0	57	207.7
UCR 207	38	64	1.7	3.7	38	205.8
UCR 193	38	69	1.0	2.0	48	200.1
TVU 652	56	71	0.3	2.7	48	196.7
UCD 84-857	38	61	0.3	4.0	54	196.6
TVU 645	52	60	1.0	3.7	54	196.2
IT82D-885	39	61	1.3	4.0	71	194.3
UCR 194	38	61	1.3	3.7	56	194.2
B052-A	42	72	1.3	2.7	48	191.9
IT82D-889	38	65	1.0	3.7	45	190.7
PI 293505	39	62	1.7	4.3	54	190.4
B009-B	38	66	1.0	3.3	48	185.2
TVU 984	48	73	0.0	2.7	63	184.5
IT83E-70	39	63	1.3	3.0	41	184.3
PI 293570	43	62	1.0	3.7	43	182.1
IT82D-881	42	62	1.7	3.3	57	179.7
IT82D-640	41	67	0.7	3.0	53	175.6

Table 4 cont.

VARIETY NAME	DFF	DAYS TO POD MATURITY	MOSAIC VIRUS	BACTERIAL BLIGHT	PLANT POPUL	YIELD (kg/ha)
PI 471521	54	66	0.7	2.7	49	172.4
B306	56	73	1.3	3.7	51	149.0
B123	68	84	1.0	3.0	56	135.2
B109-B	58	60	0.7	3.0	54	133.9
UCR 237	64	72	1.0	3.7	60	132.6
B111-C	68	-	1.7	2.7	56	127.2
B245-B	49	75	1.0	2.3	55	126.6
TVU 3000	53	65	1.7	4.0	53	125.0
TVU 801	62	78	1.7	3.3	52	122.7
CB5	39	64	0.7	4.7	41	121.9
B032-A	42	62	1.7	3.0	51	121.4
TVU 410	58	71	0.3	2.7	52	120.0
7964	38	67	1.7	3.3	47	119.2
UCD 84-243	39	63	0.7	2.0	51	118.0
TVU 36	44	-	1.0	3.3	49	109.0
TVU 2896	51	58	0.7	2.7	52	103.7
TVU 1000	60	63	1.3	4.0	52	100.6
B016-A	70	71	1.0	3.7	54	99.5
B232	47	71	0.7	2.7	52	99.0
TVX 1999-01F	51	71	1.3	3.3	47	94.0
B055	49	71	1.0	2.7	54	93.9
VITA 3	67	-	1.7	3.0	48	92.2
BLACKEYE	45	62	0.7	3.3	56	74.7
UCR 264	55	60	1.0	4.0	49	68.8
B097	37	71	1.7	2.0	49	60.4
PI 353271	60	-	1.0	3.3	49	42.7
VITA 1	58	65	2.3	2.3	61	41.1
B201	64	-	2.0	3.0	46	40.5
B111-C	67	-	3.0	2.3	47	37.8
TVU 347	62	72	0.3	2.0	56	36.0
VITA 9	48	71	2.0	3.0	48	35.1
B005-C	62	70	1.0	1.7	44	33.8
UCR 238	46	66	3.0	3.7	47	33.4
WORTHMORE	48	60	1.3	4.0	48	33.2
TVU 493	67	-	1.0	3.7	47	24.7
B027	-	-	0.7	2.3	43	16.9
B135	66	73	0.0	3.0	53	14.1
B183	74	78	0.3	4.0	47	10.6
B022	-	-	2.0	2.7	44	0.0

Plant Population is in thousand plants/hectare ('000 plants/ha)

IITA VARIETY EVALUATION TRIALS

Evaluation of new extra-early varieties.

Twelve extra early cowpea lines from IITA in four-row plots and three replications were evaluated at Sebele and Goodhope. However, the trial at Goodhope failed because of flower drop, hence yield data was not obtained.

The variety IT83D-362-2 was the best grain producer under great moisture stress as occurred during 1986 especially at flowering. ER7 was the worst grain producer (Table 5).

Table 5: YIELD OF GRAIN OBTAINED FROM IITA EXTRA EARLY MATURING VARIETIES AT SEBELE, 1986/87. (Means of 3 reps).

VARIETY NAME	PLANT POPULATION (Plants/ha)	YIELD (kg/ha)
IT83D-362-2	87 000	440.4 a (1)
IT83S-689-4	65 000	284.6 ab
IT84S-2231-15	73 000	185.2 bc
IT83S-16	55 000	143.6 bc
IT83D-442	52 000	139.0 bc
IT83D-356-1	74 000	119.6 bc
IT83D-666	47 000	99.5 bc
B097	59 000	84.6 bc
IT83S-818	85 000	80.2 bc
IT83E-124	65 000	74.7 bc
IT83E-1-108	78 000	68.3 bc
ER7	35 000	33.7 c
CV (%)	20.87	47.48

(1) Means followed by the same letter are not significantly different at 0.01 probability level using the Student-Newman Keuls' test.

Evaluation of new medium maturity varieties from IITA

Medium maturity variety evaluation trial was conducted at Mahalapye in four-row plots and three replications. None of the varieties tested were superior than B052-A (local) or significantly better than TVX 3236 (Table 6).

Table 6: PRODUCTION OF MEDIUM MATURITY VARIETIES AT MAHALAPYE.

VARIETY NAME	PLANT POPUL	DFF	DAYS TO POD MATURITY	MOSAIC VIRUS	BACTERIAL BLIGHT	YIELD (kg/ha)
IT84S-2127	61	37	51	2.00	1.67	605.9
IT83S-875	52	40	53	2.00	1.67	503.8
TVX 3236	64	44	57	1.33	1.00	461.1
IT84S-2213-2	56	31	47	4.33	2.00	435.5
IT84D-449	53	41	61	1.67	1.00	412.9
IT84D-716	67	43	62	2.00	1.33	409.9
IT84S-2081	54	39	54	1.67	2.00	403.1
B052-A	59	40	56	1.33	1.67	379.0
IT83D-320-10	61	40	57	2.67	1.33	377.4
IT84D-448	58	47	61	1.67	1.00	372.8
IT84D-371	57	35	50	2.67	1.67	370.8
IT83S-728-18	56	37	50	2.33	1.33	343.9
IT84D-552	44	39	51	3.00	2.00	325.2
IT84S-2137	62	39	52	3.67	2.33	312.3
IT84D-513	61	48	57	2.67	3.00	287.5
IT84D-2049	63	45	61	2.00	2.33	186.4
IT84D-368	62	37	47	1.67	1.00	164.7
IT84D-453	56	50	72	1.67	2.67	113.8
IT83S-680-9	61	46	60	2.33	3.00	104.1
IT83S-871	60	48	61	1.67	1.67	84.2
CV (%)	11.88	6.64	8.47	27.35	31.90	47.79

Disease score was recorded 48 days after planting
Plant population is in thousand plants/hectare ('000 plants/ha)

Table 7: MEAN YIELD, PLANT STAND, DISEASE SCORE AND FLOWERING CHARACTERISTICS OF INTRODUCED APHID RESISTANCE COWPEA LINES FROM IITA, at Sebele.

VARIETY NAME	PLANT POPUL	DFF	DAYS TO POD MATURITY	MOSAIC VIRUS	BACTERIAL BLIGHT	YIELD (kg/ha)
IT83S-728-5	64	44	79	0.00	0.00	828.3
B031	58	46	75	0.00	0.00	754.9
IT83S-742-13	66	41	73	0.00	0.00	706.0
IT83S-728-13	63	38	73	0.33	0.00	659.8
IT83S-742-11	64	44	78	0.67	0.00	631.6
IT83S-720-2	60	46	72	0.00	0.00	598.7
IT83S-742-1	65	40	75	0.67	0.67	584.7
IT83S-742-2	65	44	75	0.00	0.00	555.1
IT82D-812	60	49	81	1.00	0.33	490.1
IT84E-1-108	54	52	83	3.00	0.00	341.4
CV (%)	9.18	5.54	6.16	57.83	250.92	17.42

Disease score was recorded 49 days after planting.

Evaluation of aphid resistant varieties.

The trial consisted of ten lines including one standard variety, B031 which is aphid resistant. The trial was planted at Sebele on January 12, 1987. Grain yield ranged from 828 to 341 kg/ha with the local check variety (B031) ranking second. Most of the varieties also remained free from mosaic virus symptoms and bacterial blight (Table 7).

Evaluation of new vegetable cowpea varieties.

Ten vegetable cowpea varieties were grown at Sebele in a randomized block design with three replications. Four-row plots of 5 m length were used.

The varieties did not perform differently from each other (Table 8).

Table 8: MEAN YIELD AND FINAL PLANT STAND OF TEN VEGETABLE VARIETIES, Sebele 1986/87.

VARIETY NAME	PLANT POPULATION (PLANTS/HA)	YIELD (kg/ha)
IT81D-1228-13	106 000	318.9
IT81D-1228-42	27 000	279.2
IT81D-1228-10	80 000	254.0
IT81D-1228-12	94 000	248.6
IT81D-1228-9	50 000	240.1
TVU 21	87 000	213.3
IT83S-911	114 000	212.3
IT81D-1228-13	58 000	208.4
IT83E-116	89 000	194.9
IT81D-1228-14	109 000	123.5
CV (%)	24.30	48.19

Evaluation of dual purpose varieties.

Identical trials of ten dual purpose varieties were carried out at Sebele and Mahalapye. The trials were laid out in a randomized block design with three replications and four-row plots of 5 mm length.

At Mahalapye, yield ranged from 0 to 513 kg/ha while at Sebele it ranged from 66 to 268 kg/ha. Variety IT83S-797 performed well at both locations. Yield was not obtained in Mahalapye for the standard variety B005-C (Table 9).

Table 9: GRAIN YIELD (kg/ha) AND PLANT POPULATION OF DUAL PURPOSE VARIETIES.

VARIETY NAME	SEBELE		MAHALAPYE	
	PLANT POPUL	YIELD	PLANT POPUL	YIELD
IT81D-985	58 000	176.8	48 000	0.0
IT82D-875	55 000	176.0	48 000	35.2
IT82D-927	60 000	268.2	60 000	155.7
IT83S-797	62 000	212.5	42 000	513.1
IT83S-894	72 000	90.2	32 000	246.4
IT83S-880	50 000	165.4	50 000	172.7
IT83S-872	69 000	219.9	51 000	29.1
TVX 1948-01F	39 000	142.5	49 000	56.8
TVX 4659-03E	41 000	66.9	41 000	0.0
B005-C	37 000	159.2	29 000	0.0
CV (%)	30.37	57.59	13.10	37.32

Plant Population (Plants/hectare)

Objective 3 (Breeding)

Breeding in Botswana.

Fourty- ven crosses were made by Dr Doug Burke during 1984/85. However, twenty-one crosses produced viable seedlings in 1985/86. Bulk seed was collected from all 21 crosses in 1986 and planted during 1986/87 season as F2 seed at Block8 in Sebele under irrigation. These were planted on two row plots with two replications

The plants were selected based on disease tolerance and desirable plant architecture. The early lines were selected for determinant growth habit and production of pods above the leaf canopy. Medium lines were selected for semi-erect to spreading growth habit and medium to large leaves. The late maturing selections were spreading. Disease score and maturity data as well as seed quantity of F3 seed available are summarized in Table 10. Work with this material will be continued in 1987/88 under irrigation at Block8.

IITA Breeding

Three crosses were made by Dr B.B. Singh in IITA during the 1982/83 season. These were then advanced to the F3 stage in Nigeria and sent to Botswana for selection. In 1984/85 bulk seed was collected from all crosses and planted during the 1985/86 season as F4 seed. A total of 80 single selections were made (F5). This seed was planted in 1986/87 at Block8 under irrigation on single row plots spaced 75 cm apart and 20 cm within rows. The plot length varied with the quantity of seed available.

Genotypes were selected based on erect growth habit, prolific pod production, early maturity and disease tolerance to CAMV and Macrophomona phaseolina. A total of 80 selections were made this year (Table 11). Sixty-nine of the 80 selections were bulked. Work with this material will be continued in 1987/88.

SAFGRAD Breeding

Twenty-seven crosses were made by Dr Vas Aggarwal of SAFGRAD in Burkina Faso in 1983. These were then advanced to the F2 stage and sent to Botswana for selection. Three crosses were lost in 1983/84 leaving 24 (F3) crosses for planting the following season. During the 1984/85 season, two more crosses were lost, reducing the total to 22 (F4) crosses. In 1985/86, only five crosses were planted. The remaining crosses not planted in 1985/86 were planted during the 1986/87 season (16 crosses).

Selections made were based on disease tolerance and plant architecture. Bulk seed was collected (F5 - Table 12). Work with this material will be continued in 1987/88.

Table 10: F3 SEED OF CROSSES MADE IN BOTSWANA.

PARENTAGE			BACTERIAL		SEED WT
FEMALE	MALE	CAMV	BLIGHT	MATURITY	(GRAMS)
TVX 3236-01G	B319	0	1	MEDIUM	9.9
"	"	0	0	LATE	1.9
"	B359	-	-	EARLY	23.3
"	"	-	-	LATE	15.4
"	B005-C	-	-	EARLY	36.0
"	"	-	-	"	17.1
"	"	-	-	"	7.4
"	"	-	-	"	14.2
"	"	-	-	"	17.5
"	TVX 4262 -09D	0	0	MEDIUM	30.2
"	UCR 193	-	-	EARLY	25.7
"	"	-	-	"	15.5
"	"	-	-	"	21.5
"	"	0	0	MEDIUM	11.3
"	"	-	-	EARLY	9.7
"	"	-	-	"	8.3
"	(ER7 x TVX 1999-01F)	-	-	MEDIUM	22.6
"	"	-	-	"	5.3
"	"	-	-	EARLY	38.4
"	UCR 194	0	1	MEDIUM	29.7
"	"	-	-	EARLY	22.8
"	"	-	-	"	13.1
"	"	-	-	"	24.6
"	"	-	-	"	12.7
"	"	0	2	MEDIUM	21.6
"	ER7	-	-	EARLY	15.6
"	"	-	-	"	14.4
"	"	-	-	"	14.5
"	"	0	1	MEDIUM	17.1
"	"	-	-	"	17.6
"	PI 250238	-	-	EARLY	23.9
"	"	-	-	"	11.4
"	"	-	-	"	15.0
"	"	-	-	"	15.1
"	"	-	-	"	14.4
"	"	-	-	"	22.2
"	"	-	-	MEDIUM	7.7
"	B218	-	-	EARLY	20.6
"	"	-	-	"	7.5
"	"	-	-	"	32.0
"	"	-	-	"	36.6
"	"	0	0	MEDIUM	34.6
"	(B009-C x UCR 194)	-	-	EARLY	17.0
TVX 3236-01G	(B009-C x UCR 194)	-	-	EARLY	15.4
"	"	-	-	"	23.1
"	"	-	-	"	30.3
"	"	0	0	MEDIUM	9.3
"	"	0	0	"	15.0
"	"	0	1	"	41.4
"	"	0	0	"	18.0

Table 10 continued

PARENTAGE		CAMV	BACTERIAL BLIGHT	MATURITY	SEED WT (GRAMS)
FEMALE	MALE				
"	"	-	-	EARLY	29.6
"	"	-	-	"	23.4
"	"	-	-	"	11.0
"	"	0	1	"	20.6
"	"	0	1	MEDIUM	21.8
UCR 194	PI 471521	-	-	EARLY	42.0
"	"	-	-	"	54.8
UCR ?	?	-	-	"	49.0
IT82D-716	PI 471521	-	-	"	17.1
"	"	-	-	"	14.7
"	"	-	-	"	12.0
"	"	0	0	MEDIUM	35.0
B009-B	B128	-	-	EARLY	13.4
"	"	-	-	"	13.1
"	"	-	-	"	58.4
"	"	0	1	MEDIUM	31.4
"	"	0	0	"	22.1
B009-B	IT82D-716	-	-	EARLY	27.2
"	"	-	-	"	17.2
"	"	-	-	"	22.0
"	"	-	-	-	18.2
B009-B	B171	-	-	EARLY	26.7
B007-F	IT82D-716	-	-	"	15.5
"	"	-	-	"	60.1
"	"	-	-	"	65.5
"	"	0	0	MEDIUM	13.2
"	"	-	-	EARLY	23.4
"	"	0	1	MEDIUM	16.3
CB5	PI 152196	-	-	EARLY	17.6
"	"	0	2	"	29.4
UCD 84-208	UCR 7977	-	-	"	13.0
"	"	-	-	"	23.8
"	"	-	-	"	16.0
"	"	-	-	"	15.6
PI 471521	IT82D-716	0	0	"	32.6
"	"	0	0	"	14.8
"	"	-	-	LATE	13.4
"	"	0	0	MEDIUM	12.7
"	"	-	-	"	10.7

Table 11: F6 SEED OF CROSSES MADE IN IITA

SINGLE SELECTION				BULK SELECTION	
PARENTAGE		PLANTS	SEED	PLANTS	SEED
FEMALE	MALE	SELECTED	WT (g)	SELECTED	WT(g)
IT82D-60	ER7	-	-	4	65.6
"	"	-	-	11	110.0
"	"	-	-	5	41.3
"	"	-	-	4	33.4
"	"	1	13.3	7	49.4
"	"	-	-	3	65.7
"	"	-	-	2	19.0
"	"	-	-	6	52.1
"	"	-	-	5	31.1
"	"	-	-	6	33.1
"	"	-	-	3	10.4
"	"	-	-	10	122.9
"	"	-	-	3	0.9
"	"	-	-	3	24.6
"	"	1	6.9	4	56.3
"	"	-	-	9	84.6
"	"	2	14.1	22	325.7
"	"	-	-	20	264.6
"	"	-	-	3	81.0
"	"	-	-	8	78.0
"	"	1	10.4	-	-
"	"	1	31.8	7	173.1
IT82E-716	ER7	1	23.9	4	23.5
"	"	-	-	17	274.2
"	"	1	24.1	7	76.4
"	"	1	33.6	36	529.3
"	"	-	-	4	20.6
"	"	1	14.8	-	-
"	"	-	-	3	37.5
"	"	1	10.6	13	165.8
"	"	-	-	11	65.1
"	"	-	-	6	101.6
"	"	1	30.2	12	131.9
"	"	-	-	6	52.1
"	"	1	12.9	4	32.3
"	"	-	-	2	5.3
"	"	-	-	4	133.6
"	"	-	-	18	29.6
"	"	-	-	46	342.4
"	"	-	-	15	140.1
"	"	-	-	14	101.4
"	"	1	22.6	-	-
"	"	1	3.2	-	-
"	"	-	-	3	48.0
"	"	-	-	8	37.2
"	"	1	22.0	18	165.3
IT83E-716	ER7	-	-	47	582.6
"	"	1	4.6	19	116.2
"	"	-	-	4	17.5
"	"	-	-	22	7.6
"	"	1	23.5	14	66.5
"	"	1	33.5	5	99.2
"	"	-	-	3	59.5
"	"	1	22.1	5	80.4
"	"	-	-	6	133.1

Table 11. continued

SINGLE SELECTION			BULK SELECTION		
PARENTAGE		PLANTS	SEED	PLANTS	SEED
FEMALE	MALE	SELECTED	WT (g)	SELECTED	WT(g)
"	"	1	3.0	20	277.1
"	"	-	-	4	102.3
(CNC x 10-2E)	ER7	2	40.8	21	183.2
"	"	-	-	5	117.4
"	"	1	31.5	10	99.4
"	"	-	-	6	77.0
"	"	-	-	20	127.0
"	"	1	22.2	6	35.3
"	"	1	10.9	4	45.6
"	"	2	13.6	-	-
"	"	3	14.6	-	-
"	"	1	10.5	9	55.2
"	"	1	23.9	13	316.3
"	"	2	19.9	-	-
"	"	-	-	11	166.9
"	"	1	6.1	-	-
"	"	-	-	23	231.6
"	"	1	13.2	9	61.9
"	"	1	31.9	21	212.4
"	"	3	8.9	-	-
"	"	4	6.9	-	-
"	"	-	-	6	60.6
"	"	-	-	9	35.1
"	"	-	-	32	366.9
"	"	-	-	35	389.7

Table 12: F5 SEED OF CROSSES MADE IN SAFGRAD, BURKINA FASO.

		SINGLE SELECTIONS		BULK SELECTIONS	
PARENTAGE		PLANTS	SEED	PLANTS	SEED
FEMALE	MALE	SELECTED	WT (g)	SELECTED	WT (g)
B178	SUVITA-2	2	23.4	-	148.0
"	"	2	18.8	6	32.9
"	"	-	-	37	330.9
"	"	-	-	26	219.4
"	"	-	-	8	123.1
TVX 3072-01E	58-57	-	-	10	116.5
"	"	4	57.6	20	286.0
"	"	-	-	9	131.3
IT82E 12	SUVITA-2	1	9.7	88	668.2
"	"	2	17.9	-	226.6
"	"	-	-	15	126.5
?	?	1	17.7	3	49.7
"	"	-	-	20	223.2
"	"	-	-	33	351.3
"	"	3	38.5	18	218.9
"	"	-	-	20	208.4

Objective 4 (Tillage practices/Intercropping)

The cultural practice program continued to focus on the application of minimum tillage concepts and new planting methods to Botswana. However, this year the tillage experiment failed owing to late planting which resulted in poor plant establishment because of lack of moisture.

Evaluation of blending cowpea varieties.

Botswana farmers rarely plant pure seed of any one cowpea variety but usually a mixture of many indigenous cultivars. On the other hand, occasional pure stands occur. The question arose as to whether blends give an advantage in cowpea yield or provide yield stability for the small farmer who uses most of his produce for home consumption. Hence a study was undertaken to investigate the advantage of cowpea blends in comparison with pure varieties under field conditions.

Two cowpea varieties, a short and long season variety were grown in pure stand and intercropped within rows at three population levels (12 500, 25 000 and 50 000 plants/ha). A broadcast intercrop treatment at 50 000 plants/ha was included. The short season variety was removed at four stages of development (Germination, Vegetation, Flowering and Podfill) to simulate crop failure. The experiment was conducted at two locations, Sebele and Goodhope, for two seasons, 1985/86 and 1986/87. Soil moisture was monitored on weekly basis with a neutron probe. Data collected included plant height, number of main branches, number of runners between and across rows, pods per plant, seeds per plant, 100 seed weight and grain yield.

It was found that blending cowpea varieties gives yield advantage provided the right variety combination is used. The best yield advantage was obtained at a plant population of 25 000 plants/ha at all locations and sites (Table 13). A higher yield (545 kg/ha) was obtained from the broadcast treatment at 50 000 plants/ha compared to within row treatment (301 kg/ha) at the same plant population at Sebele. Similar results were obtained at other sites.

Pods per plant decreased with increasing plant population (Table 14). Simulated crop failure of the short season variety in the mixture at the various stages of development did not influence the grain yield of the remaining variety at any of the experimental sites at all population levels (Table 15).

Table 13: YIELD OF COWPEA GRAIN AND MEAN LER.

		PLANT POPUL	YIELD (kg/ha)				
			MONOCROP		BLEND		
SEASON	LOCATION	(plants/ha)	V1	V2	V1	V2	LER
1985/86	BLCCK8	12 500	470	255	191	106	0.82
		25 000	539	181	219	288	1.99
		50 000	968	114	167	139	1.39
1986/87	LABFIELD	12 500	272	280	78	98	0.64
		25 000	365	246	153	169	1.11
		50 000	395	221	172	129	1.02

V1 : ER7

V2 : B111-C

Table 14: THE EFFECT OF BLENDING AND PLANT POPULATION ON PODS PER PLANT, 1985/86.

PLANT POPULATION (plants/ha)	PODS PER PLANT	
	BLOCK 8	GOODHOPE ER7
12 500	34.3 a *	23.0 a
25 000	25.5 b	17.5 bcd
50 000	18.0 de	18.5 bcd
	B111-C	CB5
12 500	18.3 de	14.0 cdefg
25 000	11.3 f	12.3 defg
50 000	13.0 ef	8.8 fh
	BLEND	
12 500	16.0 deg	21.0 ab
25 000	9.3 g	15.3 cde
50 000	14.5 def	9.8 fgh
50 000 (Broadcast)	23.5 bc	15.5 cde

Table 15: THE EFFECT OF ER7 REMOVAL FROM THE BLEND, 1985/86.

TIME OF ER7 REMOVAL	YIELD (kg/ha)			
	BLOCK 8-1	BLOCK 8-2	BLOCK 13	GOODHOPE
12 500 Plants/ha				
0 days	884 cde*	301 c	114 cde	248 fgh
25 "	702 de	241 cd	126 cde	234 gh
45 "	705 de	255 cd	340 cd	206 h
55 "	687 de	143 d	125 cde	246 fgh
25 000 Plants/ha				
0 days	757 de	255 cd	99 de	336 efg
25 "	597 e	256 cd	117 cde	268 fgh
45 "	1021 bc	207 cd	94 e	254 fgh
55 "	615 e	130 d	242 cde	292 fgh
50 000 Plants/ha				
0 days	653 e	181 cd	126 cde	574 b
25 "	654 e	213 cd	158 cde	292 fgh
45 "	658 e	180 cd	80 e	291 fgh
55 "	692 de	126 d	100 de	333 efg

* Means within each column followed by the same letter are not significantly different at 0.05 probability level using the Student-Newman-keuls' test.

Table 16: LOCAL CULTIVARS AND INTRODUCED COWPEA VARIETIES SCREENED FOR CAMV RESISTANCE USING LEAF INOCULATION AT THREE LOCATIONS.

B016-A	IT81D-1137	MISSISSIPPI WHITE	TVX 3236
B027	IT82D-640	PI 293505	TVX 3236-01G
B055	IT82D-641	PI 471521	UCD 84-857
B057	IT82D-709	TVU 347	UCR 193
B097	IT82D-755	TVU 408	UCR 194
B111-A	IT82D-785	TVU 410	UCR 207
B127	IT82D-880	TVU 645	UCR 236
B163	IT82D-881	TVU 652	UCR 237
B171	IT82D-885	TVU 801	UCR 264
B201	IT82D-889	TVU 1000	VITA 9
B232	IT83E-60	TVU 1185	7964
BLACKEYE	IT82E-70	TVU 2755	9055
ER7	MAGNOLIA BLACKEYE	TVX 1999-01F	

Table 17: THE INCIDENCE OF CAMV ON COWPEA VARIETIES TESTED AT SEBELE, 1986/87 SEASON.

VARIETY NAME	% EARLY INFECTION	INOCULATED PLANTS	% CAMV INCIDENCE
UCR 237	0	0	0
TVU 410	0	0	0
B027	0	1	0
BLACKEYE	0	1	0
VITA 9	0	0	1
TVU 1000	0	0	3
TVU 645	0	0	3
B111-A	0	3	3.5
UCR 236	0	0	4.5
TVX 1999-01F	0	2	4.5
TVU 2755	0	3	4.5
UCD 84-857	5.34	0	5.5
IT82D-881	0	3	6.0
IT82D-885	0	0	6.5
IT81D-1137	0	2	6.5
TVU 408	0	0	6.5
IT82D-889	0	2	6.5
8055	0	1	7.0
7964	0	2	7.5
MAGNOLIA BLACKEYE	0	3	7.5
B097	2.47	0	8.0
TVU 1185	4.26	0	10.0
IT82D-709	6.25	3	10.5
IT82D-880	0	1	11.0
UCR 264	0	4	12.5
B163	0	2	14.0
IT82E-70	0	0	14.0
B127	0	5	15.5
IT82D-785	0	4	16.0
UCR 207	2.23	0	16.0
MISSISSIPPI WHITE	3.53	1	16.5
IT82E-60	1.52	0	19.0
B016-A	0	5	19.5
UCR 193	0	0	20.5
PI 293505	4.06	1	21.5
TVU 801	0	6	21.5
B171	0	1	21.5
IT82D-640	6.25	1	22.5
TVU 652	0	2	23.5
TVX 2336-01G	3.03	3	26.5
UCR 194	0	3	27.0
IT82D-755	0	2	28.0
B055	0	4	30.5
TVU 347	0	3	31.5
B057	5.75	3	32.0
TVX 3236	3.34	2	35.5
B232	5.41	6	35.5
IT82D-641	16.00	1	35.5
ER7	3.03	4	37.5
PI 471521	1.41	2	50.0
B201	9.84	3	51.5

Objective 6 (Collaborative Field Trails)

Sparying technique.

In continuation of field work with the Department of Field Services, Agricultural Demonstrators (A/D's) from the Northern and Southern region assisted the farmers with on-farm trails, to compare varieties and spray application of insecticides. A total of sixty-nine A/D's participated. Most of the cooperating farmers failed to plant any crop owing to the continuing extreme drought conditions. Only six trials were were successfully completed and yield recorded, five in the Southern region and one in the Northern region. However, four of the six trials were sprayed against insects while two were not.

The field design consisted of ER7 and Blackeye varieties planted in eight-row plots spaced 75 cm apart. The plot length ranged from 40 to 100 m depending on the area available. Each variety was replicated twice. The four center rows were harvested for yield.

The grain yield ranged from 51 to 366 kg/ha with an average of 200 kg/ha (Table 18). Statistical analysis showed no significance for varieties or spraying treatments. However, location was highly significant ($P<0.01$). The amount of available moisture in the soil played an important role in these results. This is indicated by a significant yield difference among locations with different moisture levels as opposed to no significant yield increase within a location.

ER7 Evaluation Survey

In another collaborative program with the Department of Field Services, fifty-eight farmers in the Southern region were given 5 kg pockets of ER7 to plant. A questionnaire was then submitted to the farmers after harvesting to get a fedback from them. The results of this questionnaire indicated general acceptance of ER7 variety mainly due to its early maturing ability.

The general method of planting was by rows as opposed to broadcast planting with 86% and 14% respectively. Among the surveyed farmers, 83% had good plant stand establishment, 14% had poor plant stand and 3% had no germination. Insect pests were common. Seventy-four percent of the farmers reported infestations of either elegant grasshopper or aphids, and in a few cases game animals browsing the plants. Among the farmers who experienced pest problems, 30% would have liked to spray if the means were available. Four fields were entirely lost due to feeding insects. Sixty-two percent of the farmers who harvested seed were going to keep all the seed for both home consumption and to increase planting the next season. Only 32% said the seed would be sold either locally in small portions or to BAMB in larger quantities, and the remaining 6% were undecided.

Table 18: AVERAGE YIELD (kg/ha) OF ON-FARM COWPEA TRIALS.

LOCATION	VARIETY	YIELD (kg/ha) NOT SPRAYED	SPRAYED
Moshaneng	ER7	366	345
	Blackeye	337	285
Kgomokasitwa	ER7	51	72
	Blackeye	122	159
Ralekgetho	ER7	183	202
	Blackeye	287	150
Shorobe	ER7	78	-
	Blackeye	159	-
Ntlhantlhe	ER7	139	-
	Blackeye	142	-

5.3 Mungbean selection

PERFORMANCE OF EXOTIC MUNGBEAN LINES UNDER BOTSWANA CONDITIONS

5.3.1 INTRODUCTION

The scale of mungbean (Phaseolus aureus) production in Botswana is difficult to assess because it is not covered individually by crop statistics reports. It is bulked with other pulses. Generally mungbeans play an important role in the traditional farming system. It is a source of protein,adds variety to staple diets and is tasty and lack flatulence that is characteristic of other grain legumes. Production countrywide is hampered by low yields (+/- 100 kg/ha),lack of recognisable varieties,labour intensiveness associated with several pickings,and the tendency to shatter that demands timely harvesting.

Previous work on mungbean lacked continuity,but dealt with variety screening. This indicated yield could be increased by introducing varieties from outside Botswana. Yield ranges of 500 - 1000 kg/ha were recorded at least five fold what the farmers get from local strains.

5.3.2 OBJECTIVES

To improve mungbean production countriwide through identification of varieties with agronomic characters that suit the environment.

5.3.3 MATERIAL AND METHODS

Initially the programme will collect mungbean germplasm to screen for characters of interest. Botswana does not have a collection large enough for screening,but the Asian Vegetable Research and Development Center (AVRDC - China),is a good source of germplasm.

Two trials (Mungbean trial No. 1 and No. 2) were conducted,each in two locations. Trial No. 1 included fourteen entries selected from the 1985/86 AVRDC trial and trial No. 2 was a complete 1986/87 AVRDC International Mungbean Trial (20 entries).

Trial No. 1 was conducted at Sebele and Mahalapye and trial No. 2 at Sebele and Goodhope. Each included a local check. Randomised complete block design with four replications was used for both trials. Each plot included four 6-metre rows,with 0.6m apart and 0.15m spacing within rows.

Data were collected on yield and its components (number of pods per plant,number of seeds per pod,pod length and days to first flower).

5.3.4 RESULTS

Results by location show a significant difference between varieties for different characters (pod and seed yield, pod/plant, plant height, seed/pod, day to first flower and 1000 seed weight). The existence of such variability among the varieties indicates a possibility for selection. Generally the local check was outyielded by exotic lines and also is late maturing,thus creating a chance for improvement through varietal introduction. The trials at Sebele were hit by a hail storm at flowering and early podding stages. This might have influenced varietal performance depending on the productive stage at which the hail occurred.

Yellow mosaic virus was noted at Sebele and Goodhope,but its effect on production was difficult to assess on the basis of symptoms.

Across locations,varieties were significantly different for all characters presented (table 1-2). Also,there was a significant interaction (variety/location) for pod and seed yield and 1000 seed weight in trial No. 2 and days to first flower in trial No. 1. This indicates some varieties perform differently according to location. The interaction shows that the best varieties at Sebele are not necessarily the best for Goodhope. This is probably due to environmental conditions,such as temperature, rainfall and soil type. The trend showed an increase in days to first flower between Gaborone and Mahalapye for each variety. Time of planting may determine varietal performance thus the increase may be due to that otherwise it may be necessary to give specific recommendations by location.

It seems pod/plant is strongly correlated to yield, followed by 1000 seed weight,which is indicative of seed size . Selection for these characters may be important in yield improvement. A negative correlation was observed between plant height and yield,under dryland conditions the taller the plant the fewer pods it produces. A shorter plant probably directs the resources to production of more branches and therefore more reproductive initials instead of investing in height. Future trials should look at branches per plant.

Means for seed yield across locations show that varieties V 3726 and VC 2768 performed fairly well. A thorough assessment of varietal differences within and between locations will be made through inclusion of planting date as a factor in variety trials next season.

Table 1 :MUNGBEAN VARIETY TRIAL NO 1 1986/87 - RESULTS ACROSS 2 LOCATIONS.

Varieties	Plant height (cm)	days to 1st flower	Pod yield Kg/ha	Seed yield Kg/ha	Pod lenght (cm)	Weight 1000 seed (g)	Pod/ plant	Seed yield range Duncan test
LOCAL	36.4	57	19.0	12.5	6.5	47.0	4	F
V 3726	24.8	37	707.6	489.1	8.4	74.3	15	A
VC 1000C	26.1	37	654.1	445.7	7.5	67.1	21	AB
VC 1973 A	28.2	37	641.8	442.4	8.5	77.0	17	AB
VC 2768 A	27.8	37	612.6	436.2	8.3	73.6	12	ABC
VC 1482 E	26.2	41	607.7	423.4	8.5	63.7	16	ABCD
VC 2307 A	29.6	39	559.5	387.7	7.8	57.1	16	ABCD
V 2984	31.1	38	594.6	382.9	7.9	56.1	25	ABCD
VC 2755 A	32.0	40	557.1	381.0	8.5	77.3	16	ABCD
VC 2768 B	26.5	37	533.9	374.0	8.5	75.9	14	BCD
VC 2778 A	28.3	38	502.4	351.6	9.2	73.9	16	BCD
VC 2523 A	29.2	40	506.9	339.4	8.5	58.2	29	BCDE
V 3476	28.6	42	478.8	327.4	8.3	59.2	14	CDE
VC 2750 A	29.8	43	457.0	312.2	8.8	68.3	15	DE
VC 2764 A	28.9	41	362.0	238.2	8.3	63.4	13	E
Trial mean	28.9	40	519.7	356.2	8.2	66.1	16	
SEBELE	29.1	37	538.9	374.1	8.5	66.4	18	
MAHALAPYE	28.6	44	500.4	338.4	8.0	65.8	14	
F Locations (L)	0.55	11.34*	1.63	2.44	60.22	0.28	24.57**	
F Varieties (V)	7.36**	11.75**	20.02**	18.46**	5.10**	18.77**	9.25**	
F (L)*(V)	1.82	2.92**	2.41	2.44	1.77	1.06	1.13	
LSD Locations	n.s	4	n.s	n.s	0.2	n.s	2	
LSD Varieties	3.9	5	136.3	98.9	1.1	7.9	7	
LSD Interaction	n.s	7	n.s	n.s	n.s	n.s	n.s	
C.V. (%)	[illegible]	9.63	19.91	21.06	6.78	9.14	23.68	

Significant level at 5% (*) or 1% (**).
Duncan's test at 1% level.
Varieties ranked in descending order according to seed yield (kg/ha).

Section 6 . HORTICULTURE

INTRODUCTION

This report covers a few trials which were conducted over the past twelve months. Some of the trial data, e.g. like Irrigation Method Study, were not properly recorded and therefore, it is not included in this report. The same trial will be conducted again. The report includes trials on cabbage and green mealies.

6.1 Variety Trials

6.1.1 CABBAGE

A cabbage variety trial was sown on 13th February 1987 and transplanted on 18th March at Sebele. The trial was designed to compare new varieties (Leo, Transmark) with the existing recommended varieties. It was a randomized block design with 5 replications. It received 500 kg/ha Ammonium sulphate. Pests and weeds were controlled as necessary. Harvesting commenced on 16th June 1987 and continued till 17th August. The last harvest was delayed and some of heads were damaged at harvesting time. Yields are presented in Table 1.

Table 1. RESULTS OF CABBAGE VARIETY TRIAL SEBELE WINTER 1987

Variety	Marketable Yield (Mt/ha)	Average head weight (kg)
Big Cropper	78.44	2.58
Leo	67.67	2.22
Gloria	66.40	2.26
Grandslam	66.13	2.50
Transmark	57.56	2.18
Green Star	49.93	2.01
Trial mean	64.36	2.29
S.E.		
L.S.D.		
C. of V.		

Leo compared very well with the existing recommended varieties and Transmark also showed promise.

6.1.2 GREEN MEALIES

A green mealies variety trial was planted at Sebele on 17th September 1987. A randomized block design with 4 replications was used. A plot size was 6 m x 1.5 m. Spacing was 0.75 m x 0.30 m. The trial received 500 kg/ha 3.2.1 (25) before planting and one top dressing of 300 kg/ha Ammonium sulphate. Pests and weeds were controlled as necessary. Alphamethrin (Fastac) was used to control stalk borer 4 weeks after planting and repeated whenever damage was seen until silk flowering was 80%. Two counts of silk flowering was done. Harvesting started on 15th of Decmber and ended on 31st December 1987. The results of yields and percentage of silk flowering are presented in the Tables below: Tables 2 and 3.

Table 2. RESULTS OF GREEN MEALIES VARIETY TRIAL - SEBELE 1987

Variety	Marktable Yield (Mt/ha)	Total Yield (Mt/ha)	Av. Cob wt. (g)
PNR 473	10.05	12.09	286
PNR 6429	9.96	12.13	295
CG 4403	9.20	10.85	273
PNR 6549	9.05	11.06	273
R 201	8.C6	10.02	280
PNR 6405	7.78	9.73	287
CG 4141	7.69	10.02	279
RO 419	7.07	8.81	274
PNR 6427	6.72	10.04	248
KEP	6.32	9.96	270
CG 4801	4.65	8.00	255
Trial Mean	7.87	10.25	275

Table 3. PERCENTAGE OF SILKING AT TWO DATES

Variety	26-11-87	1-12-87
CG 4141	69	88
CG 4403	67	92
R 201	54	81
R O 419	52	82
PNR 6429	41	82
PNR 6427	35	59
KEP	34	68
PNR 473	29	71
PNR 6549	25	74
PNR 6405	17	59
CG 4801	4	42

The trial has experienced poor growth due to uneven distribution of water, high infestation of stalk borer and red spider mite. The trial will be redone.

Section 7. CROP ESTABLISHMENT

7.1 Impact of ploughing on crop establisment

In the traditional planting system, seeds broadcast onto unploughed soil are incorporated by a single moldboard ploughing operation (single plough system, SP). A ploughing operation prior to the planting operation generally has shown improvements in plant stand and yield (Double plough system, DP). The initial ploughing operation presumably controls weeds, reduces rainfall runoff, and improves infiltration. Double Plough trials conducted on-farm by ATIP have addressed a broad range of important factors which have included farmer implementation problems, draft requirements, and labour use as well as agronomic responses. These on-farm trials raised a question as to the length of beneficial affect accured from the first ploughing operation.

The 1985/6 results demonstrated that soil moisture at planting, seedling emergence, and grain yield were improved with double ploughing. This was true when the initial ploughing operation was done in either mid-December or mid-January. The effects of double ploughing on grain yield were noticeable on planting dates 5 and 7 weeks later on the hardveld and sandveld, respectively, (see Anon 1987, section 6.1).

This year seven planting dates were established on early ploughed (DP) and non-early (SP) ploughed plots, a change from last year by the elimination of the second 'early ploughing'. Seedling emergence, soil moisture at planting, and grain yield were the major variables under study. As in the previous year, seedling emergence (Table 1 and 2) was improved, however the response was more variable this year. Emergence counts 10 days after planting (DAP) were consistently better for the DP only after the 1st. December planting on the hardveld. Seedling emergence on the sandveld was nearly similar between SP and DP at 10 DAP. This changed by the 20 DAP counts as the DP showed a mark improvement in the DP on the sandveld. The sandveld data presented in Table 1 suggested that seedling vigor was a factor in the magnitude of the 20 DAP counts. Reduction in plant numbers are evident in the SP treatment between 10 and 20 DAP, while seedling counts generally improved in the DP treatments.

Soil moisture (gravimetric) at planting was consistently higher in the DP treatments (Table 3). In only one case was the DP soil moisture less than the SP, in all other combinations of planting date and soil type, the DP had higher soil moisture than SP. Similar data were reported for last year's trial.

Grain yield response to DP was consistently better than SP on the hardveld, but results were decidedly mixed on the sandveld, (Table 4). Results on the hardveld agreed with ATIP data which showed, on average, a doubling of grain yield between SP and DP. The different response between soil types supported the results from the Tillage Trial. Those results suggested that DP was most effective on the hardveld while deep ripping seemed most effective on the sandveld.

Table 1. SEEDLING EMERGENCE AT 10 DAYS AFTER PLANTING AS AFFECTED BY PLANTING DATE, SINGLE (SP) AND DOUBLE PLOUGHING (DP), AND SOIL TYPE, SEBELE 1986/7.

Date	---(hardveld)--- SP	DP	---(sandveld)--- SP	DP
	----------(plants/m2)------------			
11-Nov-86	0.13	0.13	0.25	0.38
13-Nov-86	0	0.25	0.5	0.38
23-Nov-86	3.88	2.13	4.38	3.75
01-Dec-86	2.63	3.25	3	4.75
10-Dec-86	0.38	1.5	1.5	2.25
24-Dec-86	0.25	1.5	0.75	0.38
14-Jan-87	0	0.38	2.13	2
Means	1.04	1.31	1.79	1.98

Table 2. SEEDLING ESTABLISHMENT, 20 DAYS AFTER PLANTING AS AFFECTED BY PLANTING DATE, SINGLE AND DOUBLE PLOUGHING, AND SOIL TYPE, SEBELE 1986/7.

date	---(hardveld)--- SP	DP	---(sandveld)--- SP	DP
	----------(plants/m2)------------			
11-Nov-86	0.75	0.13	0.88	0.63
13-Nov-86	0.38	0.5	0.63	0.5
01-Dec-86	1.75	2.88	2	3.5
10-Dec-86	0.88	0.88	1.5	2.25
24-Dec-86	0	1.13	0.25	2
14-Jan-87	0	0.5	0.75	2.38
Means	0.63	1.00	1.00	1.88

Table 3. SOIL SURFACE (15 CM) MOISTURE AT PLANTING AS AFFECTED BY PLANTING DATE, SINGLE AND DOUBLE PLOUGHING, AND SOIL TYPE. SEBELE 1986/7.

Date	---(hardveld)--- SP	DP	---(sandveld)--- SP	DP
	Gravimetric Moisture (% water)			
11-Nov-86	6	8	6	7
13-Nov-86	5	7	7	5
23-Nov-86	5	7	6	7
01-Dec-86	6	8	7	9
10-Dec-86	3	6	4	6
24-Dec-86	4	8	5	6
14-Jan-87	5	7	6	7
Means	5	7	6	7

Table 4. GRAIN YIELD AS AFFECTED BY PLANTING DATE, SINGLE AND DOUBLE PLOUGHING, AND SOIL TYPE. SEBELE 1986/87.

Date	---(hardveld)--- SP	DP	---(sandveld)--- SP	DP
	Grain Yield (kg/ha)			
11-Nov-86	51.3	56.2	17.1	29.7
13-Nov-86	104.7	131.7	62	44.7
23-Nov-86	189.5	402.3	76.3	104.2
01-Dec-86	221.1	323.5	52.4	74.3
10-Dec-86	161.9	392	57.8	46.1
24-Dec-86	26.9	245.1	79.6	76.2
14-Jan-87	0	34	19.8	108.3
Means	107.9	226.4	52.1	69.1
Percent increase		+110%		+33%

7.2 Impact of tillage and planting methods on plant establishment

Average percent establishment figures are given in Table 1 for sorghum grown under four tillage and planting systems. The four systems are also defined in Table 1. These four systems are among the principal options currently available to farmers in the Central Agricultural Region. In these analyses, establishment refers to the percent of seed sown that emerges and results in an established plant by approximately 45 days following planting. Percent establishment is used instead of actual plant population counts because once the percentage is known, target plant populations can be acheived by adjusting the seeding rate. Data are from a three year multi-location researcher implemented study. In this study, sites in every season were selected so that previous management of the land corresponded to traditional norms (ie., single ploughing and weeding and no dry season tillage).

Table1. PERCENT PLANT ESTABLISHMENT FOR FOUR TILLAGE AND PLANTING SYSTEMS

Statistic	Tillage-Planting System*				
	T	DP	EP+RW	RW	
				Sandy Soil	Loamy Soil
mean	10.8	15.5	30.2	34.7	24.6
minimum	0	1	6	6	0
maximum	27	32	64	62	86
s.e.(mean)	0.9	1.1	2.0	3.0	3.8
sample size	56	56	56	24	32

DATA SOURCE: Commercial Steps In Technology Trial, ATIP Mahalapye 1984-87.

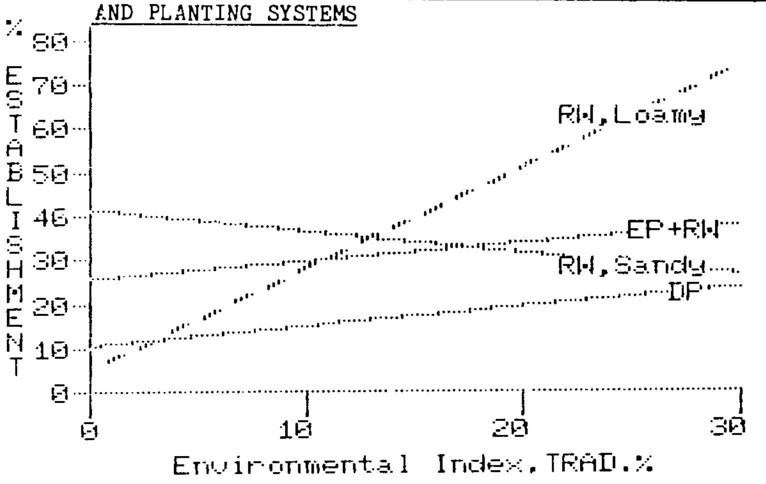
* T = Traditional, Single-Plough Planting
DP = Double Ploughing
EP+RW = Early Ploughing + Row Planting
RW = Row Planting on same day as Ploughing

In drought prone environments, any system can fail to establish a desired plant stand. This is reflected in the range of results in these trial data (Table 1) regardless of the system tested. When combined with seeding rates of 130,000 seed/ha for row planting to nearly 300,000 seed/ha for broadcast, it is clear that minimum and maximum percent establishment give excessively low and high plant stands. In the Central Region, high numbers are undesirable because of expected drought periods during crop growth of most seasons and because farmers are usually unable to thin over large areas of their fields.

However, because the tillage and planting system is the primary practice affecting plant population, it is useful to compare the systems in terms of their stability in establishing plants across a range of environments.

The relative establishment stability of these systems is illustrated in Figure 1. In this stability analysis, the establishment of the traditional single plough-planting is taken as an index of the environmental circumsances related to plant establishment. Corresponding values from the other tillage and planting systems are regressed on these index values.

Figure 1. PERCENT PLANT ESTABLISHMENT STABILITY OF FOUR TILLAGE AND PLANTING SYSTEMS



Stability Statistic	DP	EP+RW	RW Sandy Soil	RW Loamy Soil
intercept	+11	+24	42	5
b	+0.4	+0.5	-0.5	+2.3
s(b)	.24	.44	.48	.46

(Column heading spanning the system columns: Tillage-Planting System)

A desirable establishment pattern includes:

(a) A large positive intercept value which indicates better than average establishment under adverse conditions. DP, EP+RW and RW on sandy soils all have intercepts significantly higher than zero. The intercept of RW on loamy soils is not different from zero.

(b) A regression coefficient (b) equal to zero. This indicates a consistant establishment over a range of environments. DP, EP+RW and RW on sandy soils all have b values that are not significantly different from zero. This coefficient is highly positive and significantly different from zero for RW on loamy soils.

(c) A low standard deviation of (b) which indicates that establishment is relatively reliable for any given Environmental Index value. In this study, all systems have relatively high s(b) values. Obviously, circumstances can favour systems differentially (eg., moisture stored through double ploughing may result in germinated seed but failed establishment if planting is on marginal moisture, whereas seeds single-plough planted remain dry for delayed emergence). Other factors also affect the consistency of the establishment response. These data should represent, however, a reasonable sampling of circumstances in seasons with below average rainfall.

From these results, it is apparant that stored moisture at planting for DP and EP+RW results in a more stable plant establishment for these two systems than for the traditional system. Average percent establishment is still below a desired 60% or more, however, and the s(b) high. The need to underseed/overseed to compensate for erratic establishment still puts these systems at some risk. Over all test sites, EP+RW provides the most reliable establishment of any system tested.

On sandy soils, RW gives a highly stable establishment over a range of environments. On loamy soils, percent establishment increases sharply as traditional establishment increases. Under poor establishment environments, plant establishment of RW also fails. Under ideal conditions, establishment is very high. These data indicate that on loamy soils, seeding rates of row planting should be adjusted to account for surface soil moisture conditions at planting.

7.3 Hand planting

In most broadcasted plots, there are gaps where few or no plants emerge. This represents a loss of the investment made in ploughing that land. One option farmers might consider is investing a small amount of seed and labour in order to gap fill by hand planting. Over a series of years, the Mahalapye team has been exploring options for hand replanting. Among the best results were obtained when using a hand jab planter for cowpeas during the 1984-85 season. Generally favourable results were again obtained during the 1985-86 season when using the Sanitas hand planter for sorghum and millet.

In the previous trials, there was no systematic comparison of the different crops which might be hand planted. Also, no information was generated on the impact of planting soil moisture on the emergence of different crop/varieties. Therefore, the objective of this trial was to compare the percent field emergence and returns to labour when hand replanting sorghum, millet, cowpeas, groundnuts and maize in good and poor soil moisture environments.

Materials and Methods

A split plot design with two replications was used. The main block was crop-variety. Six crop-varieties were included: Segaolane sorghum, Serere 6A millet, ER-7 cowpeas, Blackeye cowpeas, Sellie groundnuts, and KEP maize. The first three were planted using the Sanitas push planter. The latter three were planted using a hand jab planter.

Each plot was split into three planting dates. Each date represented a different level of soil moisture (determined by the number of days after a profile soaking rain). All plantings were made in December. The first two plantings were made on good to intermediate soil moisture in all three villages (within seven days of a rain). The last planting was made into drying soils (more than ten days since the last rain) in all three villages.

The trial was planted at nine sites. Host farmers assumed responsibility for ploughing and weeding. ATIP staff did the planting and most harvesting. Planting times were recorded on the first two planting dates (a total of 36 plots per crop). At planting, seeding rates were monitored and recorded. At four to six weeks after planting, emergence stand counts were taken.

Results

Information on seeding rates, planting times, emergence stands and percent field emergence is presented in Table 1. Seeding rates were close to the targeted range for Segaolane, Serere, Blackeye cowpeas and Sellie groundnuts. The rate for KEP maize was slightly above target and that for ER-7 cowpeas was more than twice the desired rate. The seed hole on the Sanitas planter was too large (but no mid-season adjustment was made since it would have confounded the planting dates analysis).

Planting times were three times as great for the hand jab planter, compared to the Sanitas planter. Neither planter was difficult to use on a small plot basis but would have been arduous for large areas.

The results on stand establishment have been grouped for the first two plantings since the soil moisture was quite similar for those plantings. Acceptable stands were obtained for all crops. However, too many plants were established for all three crops planted with the Sanitas planter, particularly on the days planted when there was good soil moisture. On days with little moisture, the average number of plants was good but the stands were erratic. Because the seed is placed on the surface, plantings made with the Sanitas planter were very susceptible to drying soil moisture conditions. The drop off in percent field emergence between wet and dry planting conditions was especially notable for ER-7.

A modified stability analysis was carried out on the percent field emergence data. Results are summarized in Figure 1. Part A shows the regression lines for each of the crops as a function of the average emergence at each of the 27 environments (9 sites times 3 planting dates). Surprisingly, sorghum was most responsive to environment, with a slope of 1.36. The slope was greater than one for KEP and both cowpea varieties as well. Groundnuts had the best emergence in poor environments while KEP had the best emergence in the better environments.

Part B of Figure 1 shows the pula seed loss for each crop relative to sorghum. This stability analysis incorporated the value of the seed and seeding rates, as well as the emergence percentage. Sorghum emergence was used as the environment since this is the reference crop for farmers. Overall, there was relatively little difference in seed cost for five of the six crops. Seed costs were less than sorghum when planting either KEP maize or Serere 6-A millet, regardless of environment. Losses were slightly higher across all environments for Blackeye and Sellie groundnuts. By far, the worst crop for seed losses was ER-7. Over P20 was lost per hectare in ER-7 seed at even the best environment, increasing to nearly P45 at the worst environment.

A summary of the yields and returns to labour is presented in Table 2. The highest yields were obtained for the three crops planted at high populations -- Segaolane, Serere and ER-7. Based on field observations, the yields shown for Blackeye and Sellie groundnuts may understate the actual yields by as much as 50 percent. Nevertheless, the returns to the labour invested in hand gap filling were substantially above the urban minimum wage rate for all crops but maize.

Discussion

The data again show that gap filling by hand planting is a profitable field operation. If no special planter is available, farmers should be able to obtain similar results (to this trial) by hoe planting groundnuts or Blackeye cowpeas. The main drawback for the large-seeded crops (Blackeye, maize and groundnuts) is the time required for hoe or jab planting. Therefore, if a push planter is available, farmers should plant sorghum or millet. Unfortunately, the push planter used in this trial gave poor control over seeding rates and shallow seed placement. DAR needs to improve the push planter (to better regulate seeding rates) and then address the potential for local manufacture.

Table 1: 1986-87 HAND REPLATING TRIAL, MAHALAPYE AREA: PLANTING AND EMERGENCE RESULTS

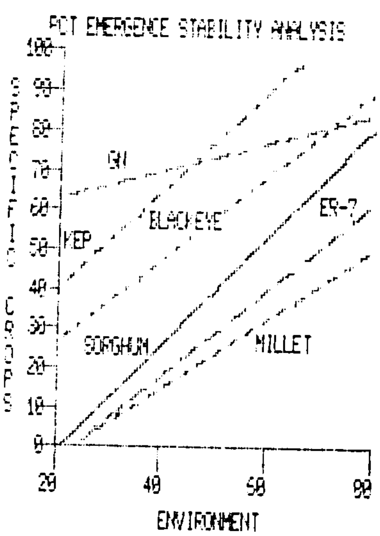
	SEGAOLANE	SERERE	BLACKEYE	ER-7	KEP	SELLIE
Seeding Rate (kgs/ha)	7.0	4.4	8.4	30.2	17.0	13.9
Planting Time (hrs/ha)	8.4	8.5	26.8	7.4	27.4	26.4
Emergence Stand ('000 plants/ha):						
Good Moisture	108.1	106.8	30.6	81.3	31.8	33.2
Poor Moisture	75.0	75.5	21.6	39.7	26.3	28.5
All	97.1	96.4	27.6	67.4	30.0	31.6
Pct. Field Emergence:						
Good Moisture	38.2	22.4	59.5	30.2	77.1	73.3
Poor Moisture	26.0	15.7	75.4	13.8	62.5	69.7
All	34.2	20.1	64.8	24.8	72.2	72.1

Table 2: 1986-87 HAND REPLATING TRIAL, MAHALAPYE AREA: YIELDS AND RETURNS TO PLANTING LABOUR

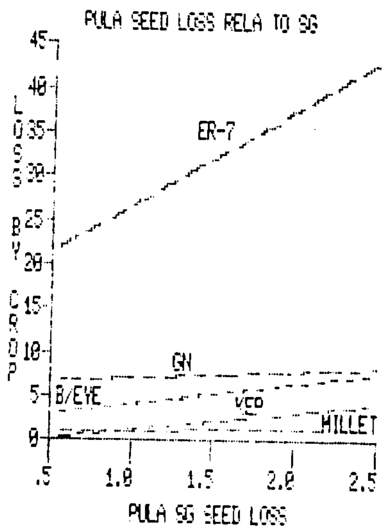
	SEGAOLANE	SERERE	BLACKEYE	ER-7	KEP	SELLIE
Yield (kgs/ha):						
Good Moisture	290.1	234.8	91.3	178.3	10.8	66.1
Poor Moisture	87.8	138.5	86.3	112.1	10.8	62.4
All	232.2	205.1	90.5	166.0	10.8	64.8
Return to Plant Labour (Pula per hour):						
Good Moisture	10.85	8.74	1.53	9.72	-0.13	3.47
Poor Moisture	3.05	5.07	1.43	5.20	-0.13	3.22
All	8.62	7.61	1.52	8.88	-0.13	3.39

FIGURE 1: HAND REPLANTING TRIAL, MAHALAPYE AREA: EMERGENCE STABILITY ANALYSIS

PART A



PART B



7.4 Hand furrow planting trial

Hand furrow planting was first investigated in the 1982-83 season. There was no establishment benefit relative to broadcasting for sorghum. In addition, hand planting was difficult with small seeds and farmers showed no interest.

The concept of hand furrow planting was revived in the 1985-86 season in response to observed establishment problems with large-seeded crops, including maize, groundnuts, sunflower, and cowpeas. Eleven farmers planted two to several crops comparing hand furrow planting and broadcasting. There were no benefits for sunflower, jugo beans or groundnuts. Slightly better stands were obtained by hand furrow planting ER-7 cowpeas and KEP maize. However, the benefits were not substantial and farmers again expressed little interest in the practice.

The objective of this trial was to evaluate the establishment benefits from hand furrow planting maize and cowpeas, in order tc to determine whether farmers should invest time in hand furrow planting.

Materials and Methods

The trial involved a simple comparison of hand furrow planting versus broadcasting. The comparison was proposed to more than forty farmers. Less than a third agreed to try hand furrow planting, and only 13 comparisons were correctly implemented (by eight farmers) -- six for KEP maize and seven for ER-7 cowpeas.

Farmers were given 666.7 grams of maize for each of the broadcast and the hand furrow plots. For the cowpeas trial, farmers were given two lots of 500 grams. Farmers determined the plot size, implemented the trial, and made all management decisions. ATIP staff made emergence stand counts. Farmers harvested the plots.

Results

The farmers' seeding rates were approximately 15.5 kgs/ha for maize and 13.5 kgs/ha for cowpeas. The average maize emergence populations were 9,200 plants/ha for hand furrow planting versus 12,850 for broadcasting. The CVs for emergence populations were 62 percent for hand furrow planting versus 58 percent for broadcasting. The average cowpea emergence populations were 11,200 plants/ha for hand furrow planting versus 13,900 for broadcasting. The CVs for emergence populations were 78 percent for hand furrow planting versus 86 percent for broadcasting. None of the differences in emergence populations or the CVs of emergence populations were statistically significant.

Because there were no differences in the populations established or the variability of the populations, yield data were not collected.

Discussion

Hand furrow planting again resulted in no benefit relative to the broadcasting system. It was difficult to interest farmers in even trying hand furrow planting. There is no evidence that the practice should be promoted or, if promoted, that farmers will respond. Unless new information comes to light, ATIP plans to abandon further investigations of hand furrow planting.

Section 8. SOIL MANAGEMENT

INTRODUCTION

The focus in crop production resource is soil water, and efforts are aimed at maximising water infiltration into the soil, reducing run-off and losses due to evaporation of soil surface water. Research involving appropriate tillage, timing of tillage operations, crop rotations and weed control is all aimed at soil moisture conservation such that the maximum amount can be made available for plant growth and production.

8.1 Impact of tillage on weeds

8.1.1 EFFECTS OF TILLAGE ON WEEDS AND WEEDING LABOUR

The following discussion is extracted from a paper presented at a symposium on weeds, held at Sebele in 1987. The paper is "Effects of Tillage Systems on Weed Growth and Weeding Labour Requirements"; G. Heinrich et. al. 1987.

The first data set (Table 1) results from data collected on a set of trials performed over two locations in the 1986-87 cropping season. There were two replications at each location, laid out in a randomised complete block design.

These trials compared seven different tillage treatments. All preliminary land preparation was performed using tractors. All ploughing or row planting done on the date of planting was performed using animal draught power. For the single plough/row plant system, one rain occurred between the ploughing and planting operations.

Within a location, all plots were planted on the same day, using sorghum (CV. Segaolane). Seeding rate was based on a target plant population of 20 to 30 thousand plants per hectare).

Plots were weeded three to four weeks after emergence, by hoe. All weeding labour times were recorded by stop watch.

Table 1: MEAN YIELDS AND WEEDING LABOUR REQUIREMENTS, AVERAGED OVER TWO LOCATIONS, TILLAGE SYSTEMS TRIALS, ATIP, FRANCISTOWN 1986-87

TILLAGE SYSTEM	WEEDING LABOUR* (PERSON HRS/HA)	YIELD (KG/HA)*
1. Traditional check	45 d	108 cd
2. Double ploughing	18 d	289 ab
3. Single plough/row plant	85 dc	12 d
4. Double plough/row plant	12 d	343 a
5. Band ploughing	135 bc	163 bc
6. Deep rip	258 a	15 d
7. Deep rip/bed shape	221 ba	3 d

*Within a column treatments followed by the same letter are not significantly different at the 5% level.

It can be seen from the table that while weeding labour requirements for single ploughed systems (1 and 3) generally averaged higher than for double ploughed systems (2 and 4), the difference was not significant. However, systems involving deep ripping had weeding labour requirements that rendered them impractical in present form. The system in treatment five consisted of ploughed bands, two metres wide, separated by unploughed bands also two metres wide. Treatments five, six and seven all included unploughed areas which resulted in unacceptable weed burdens.

A second set of data compared double ploughing versus single ploughing. The set consisted of 10 paired comparisons in each of two years, planted at five different locations in Tutume Agricultural District. Plots were largely planted to sorghum (V. Segaolane) though a few were planted to millet (V. Serere 6A) at the farmers request. Again, all labour times were collected by stop watch. Data are presented in Table 2.

Table 2: AVERAGE WEEDING LABOUR REQUIREMENTS FOR DOUBLE PLOUGHING TRIALS (RMFI). ATIP, FRANCISTOWN, 1985-87.

TREATMENT	WEEDING* (PERSON HRS/HA)	YIELD* (KG/HA)
1985-86		
Average for Single Ploughing	32 c	166 b
Average for Double Ploughing	48 b	347 a
Single Ploughing plus Opportunity Cost per 2 hectares	75 a	342 a
1986-87		
Average for Single Ploughing	42 b	49 b
Average for Double Ploughing	37 b	99 a
Single Ploughing plus Opportunity Cost per 2 hectares	108 a	98 a

*Within a column, by year, treatments followed by the same letter are not significantly different at the 1% level.

In 1985-86, weeding labour requirements (per hectare) were actually higher for the double ploughed system. It was hypothesized that double ploughing had improved the plant growth environment sufficiently to stimulate weed growth as well as crop growth. (Witness the yield data, Table 2). In 1986-87, there were no significant differences in the weeding labour requirements.

Primary conclusions from these date were that:

a) Tillage systems involving deep ripping must also include a practical and cost effective weed control component before they can be used as general extension recommendation

b) Double ploughing may effect good weed control in some cases. However, at present the effect is somewhat unpredictable.

c) Double ploughing generally increased per hectare grain yields much more than it increased weeding labour requirements, per hectare on a percentage basis.

8.1.2 EFFECTS OF TILLAGE-PLANTING METHOD ON WEED CONTROL

Data from three tillage and planting method trials are presented from the FSR team Mahalapye. In each of these trials the level of weed control at the traditional weeding time (usually more than 40-45 days following planting) is assessed.

Results from a factorial trial testing recommended tillage-planting operations are given in Table 3. The factorial trial was conducted over three seasons at five different sites (four sites only in the first season). There were two complete replications at each site with treatments laid out in a double split plus strip arrangement. Only the ploughing and planting method treatments are indicated.

All trial sites were planted to sorghum. All but two of these sites were planted to the variety segaolane. Two sites planted late in the season were planted to the variety 65D. Tillage and planting operations were carried out by research staff. All plots within a site were planted on the same day.

All non treatment variables (ie., weeding, thinning/replanting) were set to norms observed in monitoring farmer's own operations in the region. This permited a better assessment of the impact individual recommendations would have if adopted by area farmers. Weed levels were assessed visually by research staff just prior to weeding. Weeding labour times were recorded by stop watch. Variation in labour times were found to correspond closely to percent weed cover estimates.

Table 1: EFFECTS OF TILLAGE-PLANTING METHOD ON WEED LEVELS AT TRADITIONAL WEEDING TIME AND ON SORGHUM GRAIN YIELD

	Weed Cover (% of ground area)	Grain Yield (kg/ha)
NO EARLY TILLAGE		
Trad. Plough-Planting	4.3	326
Row Planting	4.7	441
Seedbed Prep.+Row Planting	5.3	338
EARLY PLOUGHING		
Double Ploughing	2.6	487
E.P.+Row Planting	18.0	475
E.P.+Seedbed Prep.+Row Planting	7.8	461
LSD (.05)	2.1	75

DATA SOURCE: Commercial Steps In Technology Trial, ATIP Mahalapye, 1984-85, 85-86, 86-87.

These results show that a reasonable level of weed control is achieved through standard ploughing on the day of planting. Early ploughing increases the level of weed growth at planting due to higher soil moisture and better germination tilth. Seedbed preparation with a cultivator greatly helps alleviate this problem. Double ploughing completely controls this increase in weed growth and actually appears to improve weed control over the traditional check. This benefit of double ploughing is not significant in the researcher implemented trials work but is significant in the farmer implemented comparisons (Table 4).

Of all the systems tested in these trials, early ploughing and later row planting gives the most erratic weed control. With this treatment, significantly higher weed levels (percent weed cover > 25%) occured on 57 percent of sites (8 of 14). On the other hand, weed levels with this treatment were no greater than with traditional ploughing on 36 percent of the sites (5 of 14) with one site with an intermediate response. Higher weed levels on the eight sites resulted in a significant reduction in grain yield when compared with ploughing and row planting on the same day (359 kg/ha versus 536 kg/ha). On the remaining six sites, early ploughing + row planting out yielded single day ploughing/row planting, 539 kg/ha versus 388 kg/ha.

In years 2 and 3 of this trial, a cultivator was used to prepare a seedbed on early ploughed plots before planting. This not only reduced weed levels at weeding time (see Table 3) but also increased grain yields by 45 percent over single day ploughing/row planting.

Table 4: WEED CONTROL AND SORGHUM GRAIN YIELD WITH DOUBLE PLOUGHING

	Weed Cover (%)	Weeding Labour (person-hrs/ha)	Grain Yield (kg/ha)
Double Ploughing	1.8	15.5	245
Traditional 2	3.3	24.6	141
LSD (.05)	0.9	8.8	48

DATA SOURCE: Farmer Implemented Double Ploughing Trial, ATIP Mahalapye 1985-86, 1986-87.

Several conclusions can be reached from these studies.

(1) Effective weed control in the Mahalapye area is generally achieved with single plough-planting provided ploughing is of a good quality. This usually requires a moderate level of soil moisture.

(2) Double ploughing can provide increased grain yield through improved soil moisture and at the same time control weed growth.

(3) Early ploughing + row planting can also provide increased grain yield but excessive weed problems will restrict early crop development and grain yield in about one-half the plantings during seasons with relatively poor rainfall.

(4) A system of early ploughing and later row planting is ideal for farmers who are able to cultvate/or double plough just before planting if weed problems do appear. The capability to inter-row cultivate very early following planting could also aid in the control of heavy weed problems. For

farmers with limited access to cultivator resources, the early ploughing + row planting system is risky. Long delays in row planting that are sometimes beyond the farmer's control could even result in weed growth that prevents row planting all together.

A note can be made that the SANITAS precision strip tillage system involving deep ripping and inter-row bed shaping was implemented at two locations in 1986-87 in a comparison with several other tillage systems. The results of this along with the 1986-87 evaluations are given in detail in a paper entitled "Tillage-Planting Method Effects On Weed Development" presented at a symposium on weeds, held at Sebele, July 1987. This paper will appear in a proceedings of this symposium.

In 1986-87, there was complete crop failure for all treatments and none of the plots were weeded following planting. It is important to note, however, that plots with untilled strips or bands produced excessive weed growth even before planting. Planting on the deep rip and shaped bed systems required that 280 person-hours be invested in hand hoeing weeds before planting could be done. It is very apparant that tillage systems that do not include some inversion of the soils cause serious increases increases in the level of weed cover and unacceptable weeding labour requirements.

8.2 **Maximising Potential**

8.2.1 RAINFALL RUN-OFF MANAGEMENT AT HIGH POTENTIAL SITES

Sites with higher than average production potential were selected and development options for these sites tested. Sites withing eight fields were selected in collaboration with farmers on the basis of criteria specified for high potential sites (HPS). These criteria include soil profile and surface hydrologic characteristics. Ideal soil profiles possess at minimum 1.25 m. depth, light textured surfaces with good infiltration rates but with important increases in clay content through the profile, soil pH values appropriate for sorghum and equilibrium infiltration rates (after several hours) of more than 3 cm/hr. Hydrologically, HPS are rainfall water "run-on" sites but situated so that surface drainage from the plots can occur.

Three of the eight sites were found unsuitable for this classification because of soil profile or hydrologic deficiencies. Two of the remaining were developed with 30 cm. high bunds constructed around one acre basin plots. In both of these cases, flood water (sheet flow) was intercepted and diverted by channel to the basins. Sandbag weirs were installed to guide water from the diversion channels into the basins.

Primary plots of all HPS were double ploughed (broadcast) with sorghum. The first ploughing was done in winter. This early ploughing was done to provide a means of retarding water run-on flow early in the season. Comparisons of single super phosphate fertiliser; 0, 20 and 40 kg P/ha, and with and without incorporated stover residue that remained from the previous season (500-1000 kg/ha) were made within the primary plots. Traditional single ploughed check areas were sampled both upstream and downstream from the designated HPS.

Grain yield data for the five sites are given in Table 1. This includes the two sites with bunded basins. Average grain yield for the farmer's own planting off the HPS are also given.

Table 1: GRAIN YIELD FOR HIGH POTENTIAL SITE DEVELOPMENT COMPARISONS

	-- Controls* --			--- HPS Treatment Comparisons** --					
	Own	C1	C2	0,0	0,20	0,40	S,0	S,20	S,40
Grain Yield (kg/ha)	136	582	416	499	545	873	607	785	948

*, Controls: Own = kg/ha combined for all grain crops (>95% sorghum) on total area planted by farmer outside HPS.
C1 = Upslope control measurement from farmer's own planting but located adjacent to HPS.
C2 = Downslope control measurement from farmer's own planting but located adjacent to HPS.

**, HPS Treatment Comparisons: Stover level, No = 0, Yes = S
Applied Phosphate level, 0, 20, 40 kg/ha

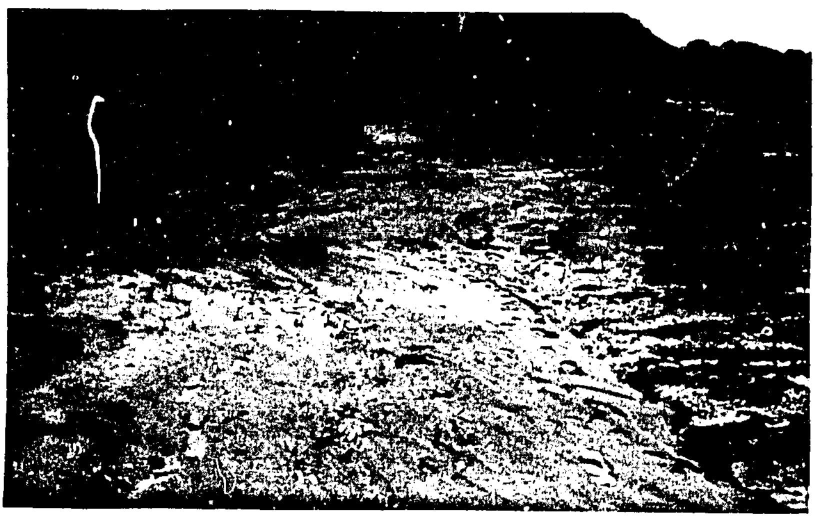
Results indicate that without the addition of P or Stover, grain yield was not improved over the traditional control plots adjacent to the HPS. These plots were also observed to receive water run-on and should be considered as having a similar production potential to the designated HPS. Because double ploughing was confounded with HPS plots, the high control grain yields raised some question as to the importance of double ploughing when water run-on occurs. The sharp increase in grain yield at the HPS area over what the farmers achieved elsewhere on the field underscored the production potential of these HPS at least during droughty seasons (Total season rainfall ranged from 226 to 359 mm. at the five sites). The responses to P at both the 20 and 40 kg/ha levels were significant. Only the 40 kg/ha treatment reponse, though, covered the estimated cost of Phosphate (125 Pula/ha). The effect of stover incorporation was not significant.

Issues in water management for the plough only sites are limited. A single consideration relates to early tillage and soil erosion. Trashy field surfaces should pose less erosion hazard than ploughed fields. It is observed, however, that by the beginning of the rainy season, most stubble/trash has been removed from fields by the feeding of livestock. It was envisaged that winter ploughing would only partially bury stubble in the stover plots.

On the two sites with bunded basins, topping over the bunds did create some erosion and some cases destroyed sections of the bunds. Water distribution within the plots was erratic because the plots were not level and because supply channels were too deep to permit ready discharge into the basins. This latter problem required that the water level be raised behind weirs in the supply channel.

Bunds did retard sheet flow both within and above the plots following some rainfall run-off events. It was obvious, though, that major run-off events produce more run-on to certain field sites than can be managed or than is desirable.

AERIAL AND GROUND VIEW OF UNCONTROLLED RUN OFF THROUGH FARMERS FIELDS



8.2.2 IMPROVING CROP PERFORMANCE WITH FERTILIZERS

INTRODUCTION

The succession of rather poor seasons recently experienced has induced farmers to make more extensive use of soils with a high sand contact - i.e. sandy loam - loamy sand.

Whilst such soils are undoubtedly easier to manage to ensure some grain production their inherent low fertility will pose a major limitation in favourable seasons.

Past research has shown that the soils are commonly very low in phosphorous and nitrogen. Most emphasis is placed upon the use of phosphate fertilizers as phosphorous helps develop better plant root systems (hence exploit the soil profile more effectively for water) and that it has strong residual properties to subsequent seasons.

The present study is the culmination of several years of work on the P response by sorghum as effected by population. The findings over the two previous seasons was related to the variety Segaolane. The current trial used four varieties selected in consultation with the sorghum breeder for their good performance and diversity of growth characteristics.

METHODS

The experiment sought to establish which plant characteristics were most effected by fertilizer application (i.e. tiller number, head size, grain number or seed size). As all these characteristics are also affected by interplant competition the trial was conducted at five plant populations using equal inter plant and inter row spacings at 3, 10, 30, 60 and 120+ thousand plants/ha. Adopting a systematic design for economy of space and having variety as a subplot of population.

Fertilizers were 3P x 2N, with three replicates. Phosphorous levels were zero, 20 Kg P/ha and 20 kg P/ha+ residual effect. This latter treatment is a two year residual of the calculated amount of P needed to bring the soil solutions up to 0.2 mg P/ml, (sufficient to completely relieve all phosphorous limitations to growth). During the previous two cropping seasons 15-25 Kg P/ha has been removed in crop production so were effectively "topped up" by the additional 20 kg P/ha.

All phosphorous treatments were applied as single super phosphate broadcast and ploughed down before planting.

Nitrogen was applied as a top dressing 30-40 days after planting at the rate of 56 Kg N/ha (LAN) and incorporated into the top soil during weeding.

The four sorghum varieties were planted with a hand operated double disc planter and thinned to the desired population 10-15 days after emergence. The varieties were:

BOT 79	Medium to late, low tillering
65D	Early, short
Segaolane	Medium, high tillering
PNR 8311	Early, well adopted commercial hybrid

RESULTS AND DISCUSSION

Growing conditions at Sebele were not favcurabale and the mean grain yield of 358 Kg/ha (population optimum 10,000/ha at 524 Kg/ha) was much lower than that achieved at Goodhope 725 Kg/ha (with an optimum at 10,000 plants/ha at 1470 Kg/ha).

Under the poor conditions at Sebele neither the phosphorous nor nitrogen treatments had any statistically significant effect on drymatter or yield. The results at Goodhope start to show interesting effects which were variety specific.

A summary of the initial analysis of variance is given in Table 1.

TABLE 1. OCCURRENCE OF STATISTICALLY SIGNIFICANT EFFECTS (* ** ***) ON PLANT HEIGHT, TILLERING AND YIELD AT GOODHOPE (at 5,1 AND 0.1 % probability).

VARIATION	Plant height	Main hd Number	Tiller hd Number	Yield			Total Dry Matter
				Main hd	Tiller hd	Total	
Phosphorous	*		*	*	***	**	
Nitrogen	**						
Population	***	**	***	***	***	***	**
Variety	***	***	***	***	***	***	***
Phos x Nit					*		
Phos x pop			**		*		
Phos x var.	*		**				
Nit x ppp			*		**	*	
Pop x Var.	**	**	**	**	**		
Nit x Var.							
Phos x pop x Var	*		**	*			

As expected the variety and population main effects prove to be dominant with strong variety population interactions.

Of the nutrient treatments phosphorous produced much more impact than nitrogen this was most marked on tiller production and yield, the only significant third order interactions being with phosphorous, population and variety. The main effects of nitrogen and phosphorous are summarized in Table 2.

At Goodhope there is a clear stimulation of tiller production leading to higher grain yields by a dose of 20 Kg P/ha. However the same dose rate applied as a supplement to the residual (1983) treatment actually produced a DECREASE in yield mainly attributable to poorer main head set. This finding confirmed those of the previous season which also showed a negative effect of high doses of phosphorous fertilizer, especially at high populations (Anon 1987, page 126).

TABLE 2. MAIN EFFECTS OF NITROGEN AND PHOSPHOROUS AT GOODHOPE AND SEBELE

	Goodhope					Sebele				
	Nitrogen		Phosphorous			Nitrogen		Phosphorous		
Observation	Zero	56	Zero	20	20+R	Zero	56	Zero	20	20+R
Yield (Kg/ha)										
Main head	363	319	382	480	159	218	222	238	199	222
Tiller	394	379	280	586	292	134	144	132	120	165
Total	757	691	660	1077	435	352	364	370	317	387
Dry Matter (Kg/ha)	3133	2893	2660	3951	2427	1533	1517	1561	[illegible]	1614
Head No. (x1000/ha)										
Main head	9.6	8.0	10.4	11.8	4.3	11.1	10.8	14.8	9.1	8.9
Tiller head	11.1	9.3	6.9	15.4	8.2	9.8	8.4	9.6	7.1	10.9

Conventional understanding of the action of phosphorous is to promote better rooting which induces more efficient water exploitation of the soil profile, this may then leave less moisture for potential carry over to the subsequent crop. After a highly successful crop (1983/84) the subsequent crop may be negatively affected. This situation is believed to have occured at Goodhope and will not be overcome until substantial rains recharge the profile.

In seasons of marginal rainfall the residual effect is negative. If however phosphorous treatment is applied to new sites on which suboptimal moisture extraction has previously occurred then a yield advantage can be obtained for very modest phosphorous investment.

More light should be shed on this point with a reterospective assessment of soil moisture records.

The nutritional aspects confirm that the application of just 20 Kg P/ha does not greatly influence the P content of the plant tissues but due to improved growth results in a higher P removal. The higher P residual treatment markedly increases the plant tissue P but due to poor crop growth may remove less P/ha. See Table 3.

TABLE 3. CROP NUTRIENT STATUS AS EFFECTED BY FERTILIZER TREATMENTS

a) Goodhope

Treatment	Nitrogen % Grain Main hd	Nitrogen % Grain Tillers	Nitrogen % Stover	Nitrogen Kg/ha Removed	Phosphorous % Grain Main hd	Phosphorous % Grain Tillers	Phosphorous % Stover	Phosphorous Kg/ha Removed
Nitrogen Zero	1.88	1.84	1.13	48.2	.26	.25	0.10	4.98
56	1.93	1.90	1.28	50.5	.25	.26	0.10	5.09
Phosphorous								
Zero	1.81	1.74	1.16	41.8	.24	.23	0.09	3.96
20	1.86	1.83	1.14	60.2	.24	.24	0.09	5.97
20 + Residual	2.11	2.06	1.28	45.9	.30	.30	0.12	5.12

b) Sebele*

Treatment								
Nitrogen Zero	-	-	1.35	-	-	-	.10	-
56	-	-	1.46	-	-	-	.10	-
Phosphorous								
Zero	-	-	1.42	-	-	-	.10	-
20	-	-	1.38	-	-	-	.10	-
20 + Residual	-	-	1.43	-	-	-	.11	-

* Sebele data on grain update still to be completed.

CONCLUSIONS

An appreciation of the moisture resources available for exploitation - either derived from rainfall or as residual moisture from the previous season is of fundamental importance to future agronomic studies in Botswana. This is especially true when dealing with agents which potentially enhance plant growth and thus enhance the rapidity and degree of moisture exploitation.

Given the uncertainty of adequate sustained rainfall for crop production there seems great merit in applying small interventions of phosphorous fertilizer to exploit the advantages of water conservation measures previously affected or presently implemented. Of the numerous permutations possible tight suboptimal population control may be an option most likely to be successful with the smaller farmers. Taking this route would require attention to be given to promoting the potential for profilic short tillers under moisture favourable conditions.

The use of no more than 20 kg P/ha (at a cost of about P45/ha) should remain the basis for general recommendations based upon agronomic performance, investment costs and phosphorous removal. Repeat applications only should be encouraged in those years succeeding favourable seasons. Soil analysis should be used to monitor regularly fertilized soils so as to avoid a build up of available P., under which circumstances it appears possible that the crop will undully suffer during dry years by regularly attempting to out grow the water supply.

The variety population phosphorous interactions deserves more careful consideration than given to date so will be discussed in a separate report.

8.3 Economic analysis of double ploughing

Ploughing times were recorded for 14 sites. The first ploughing averaged 13.8 hrs/ha. Ploughing was done with an average of 2.4 people, therefore involving 31.9 person hours. The second ploughing took 13 hrs/ha, again with 2.4 people -- or a total of 30.9 person hours. Most implementations were made with donkey traction using a single furrow plough. Ploughing with a single furrow plough took 14.2 hrs/ha compared to 11.9 hrs/ha for people ploughing with a double furrow plough. Ploughing with oxen took 10.5 hrs/ha compared to 14.5 hrs/ha with donkeys.

Weed burden estimates were recorded at all sites. Weeding labour data are available for eight sites (24 plots). The average weeding time for T1 plots was 48.8 hrs/ha, for T2 plots was 32.7 hrs/ha, and for DP plots was 14.7 hrs/ha. Thus, there was a large reduction in weeding time on DP plots. However, a comparison of T2 versus T1 plots suggests that part of the reduction was due to the fact that DP plots were ploughed later than T1 plots.

As in prior seasons, partial budget analyses were carried out to determine the net gain associated with double ploughing. The analyses took into account differences in ploughing costs, seed, weeding time, yields, and harvesting time. When DP was compared to T2, the net gain was P34.06 per hectare based on a yield increase of 52 percent (337.1 kgs/ha for DP versus 221.7 kgs/ha; with grain valued at 43 t/kg, labour at 38 t/hr, seed at 30 t/kg, and equipment depreciation at P1.50/ha.) The net gain was achieved with an extra labour investment of 37 hours. When only the extra post-planting labour was costed, and the benefit was expressed as a ratio to the required ploughing labour, the return to the extra ploughing labour was P1.44.

If farmers do not face a land or weeding labour constraint, they have the option of planting both the T1 and the T2 plots, instead just the one DP plot. In an analysis of T1+T2 versus DP, there was a labour saving of 114 hours (66.8 weeding, 47.2 processing), a seed saving of 6 kgs, and a reduced equipment depreciation estimated to be P1.50. However, the DP system gave 236 kgs less grain, resulting in a net loss of P54.96.

Discussion

In this season, farmers who used owned traction and could have double ploughed without reducing the area planted would have benefited from double ploughing. Farmers who used owned traction but could have double ploughed only by reducing the area planted, should have double ploughed only if they had one of the special field situations identified in the technical analysis above. Farmers who hired traction, the majority in the Central Region, should not have double ploughed.

If the government wants to obtain the 50 to 75 percent yield increase which is consistently obtained with double ploughing, it appears that a subsidy on the extra ploughing will be required for most farmers. The alternative uses of the funds required for the subsidy should be examined before a decision is made to implement such a subsidy.

8.4 Management of the stover

The Residue Management study consisted of two experiments which examined the use of manure and stover. The trials were established in 1984/5. In the first experiment (Residue Management Trial), manure and stover were incorporated into the soil at a rate of 9 and 5 ton/ha., respectively. In the second trial (Manure/Mulch trial, formerly the Grain Yield Stability trial), manure (9 ton/ha) was incorporated into the soil and a stover mulch was applied at a rate of 5 ton/ha.. The 5 ton/ha. produced a ground cover of 45-60%. The Residue Management Trial (RM) was conducted at the Goodhope substation and one on-farm site near Sebele (Mmamashia). The Manure/Mulch Trial (MM) was conducted at Goodhope substation and two sites at Sebele Research station. Sorghum variety Segaolane has been grown every year in the RM trial. During the first two years the MM trial had 16 treatments , however in the third year, millet variety Serere 6A was grown. Soil moisture was monitored in the MM trial. The objective of the trials were to determine the long term effect of residue management on soil fertility as measured by grain and stover yield, infiltration rates, and soil organic carbon and nitrogen.

The RM trial was composed of a 2 x 2 factorial arrangement of 0 and 9000 kg/ha manure and 0 and 5000 kg/ha stover. Manure and stover incorporated into the soil generally improved the stover yield response over the control (no manure/no stover). This relationship was evident when treatment stover yield was regressed against the mean of all four treatments at a given year/location arrangement (Figure 1). This simple stability analysis showed that the treatment with both manure and stover incorporated into the soil responded to improved environments as was demonstrated by the slope of the linear regression line (1.33 and r=.99). The treatment with manure incorporated had a slope of 1.19 and a simple correlation of .94 compared to the control (no manure or stover) with a slope and correlation of .88 and .99, respectively. Stover incorporated had the least responsive yield to improved environments (slope .59 and correlation of .84). Sorghum grain yield (Table 1) were good at Goodhope, but the yield results from the Mmamashia site were suspect due to an uncontrolled attach of corncrickets.

Table 1. SORGHUM GRAIN AND STOVER YIELDS UNDER DIFFERENT LEVELS OF SOIL INCORPORATED MANURE (9 TON/HA) AND STOVER (5 TON/HA.) AT TWO LOCATIONS IN 1986/7.

	Goodhope		Mmamashia	
Treatments	grain	stover	grain	stover
	--(kg/ha)--		--(kg/ha)--	
No manure/no stover	251	962	56	974
+ Manure + Stover	577	1441	57	1632
+ Manure - Stover	963	1445	0	1359
- Manure + Stover	446	729	148	1132

Millet grain yields in the MM trial were categorized as to the previous 2 years application of manure and stover mulch (split plot design). Plots which received manure and stover mulch in the previous 2 years were divided into the 4 treatments as shown in Table 2. Plot which received no manure or stover mulch were divided similarly. Two points are evident from Table 2; the plots with no previous application of manure or stover mulch did much better than the plots which had manure and stover mulch, and 2) averaged across previous manure and stover mulch levels, the manure plus stover mulch and the stover mulch treatments achieved the highest yields. Concerning point 1, the superior yield levels probably reflect the use of accumulated soil moisture from the previous year's poor yield. Yield results from the Grain Yield Stability showed poorest crop performance in the non-manure/no stover mulch treatment. On the second point, manure plus stover mulch produced yields only slightly higher than the stover mulch treatment, therefore the relative contribution of the manure must have been meager.

This suggested that mulch was the dominant factor affecting yield. Given the rainfall pattern, e.g. normal early season followed by a 10 week mid-season drought, water stored in the soil profile could make a significant difference to crop yields. The stover mulch apparently provided an improved environment for crop yields, perhaps due to enhanced soil water status. A detailed analysis of the neutron probe data will provide insight into both of these points.

Table 2. MILLET GRAIN AND STOVER YIELDS UNDER DIFFERENT COMBINATIONS OF APPLIED MANURE (9 TON/HA) AND STOVER USED AS SURFACE MULCH (45-60% GROUND COVER), AVERAGED ACROSS THREE LOCATIONS.

Treatments	Previous M+SM ---Yields--- grain -(kg/ha)-	stover	HI	No previous M or SM ---Yields--- grain -(kg/ha)-	stover	HI	Means kg/ha
No manure/no mulch	210	1615	.12	360	1412	.20	285
+ Manure + Mulch	289	1840	.14	605	1638	.27	447
+ Manure - Mulch	166	1561	.10	368	1420	.21	267
- Manure + Mulch	208	1626	.11	663	1704	.28	436
Means	218	1661		499	1544		

8.5 C rop Rotation And Fertilizer Research

INTRODUCTION

Rotation studies iniated during the 1981/82 cropping season were continued into their sixth year at Goodhope and Sebele. A new legume-cereal trial was planted at the Matsaudi Sandvel site. At the Goodhope Experiment Station, although conditions were dry, the few seasonal showers were enough to sustain reasonable crop growth resulting in better grain yields compared to Sebele. At Sebele two rotation trials were implemented, one on B33 where sorghum is rotated with cowpeas with the sorghum crop receiving four levels of nitrogen, and the other on Block 8 where sorghum is grown after a crop of either sorghum , cowpea or groundnut also at four levels of nitrogen. At either site the drought situation was so severe to mask any treatment differences although at Goodhope the rotation plots performed better than the continuous sorghum plots, the differences being greater where fertilizer nitrogen was not applied.

Fertilizer studies were conducted at Sebele, Xhwaa Molapo and Pandamatenga. Again severe drought restricted crop growth and development with the result that no treatment responses were observed because crop stands were also very variable. At Pandamatenga on the other hand, although the yields were very poor, nitrogen and phosphorus fertilization significantly increased total biomass production of an otherwise moisture stressed maize crop.

Rotation Study at Goodhope

The trial at Goodhope was a randomised complete block design where sorghum was grown after either sorghum or groundnuts (designated continuous and rotation sorghum, respectively), in a rotation sequence. Nitrogen was applied as limestone ammonium nitrate (LAN, 28%N) to the sorghum crop only at the rates of 0, 20, 40 and 60 kg ha-1 in a band along the row 3 weeks after planting. The plots were 10 m long, 8 rows wide at a row spacing of 0.75 m and intra-row plant spacing of 20 cm. The whole experimental plot had received 30 kg P ha-1 as single superphosphate at seedbed preparation.

The central 5 m of the 4 middle rows were harvested for grain and stover yield estimates. The grain yields were adjusted to 13% moisture before reporting whereas stover and total dry matter yields were reported on an oven-dry basics. Small oven dry grain and stover samples were ground and used for N, P and K analysis using wet digestion procedures. Other data collected included 1000 seed weight, plant stand and head number per hectare.

Results

Table 1 below summarises the effects of cropping system and nitrogen fertilizer on grain yield, stover and total dry matter (DM) yields. Although the rotation system produced more stover and total dry matter compared to the continuous sorghum system ($P \leq 0.10$), grain yields were not statistically different but the rotation system gave slightly higher yields (> 200 kg more) compared to the continuous sorghum treatments when averaged over N levels. At the zero level of fertilizer application on the other hand, dramatic increase of 72% in grain yield was obtained due to the rotation treatment.

Table 1. THE EFFECTS OF CROPPING SYSTEM AND NITROGEN FERTILIZER ON GRAIN, STOVER AND TOTAL DRY MATTER (DM) YIELDS AT GOODHOPE

N Rate	Cropping System	Grain	Stover	Total DM
kg N ha-1		---------------	---------------	kg ha-1
0	Continuous	819	1438	2163
	Rotation	1407	1959	3204
20	Continuous	1507	1435	2768
	Rotation	1443	1679	2956
40	Continuous	1365	1557	2944
	Rotation	1806	1704	3302
60	Continuous	1510	1608	2944
	Rotation	1421	1682	2950
System Means:	Continuous	1300	1510	2660
	Rotation	1519	1756	3103
N rate means	0	1113	1698	2684
	20	1475	1557	2862
	40	1585	1631	3034
	60	1466	1645	2947
$P \leq 0.10$:	Cropping system (A)	NS+	*	*
	N rate (B)	NS	NS	NS
	A x B	NS	NS	NS
C.V. %		27.4	20.4	19.5

+NS, nonsignificant; * significant at $P \leq 0.10$.

Nitrogen fertilizer did not affect any of the yield parameters estimated although there was a tendency towards higher yields as nitrogen level was increased in the continuous sorghum treatments. The lack of treatment responses could partly be attributed to the high C.V's especially in the grain yield estimates. This was due to the uneven stands as a result of poor moisture conditions during crop establishment.

Table 2 shows the effects of cropping system and nitrogen fertilizer on stand and head counts and 1000 seed weight. No significant treatment differences were obtained except in the case of number of heads where more heads were harvested in the rotation than in the continuous plots.

The above results indicate that at the yield levels obtained using groundnuts in rotation with sorghum will supply enough nitrogen to the sorghum crop without any additional benefits from applied nitrogen when the crops are grown in rotation system. The problem, however, may be the practical application of the system in the current Botswana's production patterns in that farmers tend to restrict their groundnuts or indeed any legume crop to very small areas of their fields.

TABLE 2. SORGHUM PLANT STAND, HEAD COUNTS AND 1 000 SEED WEIGHT AS AFFECTED BY CROPPING SYSTEM AND NITROGEN FERTILIZER RATE AT GOODHOPE

N rate	Cropping System	Plant Stand	Head Number	1000 Seed Weight
kg ha-1		---- No. x 100 ----		g
0	Continuous	39.38	26.46	19.20
	Rotation	38.96	38.96	19.45
20	Continuous	35.42	35.21	18.92
	Rotation	35.42	37.71	18.45
40	Continuous	37.29	35.62	18.28
	Rotation	41.66	47.08	18.39
60	Continuous	42.08	43.08	18.97
	Rotation	39.17	38.96	18.88
System means:	Continuous	38.54	35.26	18.84
	Rotation	38.80	40.68	18.79
N rate means	0	39.17	32.71	19.33
	20	35.42	36.46	18.68
	40	39.48	41.35	18.34
	60	40.62	41.36	18.92
$P \leq 0.10$	Cropping system (A)	NS+	*	NS
	N rate (B)	NS	NS	NS
	A x B	NS	NS	NS
	C.V%	27.1	26.1	6.2

+NS, nonsignificant. *, significant at $P < 0.10$

Rotation Studies at Sebele

The rotation trial at Sebele on B33 was designed similar to the one at Goodhope except that cowpeas were used instead of groundnuts. The experiment had to be abandoned early in the season due to severe drought.

The experiment on Block 8 was a split plot design with 3 previous crop treatments, namely sorghum, cowpeas and groundnuts as main plots and 4 levels of fertilizer nitrogen - 0, 20, 40 and 60 kg ha-1 as subplots applied to the current season crops of maize and sorghum. The plots were 20 m long 6 rows wide at a spacing of 0.75 m and each crop occupied 10 m half of the plot. The entire experimental area had received 30 kg kg P ha-1 prior to planting as single superphosphate.

The maize crop failed completely due to drought but some sort of yield was harvested from the sorghum crop. Only grain yields were estimated from this trial.

Results

Table 3 below shows the effects of the 3 previous crop treatments on the yield of the following season sorghum crop. Although treatment differences were not significant and the data very variable as reflected by the very high C.V., the legumes tended to have higher yields than the sorghum. It was also interesting to note that cowpeas tended to give higher yields than the two other crops. It will be noted that cowpeas senescences much earlier in the season which might mean that in a very dry season like this one, the current crop might have benefited from some residual moisture conserved from the previous season cowpea.

TABLE 3. THE EFFECT OF THE PREVIOUS CROP AND N FERTILIZER ON YIELD OF GRAIN SORGHUM ON BLOCK 8

N rate	Previous Crop	Grain Yield
kg ha-1		kg ha-1
0	Sorghum	246
	Cowpea	495
	Groundnut	500
20	Sorghum	27
	Cowpea	255
	Groundnut	340
40	Sorghum	155
	Cowpea	921
	Groundnut	216
60	Sorghum	497
	Cowpea	921
	Groundnut	174
Crop Means:	Sorghum	231
	Cowpea	520
	Groundnut	308
N rate means:	0	414
	20	207
	40	260
	60	531
Prob. < 0.10:	Previous crop (A)	NS-+
	N rate (B)	NS
	A & B	NS
C.V.%		118.3

+ NS, nonsignificant

This hypothesis is further supported by the fact that for the continuous season crop, fertilizer nitrogen did not increase yields suggesting that the long season previous sorghum crop could have exhausted the soil of all moisture reserves with the result that the current crop only depended on the current season precipitation. It is intended to monitor the moisture situation in these plots throughout the season in future so that a better understanding of the system could be achieved.

Fertilizer trial at Sebele

A nitrogen x phosphorus fertilizer trial was conducted on Block 8. Four levels of nitrogen, 0, 20, 40 and 60 kg^{-1} were applied as main plots and split with 3 levels of phosphorus 0, 20 and 40 kg ha^{-1} as subplots. Both fertilizers were band placed after planting. The treatments were replicated 4 times. Plot sizes were 8 m long 6 rows wide and 0.75 m between the rows. Sorghum and cowpeas were grown as test crops but only sorghum yields are reported as much of the cowpea crop was lost due to both drought and flower abortion.

Results

The effects of N and P on sorghum grain yield, stover yield, total drymatter production and seed weight are shown in Table 4. It is noted that the yields are again very low because of poor stands established. Seed size too is too low, averaging about 5 g less per 1000 seed of normal Segaolane seed size. Nitrogen did affect seed size, the zero N treatment being significantly less than when fertilizer N had been applied ($P < 0.05$). Fertilizer P tended to have negative effects on grain yield, the zero P treatment being significantly higher than where P fertilizer was applied. This was probably due to the osmotic effect of the granular band placed fertilizer pulling away moisture from the roots.

TABLE 4. THE EFFECTS OF N AND P ON GRAIN YIELD, STOVER AND TOTAL DRY MATTER YIELDS AND 1 000 SEED WEIGHT OF SORGHUM

Treatment			Grain	Stover	Drymatter	1000 Seed Weight
N	P		----------- kg ha-1		----------	g
0	0		300	912	1177	17.19
0	20		254	1056	1281	16.49
0	40		232	1131	1336	15.40
20	0		272	1079	1319	17.94
20	20		268	1278	1515	17.90
20	40		196	871	1043	17.96
40	0		275	1208	1451	17.79
40	20		173	846	999	17.04
40	40		222	1052	1248	17.92
60	0		258	996	1224	17.02
60	20		211	885	1072	16.42
60	40		225	929	1126	17.58
N means:		0	262	1033	1265	16.36
		20	245	1076	1292	17.93
		40	223	1035	1233	17.58
		60	231	937	1141	17.15
P means:		0	276	1049	1293	17.49
		20	226	1016	1217	17.07
		40	219	996	1188	17.22
Prob. < 0.10:		N	NS+	NS	NS	*
		P		*	NS	NS
		NxP	NS	NS	NS	NS
C.V. %			29.8	26.2	23.0	5.6

+NS, nonsignificant. *, significant at $P < 0.10$.

Fertilizer trials at Xhwaa Molapo

Two fertilizer trials were planted at this site. One trial was to investigate the residual effects of phosphorus in molapo soils. This trial was abandoned due to poor growth as a result of the drought. The other trial was a nitrogen by phosphorus factorial experiment which has been reported in the

Molapo Development Project section of this report.

Fertilizer trials at Pandamatenga

During the previous year it has been observed that severe nutrient deficiencies occurred in newly developed farmers' fields in the Pandamatenga vertisols. It was also observed that where cleared vegetation had been piled-up and burnt during the land clearing operation better crop development occurred and no nutrient deficiencies were observed. It was hypothesized that the large grass biomass incorporated into the soil during land preparation and ploughing of newly cleared land caused nutrient, especially nitrogen deficiencies as nutrients were immobilized by rapid microbial growth. Thus an experiment was designed to test this hypothesis whereby the following natural grass residue management treatments were imposed:

1) grass burnt before ploughing, designated Burn
2) grass mowed before ploughing, designated Cut
3) grass ploughed under, designated conventional

These treatments were laid out as main plots and the plots subdivided into two levels of fertilizer as subplots in a split plot arrangement. The fertilizer treatments were zero and a combination of N and P at the rate of 80 and 60 kg ha-1 respectively, all applied in the seed bed. Maize was the test crop planted on the 28.10.86, 3 days after the fertilizer was applied. The first planting failed due to rodent damage to the seed. The subsequent planting did not produce a good stand probably due to inadequate moisture. Treatment differences were, however, visible early in the season, the plots which received fertilizer outgrowing those without fertilizer. The residue management treatments did not show any significant trends although it was evident that burning was slightly superior to other treatments. Measurements of stover weight, grain yield, total dry matter production and plant height were made.

Results

Table 5 shows the effects of the treatments on grain yield, total drymatter yield and plant height. The various residue management practices did not significantly affect either of the parameters estimated although it was apparent that the removal of the grass cover prior to ploughing by either burning or cutting supported better plant growth. Fertilizer application on the other hand increased yields and plant height highly significantly ($P \leq 0.01$). A feature of these results was the high variability in the trial data reflected by the very high C.V.s. The unevenness of the crop stands probably accounted for this more than the drought. However, the data fully supports the use of fertilizers in these soils. The next stage of this research would be to separate the effects of N and P through a factorial design and also work with the different levels of these nutrients so that work towards a fertilizer recommendation for the area could be developed.

TABLE 5. THE EFFECTS OF RESIDUE MANAGEMENT AND FERTILIZER ON THE GROWTH OF MAIZE AT PANDAMATENGA

Residue Management	Fertilizer Treatment	Grain Yield	Total DM Yield	Plant Height
		----- kg ha-1	----	cm
Conventional	- Fertilizer	12	208	41.2
Burn	- Fertilizer	34	341	48.4
Cut	- Fertilizer	5	155	44.3
Conventional	+ Fertilizer	121	703	63.0
Burn	+ Fertilizer	192	810	72.7
Cut	+ Fertilizer	188	850	69.0
Management means:	Conventional	67	454	52.1
	Burn	113	575	60.6
	Cut	96	503	56.7
Fertilizer means:	- Fertilizer	17	234	44.6
	+ Fertilizer	167	788	68.2
Prob. $\leq$ 0.05	Management (A)	NS+	NS	NS
	Fertilizer (B)	***	***	***
	A x B	NS	NS	NS
	C.V. %	91.3	50.1	8.8

+NS, nonsignificant
***, significant at 0.01

Conclusions

The rotation work described above again indicated that there were some residual benefits to be derived from either cowpeas or groundnuts by a succeeding crop of sorghum. The severity of the drought, however, masked differences in most cases. It is also not understood whether the residual effect was moisture or nitrogen related. It is, however, suggested that at the current level of production cereal crops could be grown successfully without fertilizer nitrogen especially when rainfall is below average as it has been the case in most seasons. The biggest problem would be to devise a system that will be acceptable to farmers in terms of land allocation to the various crops as the current practice is to allocate very small fractions of the total land ploughed to these grain legume crops.

Results from fertilizer trials indicate that even in low fertility Botswana soils. fertilizers can never be of practical benefit when soil moisture conditions are limiting growth. There could even be disadvantages of fertilizer use when early rapid vegetative growth exhausts the soil moisture reserves or the mere presence of the fertilizer material near the rooting zone exerts an osmotic potential which pulls away the water from the roots. There was an indication in the case of Pandamatenga that even in years of less than favourable rainfall, fertilizers will play a major role to ensure success in any cropping enterprise. The next major task would be to address fertilizer requirements for various crops grown by the farmers in the area and come up with fertilizer recommendations for different yield goals.

Section 9. FARM MACHINARY RESEARCH AND DEVELOPMENT

SUMMARY

Observations on the implementation, management and performance of various cultivation systems has been maintained since 1979. More attention has been given to the draught requirements and forces generateu by traditional and novel animal drawn implements.

Developments on improving planting equipment include the hopper system for groundnut (first reported Anon 1987 page 152). The same system was used successfully for maize and sorghum.

In field runoff measurements were continued and considerable differences were observed due to the type of cultivation emplcyed.

The background and findings on developing a workable management system based on permanent strip cultivation, tractor managed, is given.

9.1 Alternative Systems Observation

9.1.1 ORIGINAL OBJECTIVES (commenced 1979-80 season)

By using ox power, to compare the relative merits or otherwise of beds with ridging, tied and untied and 'flat' planting using tool carriers, toolframes and conventional single purpose animal drawn equipment growing sorghum, cowpeas and maize. The observation is sited in blocks B11 and B12 on the Research Station at Sebele. At present, 15 plots are involved measuring 90 metres long and 16, 19 or 24 m wide for the beds.

9.1.2 GENERAL

Treatments were again modified, mainly to accomodate a suitable area for testing two new implements, a sub soiler/chisel plough and a rotary harrow, in cooperation with CEEMAT (Centre d' Etudes et d' Experimentation du Machinisme Agricole Tropical, Paris, France) and AFRC, Institute of Engineering Research (formerly NIAE) Bedford UK., who came to Sebele to monitor ox and implement performance using in new electronic logging technique. (See Section 9.2 of this report).

Cowpeas followed sorghum in the rotation on plots 1, 2 and 8. Plots 6, 7, 9 and 10 were planted after maize and plots, 4 and 5 were plough planted to sorghum last, following the CEEMAT/NIAE work. Plots 11 and 12 were combined to try out the new Sebele planter groundnut hopper planting also maize, cowpeas and sorghum. Plots 12 to 15 were planted to maize after sorghum forming a second replicate of the tillage trial.

9.1.3 WEATHER

Total rainfall for the season, recorded at the plots was rather better than in the previous two years, 353 mm compared with 290 mm for 1985-86 and 275 mm for 1984-85. From October the season promised well with 46 mm for the month, 6 rain days, 23 mm on the 31st. 93 mm was recorded for November, 10 rain days, 33 mm on the 8th and 67 mm for December, 14 rain days, 21 mm on the 20th. However, from then on draught set in with only 37 mm for January, 8 rain days, 12 mm on the 16th otherwise 8 mm or less. February was a disaster; 28 mm on two rain days; one mm on the 5th and 27 mm on the 28th. March produced a very respectable 56 mm but by then it was too late and the maize had failed with yields of sorghum badly affected. April brought 10 mm on two rain days making a final total of 353 mm.

Planting all the plots covered four weeks and began on 24th November with cowpeas, followed by maize 3rd and 8th December and sorghum 3rd and 17th December, finally plough planted sorghum, 15th, 18th and 22nd December, which failed to produce any grain worth harvesting.

Table 1. SUMMARY; GRAIN YIELD, IMPLEMENTATION TIME AND DRAUGHT LOAD ALTERNATIVE SYSTEM OBSERVATION PLOTS 1-15 SEASON 1986-87

System Machine Plot No	Operation	Time hrs per ha	No of oxen	Total ox hrs	Draught load kg	Crop yield kg per ha
Beds	1 Cutting Stover	2.4	2	4.8	59 - 73	
NIAE tool Carrier 1-2	2 Subsoil	3.0	2	6.0	77 - 105	
	3 Bedforming	3.2	4	12.8	175 - 200(1)	
	4 Plant	3.0	2	6.0	75 - 100(1)	
	5 Mech.Weed	2.8	2	5.6	100 - 150	
	Total	14.4		35.2		Cowpeas: 79:failed
Plough Plant 3-4-5	1 Plough plant	11.0	6	66.0	180 - 272	
	Total	11.0		66.0		Sorghum: failed
M.b.plough row plant 6 - 14	1 Plough	8.9	6	53.4	180 - 272	
	2 Harrow	2.9	4	11.6	136 - 180	
	3 Plant	5.8	2	11.6	50 - 70(1)	
	4 Mech.Weed	4.6	2	9.2	n.a.	
	Total	22.2		85.8		Sorghum 246 Maize failed

Table 1 cont.

System Machine Plot No	Operation	Time hrs per ha	No of oxen	Total ox hrs	Draught load kg	Crop yield kg per ha
M.b.plough with	1 Plough	10.4	6	62.4	180 - 272	
Dammer	2 Harrow	2.9	4	11.6	136 - 180	
Diker	3 Diker	4.6	2	9.2	175 - 250	
row plant	4 Plant	5.2	2	10.4	50 - 70(1)	
7 - 12	5 Mech.Weed	5.8	2	11.6	n.a.	
	Total	28.9		105.		Sorghum 243 Maize failed
Ariana tool	1 Plough	11.6	4	46.4	136 - 180	
frame	2 Harrow	2.9	4	11.6	136 - 180	
rowplant	3 Plant	7.5	2	15.0	50 - 70	
8	4 Weed	5.2	2	10.4	n.a.	
	Total	27.2		83.4		Cowpeas: 115
Chisel	1 Chisel	7.0	6	42.0	180 - 272	
Plough	2 Plant	5.2	2	10.4	50 - 70(1)	
rowplant						
9-15	Total	12.2		52.4		Sorghum 382 Maize failed
3 planters row plant	1 Plough	8.8	6	52.8	180 - 272	
4 crops	2 Harrow	2.4	4	9.6	136 - 180	
11	Total	11.2		62.4		Plant counts only
M.b.plough	(1) Plough	11.0	6	66.0	180 - 227	
(or split)	(2) Harrow	2.4	4	9.6	136 - 180	
tied ridges	(3) Ridge	5.2	2	10.4	140 - 180	
ridges						
10-13	1 Split ridges	6.9	2	14.0	180 - 227	
	2 (4) Tie	5.8	2	11.6	75 - 100(1)	
	3 (5) Plant	4.0	2	8.0	50 - 70(1)	
	Total (1)to(5)	28.4		105.6		Sorghum 132
	Total 1 to 3	16.7		33.6		Maize failed

(1) Typical figures; previous determination

9.2 Animal draught requirements for various implements and configuration

The studies were conducted in collaboration with CEEMAT and AFRC. Animals and implements werre monitored for the force, speed, power and stress (physiological) generated by using various implements. The implements were tested under various soil moisture conditions and bulk density to ascertain their best mode of operation.

The following implements were studied:

1) Mahon Cultivator
2) Rolling Tiller (CEEMAT)
3) Demoi minimum cultivation seeder
4) Demoi minimum cultivator + ridger
5) CEEMAT Experimental ripper
6) FMDU experimental ripper
7) The 12" and 10" mouldboard plough

The CEEMAT equipment was tested in various modes, in the case of the ripper with differing point designs and angle of contact. Full reports are available from the Farm Machinery Development Unit (FMDU) Sebele. The following serves as a summary and illustration of the work conducted.

Tests on Cultivation Equipment Using Animal Draught

9.2.1 SUMMARY OF TESTS CONDUCTED WITH THE CEEMAT TINE

The conditions were not as originally planned for these tests. Although it had been hoped to work on dry soils before the rains came, 116.5 mm precipitation had already fallen on the station's plots when the mission began.

However, this rain was well spaced out and the soils dried out and recompacted very quickly under the intense heat. For example, the soil softening effect of 30 mm of rainfall on 29 and 30 November was completely cancelled out by one week of sunny weather (30 November - 6 December). In some plots, which had been tilled previously; the soil was very compact so that water infiltration was low and drying was therefore rapid.

In general, compaction and humidity in the test plots varied greatly in the different horizons. some were moist at depth whilst others were hard (plough pans or dry horizon). The results of these tests, particularly those comparing share and shank shape, should be interpreted with caution since multiple replications were not possible.

However, the following conclusions can be drawn:

9.2.1.1 USE OF THE TINE IN DRYLAND

Under dry conditions of these soils by animal draught is not normally possible. Even in moist conditions the average tractive effort varies from 95-110 kg for depths of 16-19 cm. In order not to exceed these levels in drier soils the depth, and therefore the degree of loosening, has to be reduced.

Illustration 1. THE LOAD, SPEED AND STRESS MONITORING SYSTEM

Draught Animal Performance

An instrumentation system has been developed to · ænse and loɡ ox performance

- *Sensors are fitted to the animals and implement*
- *Signals are processed and the data logged in a micro-computer*

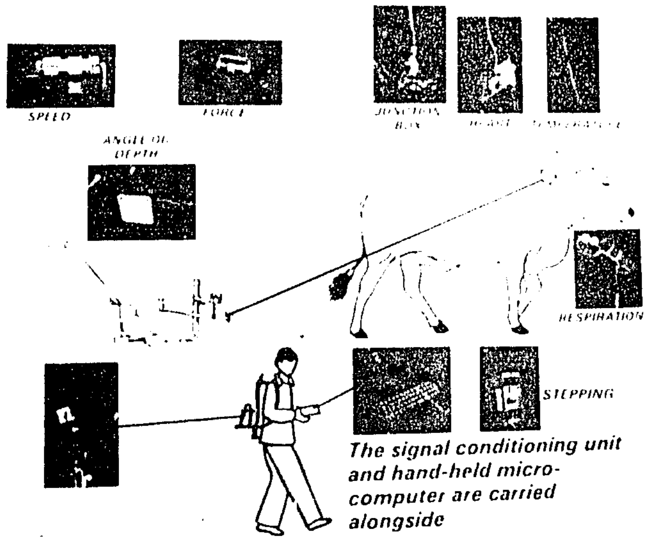


Illustration 2. SYSTEM USED UNDER FIELD CONDITIONS

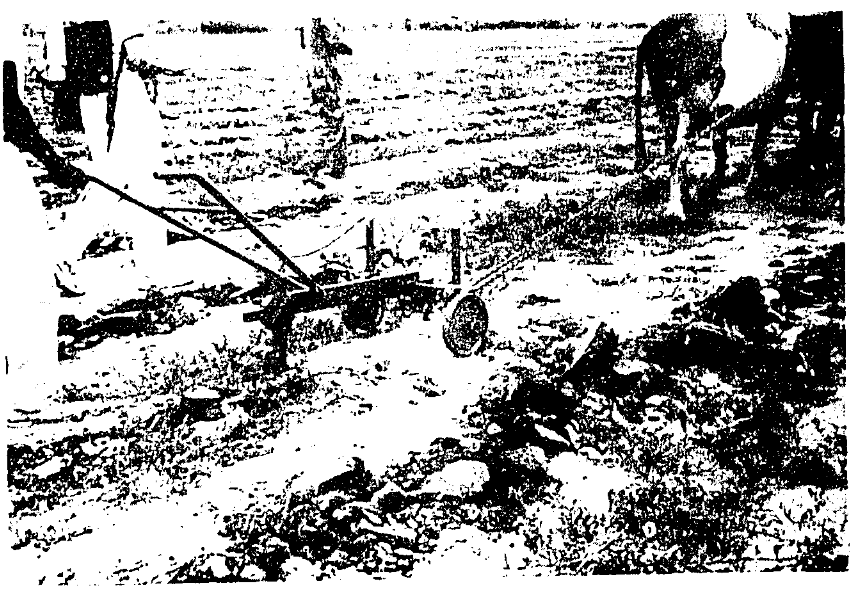


Illustration 3. THE CEEMAT TINE WITH ANGLED SHANK

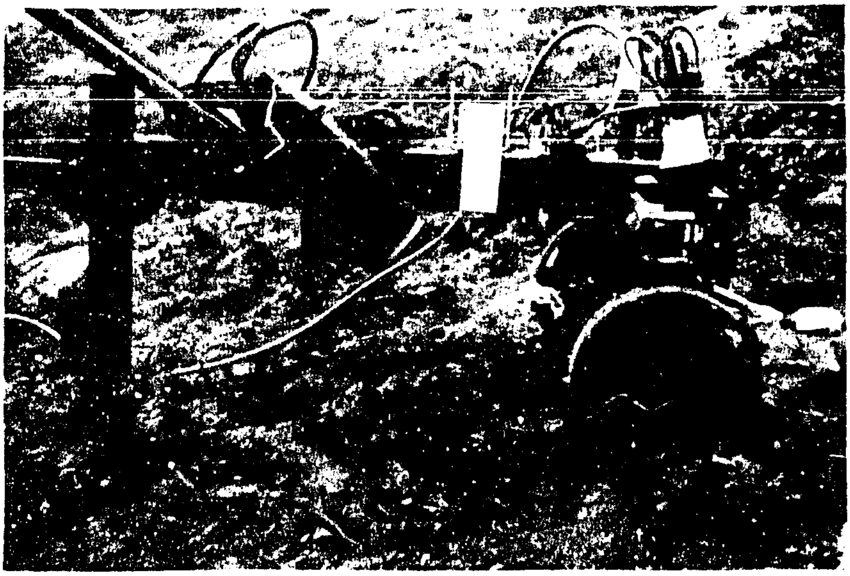
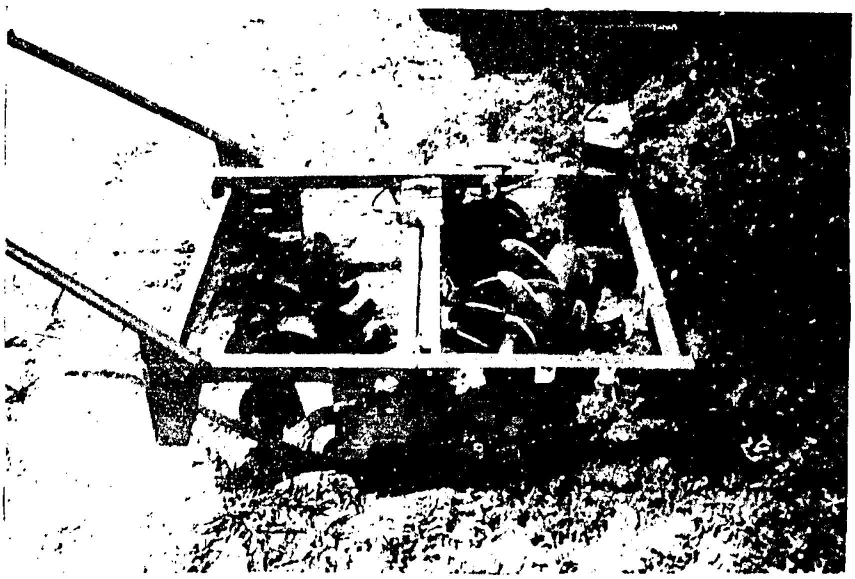


Illustration 4. THE CEEMAT ROTARY CULTIVATOR



Use of the tine is therefore subject to two contradictory requirements:

- to wait for a level of precipitation which will give an adequate moisture level,

- but the moisture the soil, the less the loosening effect; clod and fracture size is reduced.

However, it was observed that even when the tine was used in moist conditions the loosening effect was sufficient to enable water storage. Penetrometer tests and observations made on the final day, i.e. after 15 days by which time approx. 50 mm rain fell, test plots showed that in the sections not worked with the tine the compact layer (where the water did not penetrate) was at a depth of 10-15 cm whereas along the lines worked the soil was moist and loose to 35-40 cm. These lines form mini-reservoirs from which the water can percolate to depths greater than the working depth since it is retained in them.

The most highly recommended use of the tine would therefore be to:

i) till as soon as possible after the rains, regulating depth so that the tractive effort is suited to the capacity of the team,

ii) till as frequently as possible - even tilling the same lines more than once - after each rain to recreate a profile suitable for storing subsequent rain.

A seeder mounted behind the tine would be an excellent direct sowing implement.

9.2.1.2 COMPARISON OF SHARE AND SHANK SHAPES

The conclusions cannot be considered to be definitive and these tests ought to be repeated.

i) the curved shank seems to be the most stable in the furrow and best at maintaining its working depth, but the 600 shank requires lower tractive effort at equivalent depths. The 600 and 500 shanks would probably behave far less well in drier ground.

ii) winged shares can only be used in soft, and therefore moist, soils. For current usage, it would be desirable to be able to change the wing size according to the moisture level of the soil, i.e. to have a range of 2-4 types of wing of varying sizes.

Table 2 COMPARISON OF CEEMAT TINE WITH DIFFERENT POINTS

Point Number	Force (N)			Observation
	Mean	Maximum	Minimum	
1	1953	4050	852	Powerful disruption of soil
2	1245	2907	326	
3	1629	3591	256	
4	1469	3030	577	
5	1148	2564	582	Good disruption with steady loading
6	1385	2686	680	
7	1285	4188	188	Very uneven
8	881	2526	335	Failed to pene-trate properly

	Depth(cm)	MC(%)	Density g/cc
Soil conditions	0 - 4	1.6	1.20
	14-18	6.5	1.27
	19-22	6.2	1.69

iii) the further the wing from the share tip, the lower the traction required. Low wings pull too much and tooled wings seem to destabilise the implement.

iv) the heel is essential for control of working depth and tractive effort.

(See figure 1 for illustration of options tested, table 2 for results).

9.2.3 COMPARISON OF CEEMAT TINE AND PLOUGHS

This is a very brief comparison which does not cover tractive effort or variability and levels of tractive effort. Working specifications and comparative agronomic effects in particular could not be included since they require longer tests.

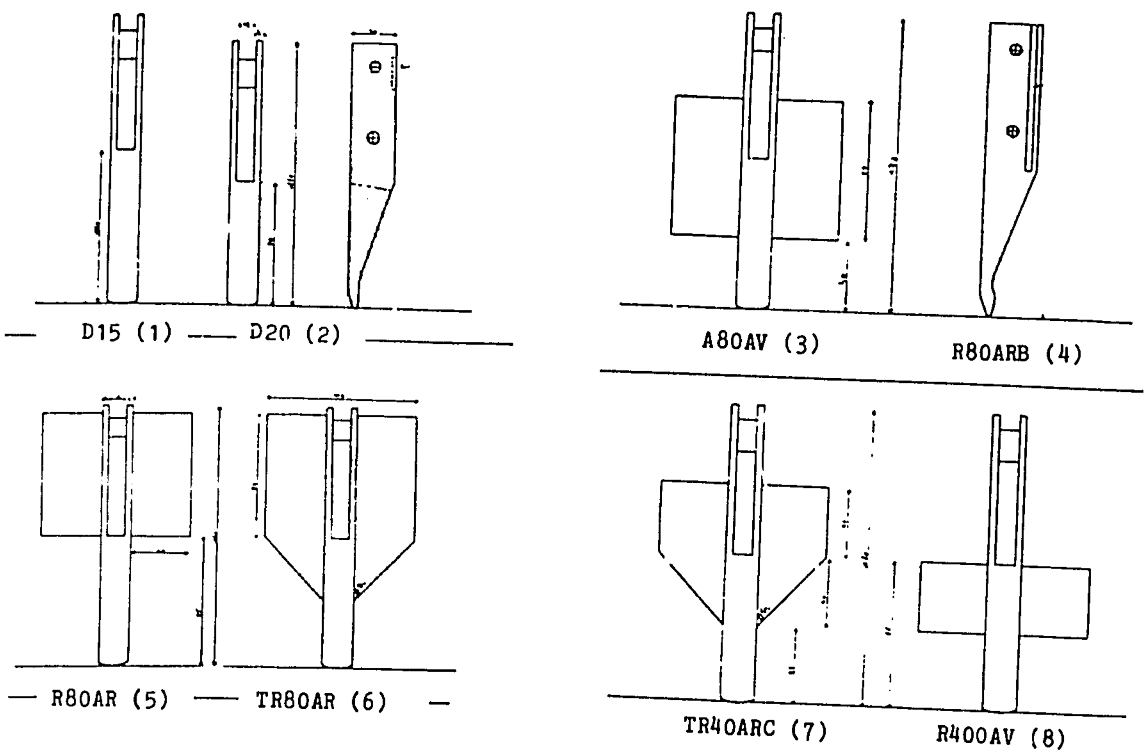
The tine requires 2-3 times less effort than a 12" plough at identical depths for a given soil compaction level. It required 137 kg compared with 181 kg with 10" plough in a compact soil. Above all, the variations in effort (max/min) are smaller: 2060 kg compared with 3000 - 4500 kg for ploughs in hard ground. Table 3. It is well known that variation in tractive effort is an important factor in fatigue of draught animals.

9.2.4 COMPARISON OF CEEMAT TINE AND FMDU RIPPER

The comparison of tractive efforts is completely in favour of the CEEMAT tine; this is attributable to the shape of the components below ground. However, although the FMDU ripper requires higher tractive effort, it is more regular; this is due to the weight of one person (say 70 kg) imposed on the tine so that it draws correctly.

The effort required for the sections worked is approximately 70 kg per dm2 for the CEEMAT tine compared with approx. 155 kg for the FMDU ripper; energy savings would be very high in favour of the CEEMAT design. See figure 2 for the histograms of force, speed and power requirements of the FMDU ripper.

Figure 1 ILLUSTRATION OF TINE POINTS AND ANGLES TESTED AT SEBELE



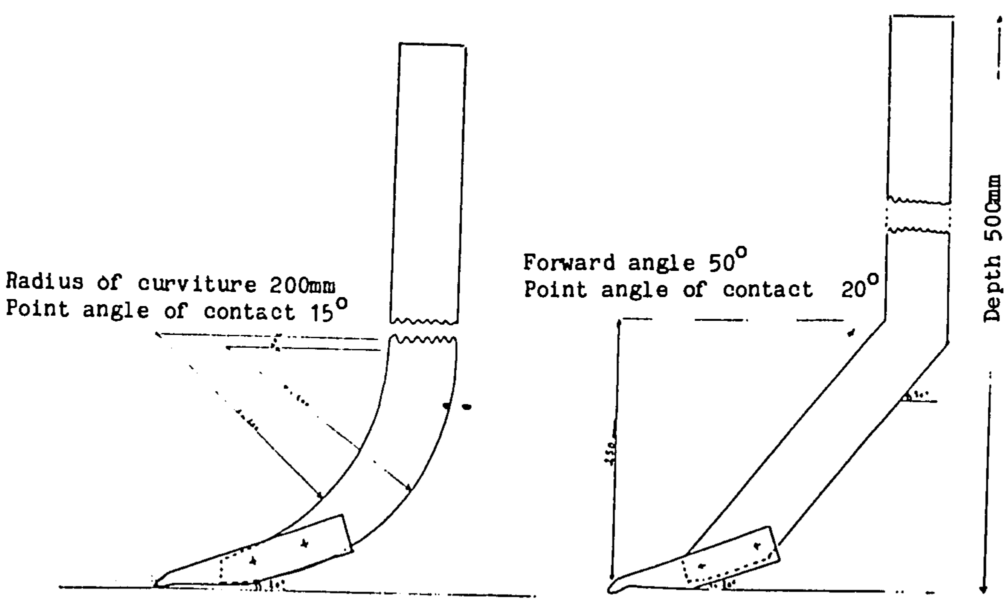


Figure 2. OPERATIONAL CHARACTERISTICS OF THE CEEMAT TINE

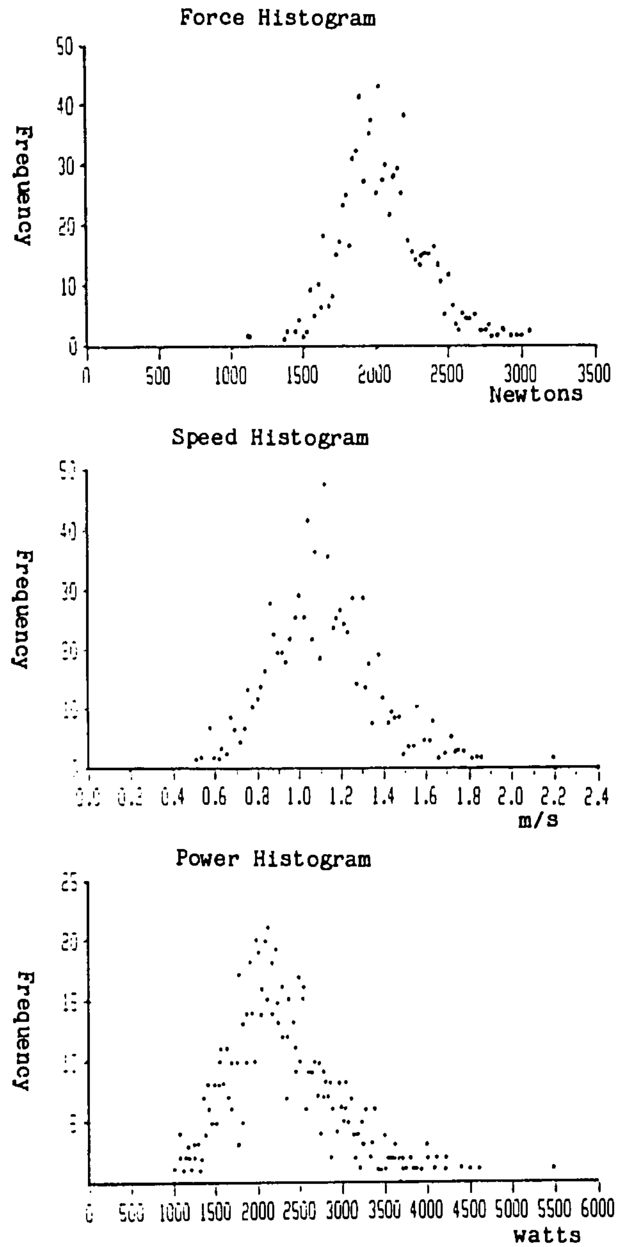


Table 3. COMPARISON OF VARIOUS CULTIVATION EQUIPMENT

Implement	Details	Depth Setting cm	Operational depth cm	Force (N)	Power (W)	Force applied to working crop Section N/dm^2	cm	Moisture %	Bulk Density g/cc
Mouldboard plough	10"	-	-	1776	1802	-	0-2	1.6	-
Mouldboard plough	1[illegible]"	-	-	2525	2562	-	2-6	0.8	1.41
							20-24	4.3	1.64
Ripper FMDU		-	16.3	2039	1533	1257	0-6		
Ripper CEEMAT	Curved shank	19	18.8	1013	1112	1102	20-24	4.3	1.64

9.2.5 SUMMARY OF TESTS CONDUCTED WITH THE ROTARY CULTIVATOR

The pull hardly ever exceeded 100-105 kg in the widest version of the implement in loose soil conditions. It was only when weights were added to improve penetration in dry land that tractive effort exceeded 110 kg.

Tractive effort required was surprisingly regular from one soil condition to the next when the weight of the implement was constant. Rotary operation permits self-regulation of tractive effort by varying the working depth. See figure 3, histogrammes for the rolling cultivator.

It is clear that this gives the rotary cultivator a clear advantage over tined implements and allows a considerable reduction in oxen fatigue.

9.2.5.1 Grass Control With the Rolling Cultivator

Grass may be controlled perfectly by timely use of the implement on the plot, i.e. a reasonable length of time after rainfall.

Problems of clogging arose during the use with forward cutting blades. This problem was spectacularly resolved by reverse mounting of the blades so that the convex edge was leading. In this mode the implement unclogged itself amost without fail.

This will guide future research redesign the shape of blades on the tiller.

Table 4. EXAMPLES OF THE ROLLING CULTIVATOR IN OPERATION

Settings	Force (N)	Speed km/hr	Power (Watts)	Operating Width (Cm)	Force/Width N/cm	Soil Depth cm	Soil Moisture %	Soil Bulk Density g/cc
1) Comparison of configuration						0-6	9.1	1.10
						20-25	5.4	1.61
a) Two axles offset tandem	816	4.18	910	50	16.3			
b) Two axles in parallel	1067	4.10	1225	100	10.7			
2) Two axles in tandem, offset 20° 160 mm between axles.						0-2	2.0	-
						2-6	6.7	1.29
						20-25	8.7	1.25
a) 1 pass weed free land	828	4.10	945	61.5	13.5			
b) 1st pass heavy weed burden	924	4.35	1110	61.5	15.0			
c) 2nd pass heavy weed burden	850	3.92	920	61.5	13.8			

In the conditions at the Sebele station it was shown in very grassy plots that the implement did not clog. These are plots where ploughing is generally considered to be the only possible method of cultivation. In these very grassy plots 2-4 passes of the rotary cultivator in tandem position (double effect) may well be necessary whereas a single pass would be sufficient on uninvaded land, Table 4.

9.2.5.2 Use of The Rotary Tiller

There are three levels of use of the implement:

i) in primary mode after the rains arrive in order to restrict grass growth and create a mulch which will enable water infiltration and retention in teh soil (sandy clay soils). Use of the cultivator after each major rainfall is recommended;

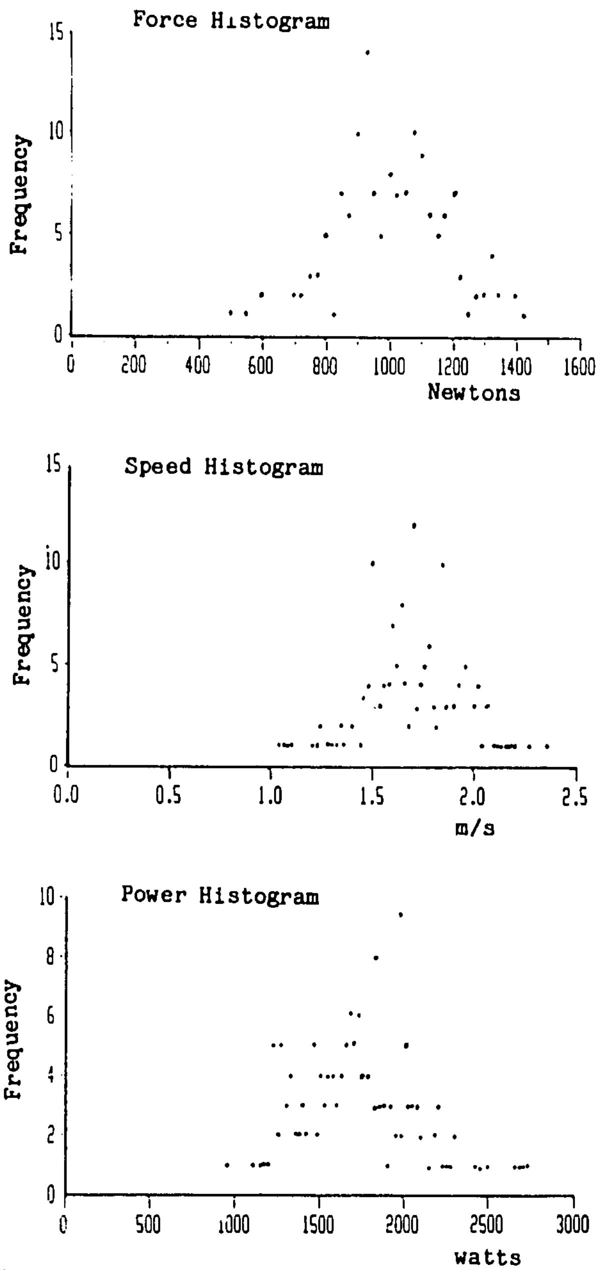
ii) as a second operation after ploughing on cloddy, sticky soils;

iii) for inter-row weeding; the implement is easy to direct once the line of traction has been correctly set.

In the context of the Sebele station the first method arouses interest and questions with a view to optimum utilisation of the low rainfall. Using the rotary cultivator is faster than the plough; the working width is more than twice that of a 12" plough (63 cm compared with 30 cm), forward speed is higher and daily working periods are longer than for ploughing because the work is less laborious. Furthermore, only 6-10 cm of soil need to be moistened to create an effect compared with 12-20 cm for a plough.

The effects of these two working methods on yields have still to be studied. This can only be done in a long-term experiment.

Figure 3. OPERATIONAL CHARACTERISTICS OF THE CEEMAT OFFSET ROLLER



9.2.5.3 Optimum Mounting of the Rotary Tiller

- the working angle offering the best compromise is 200 (FF)

- the implement is too heavy to take 3 hubs but is perfectly suitable for 2 x 4 hubs in the best working conditions (soil dried out after rain). It may well be too heavy if a new blade shape is needed for weed clog control, (and better penetration), are developed.

- "V" mounting (side by side for two roters) may be justified in that even if the profile has not been worked completely after a pass with the cultivator, it is nevertheless covered with fine earth forming a mulch. Work with this "V" mounting is twice as fast as with tandem mounting but to the detriment of quality. Whether this would be a more attractive compromise than the more effective tandem mounting, only a long-term technical study over a whole season would tell.

- the optimum distance between hubs for double effect tandem mounting seems to be between 160 and 180 mm.

9.2.6 ANIMAL DRAFT USING THE MINIMUM CULTIVATION SEEDING EQUIPMENT

The 'deMooy' ridgeshaper minimum cultivation seeding equipment was examined in an MSc study by P. Montshiwa 1985-87. The findings from an agronomic and soils perspective are reported in the previous Annual report Anon 1987 Section 7. The equipment could be used in light sandy soil without yield disadvantage under low rainfall conditions but would face problems on hardvelt soils or under higher rainfall when weeds would also grow.

The planter was included to record its draught characteristics which are illustrated in figure 4.

9.2.7 THE MAHON CULTIVATOR

As the Mahon cultivator is very widely used in Botswana its draught characteristics were included. Much interest has been expressed to develop a ligher cultivator/weeder, that avoids the necessity to use an ox team for adequate draught. The results using the Mahon, are illustrated in figure 5.

Figure 4. OPERATIONAL CHARACTERISTICS OF THE DEMOOY RIDGER/PLANTER

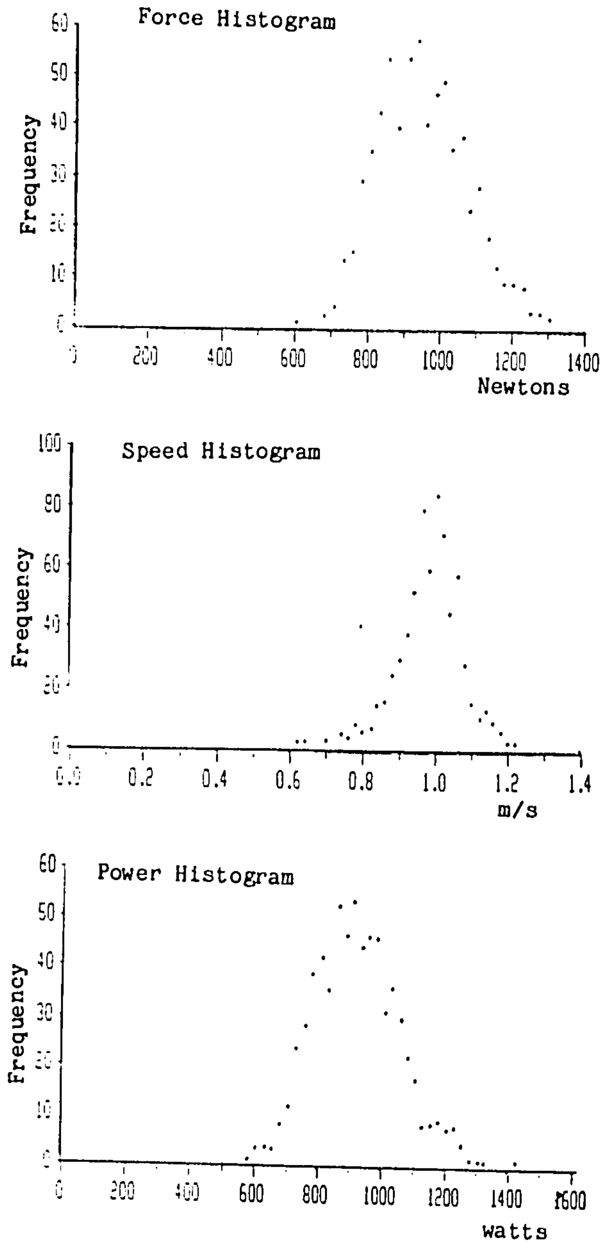
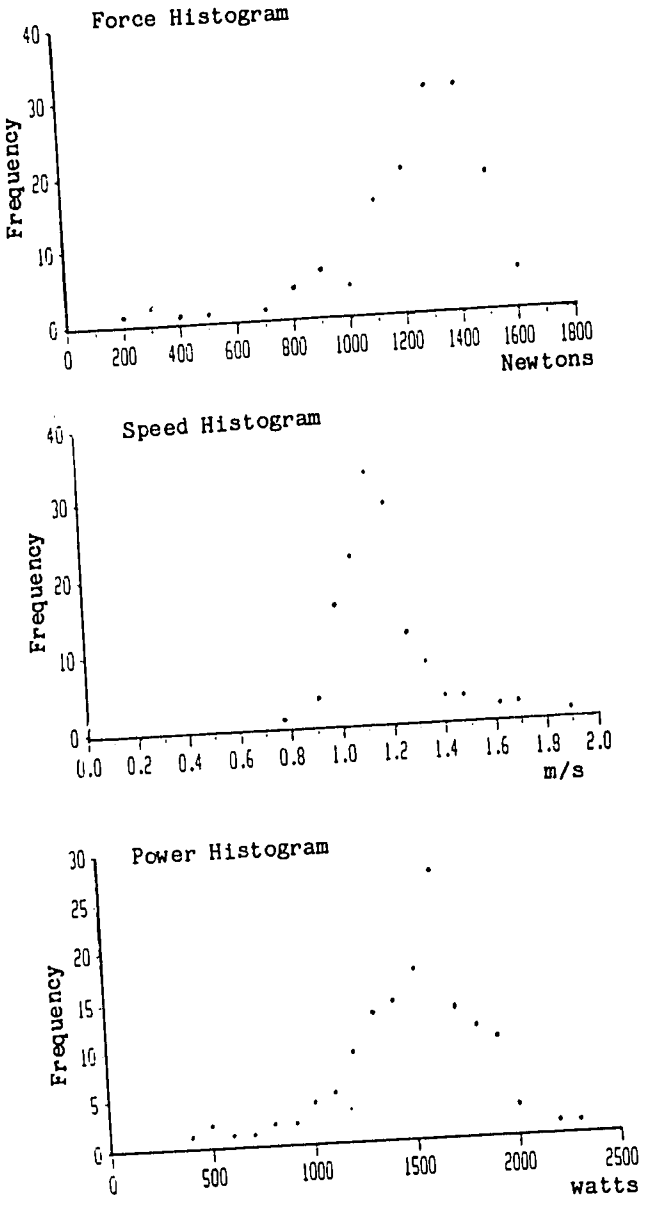


Figure 5. OPERATIONAL CHARACTERISTICS OF THE MAHON CULTIVATOR



9.3 Planter Comparison studied by Farm Machinary Development Unit

This season plot II was used to observe the new peanut hopper assembly for the Sebele standard planter report in 1985-86,. Although intended primarily for groundnuts, feed wheels for sorghum, cowpeas and maize also gave promising results. The planter was compared with the 'Master' rotary injection hand pulled (or pushed) planter and the Siscoma Super Eco planter used for plot 8 above.

Ploughing was on 11th November with a P23, producing very good work. Harrowing followed, two passes, on 21st November and the plot was planted on 16th December after a final pass with the harrows which produced a good, even, fairly fine seedbed. Two rows were planted using each machine for groundnuts, cowpeas, maize and sorghum. The remainder of the plot was filled in with the new planter and a 4 cup feed wheel. Table 2 shows the results of plant counts made from 29th December to 6th January, Table 5.

Table 5. COMPARISON OF THE SEED METERING OF 3 PLANTERS

	Cowpeas			Groundnuts		
Planter	Feed wheel or plate	Seed kg/ha	Plants per ha	Feed wheel or plate	Seed kg/ha	Plants per ha
Master	No 2(1)	26.9	36,850	No 2(2)	12.6	30,500
Siscoma	16 holes d.9.5 mm	31.3	46,850	16 holes d.9.5 mm	14.4	26,600
Sebele hopper	6 cups d.8 mm	21.6	63,450	6 cups d.10 mm	18.0	47,100
	Maize			Sorghum		
Master 300,000+	No 4(3)	45.0	69.750	No 1(5)	25.9	
Siscoma	16 holes d.9.5 mm(4)	14.4	14,350	16 holes d.6 mm	12.6	52,100
Sebele hopper	6 cups d.12 mm	26.9	45,500	4 cups d.6 mm	10.8	42,650

(1) 6 cells diam. 12 mm
(2) 6 cells diam. 14 mm
(3) 6 cells diam. 19 mm
(4) Cowpea plate used in error; the maize plate is 16 holes diam 14 mm.
(5) 6 cells diam 8 mm.

9.4 New Machinery

9.4.1 NEW CART ATTACHMENT OR THE 'NIKART' TOOLCARRIER

This work was described in last years report, the new top has been loaned to ATIP Mahalapye along with various other equipment as a contribution towards their pilot custom hire scheme for villagers.

9.4.2 TWO ROW PLANTER FRAME

A second, improved two row frame complete with a pair of unit planter fertilizers and a pole for donkeys have been built, also for the ATIP Mahalapye hire scheme, along with the original machine and two light weeders for donkeys, thus providing a very good opportunity to see how the implements behave in farmers fields.

9.4.3 LIGHT WEEDER FOR DONKEYS

Modifications agreed with ATIP last year have been completed; the angle of the rear bar is now adjsutable and a choice of (heaver) weeding blades provided. Nine such implements, including three Mark II Versions and two with ox poles have been built for testing.

9.4.4 HILLDROP ATTACHMENT

Fifteen sets were fabricated in the FMDU workshop, requested by FSSR Southern Region for evaluation in farmers fields.

9.4.5 FMDU/INTSORMIL CHISEL PLOUGH

An attempt to improve this implement, used in the tillage observation reported above, has been to replace the front blade with a revolving tiller made up of 8 sets of 4 cranked blades which create a better tilth than a single blade.

9.4.6 ANIMAL DRAWN TIE RIDGER

An oxdrawn single furrow tie ridger has been built, based on a design for a tractor mounted implement from NIAE, UK,. The machine will be tried out in the Systems Observation.

9.4.7 GENERAL

Improved double neck yokes now total 9, several of which have been loaned to projects for evaluation. Two single ox yokes on the bar and skey peg principle have also been made for testing. Two engine/pump base plates were designed and built for NADP Gomare.

9.4.5 MEASUREMENT OF SOIL SURFACE RUNOFF

The object of this work has been to try to find a practical method of measuring runoff as affected by four tillage systems being evaluated: Subsoil tine, use of the Dammer Diker implement, tied ridges and control; conventional ploughing, all treatments were machine row planted using oxen.
A measured area within each plot is used for run off determination, confined by a rectangle of metal strips set in the soil on edge, leading into a steel tank at ground level, slopes are about 0 to 1%. Full details of this

proceedure are given in the 1985/86 report (Anon 1987).

This year the measured run off area was increased from 10 to 20 m^2 and the number of tanks reduced to one per plot with two replicates. Rainfall for the season was such that only two rain days produced any runoff, making for a very limited comparison of treatments. However on both days, 20th December andd 27th February, most runoff came from the subsoiled plots, being on average about 19% of the rainfall. It would appear that the state of the surface at the time of rainfall is very important, the greater area of 'smooth compact' soil between tillage lines, coupled with the canalization effect of the rip line were responsible for the greater runoff from subsoiled plots. There was an improvement (decrease in run off to 8%) by the potholing effect of the Dammer Diker, but this remained high in comparison to the control (conventional mouldboard ploughing which resulted in only a 1% runoff).

The ridges again showed higher runoff than the control, 4%, and it is felt that the maintainance of 'ties' is of paramount importance, dispite posing a greater problem at weeding.

Had rainfall been greater then the trends illustrated above would have been more pronounced, as has been observed, but not recorded in previous years.

9.5 Implement development for permanent strip cultivation

9.5.1 INTRODUCTION

Rain-fed crop production in Botswana is ever threatened by deficient soil moisture conditions either as relatively short or prolonged dry spells. Crops failures are a common fact which discourages farmers from making substantial investment for improved management. Therefore land preparation is generally with a mouldboard plough which is widely accepted by local farmers though it enhances rapid deterioration of soil structures leading to hardening and crusting. These soils are quite difficult to handle with a mould-board plough prior to the rains. In such cases all agricultural operations are conducted following the onset of the rainy season. The rains arrive with the fields relatively bare. Crop residues are usually grazed during the winter. This situation when further compounded by the non-stable structures, enhances the soils tendency to develop surface seals which reduces infiltration and profile recharge.

Such condition deter the establishment of an adequate protective crop cover early in the season. As a consequence the traditonal system of farming is also inducive to excessive run-off and soil loss. The land scapes which prevail in farmers fields are generally quite uneven with many depression of various sizes. These uneven lanu surfaces create problems in achieving uniform crop stands and carrying out various agricultural operations. Under these or such conditions crop production and yields cannot be sustained. Soil and moisture conservation technics are very important if we are to encourage crop production with a view to feed our country. The technics should be planned to re-use crop residues for improving the structure of the soil. Our soils have or poor structural development, continous cultivation without addition of crop residues has a negative result.

Deep Ripping or Strip Cultivation and Bed and furrow system were developed as alternative cultivation system to conventional mould board ploughing. The management practices on these include the use of crop residues to improve soil structure and water holding capacity. Primary cultivation is with a subsoiler on strips and chisel plough on beds and furrow system.

Brief discription of each of the system -

Strip Cultivation

- is a special type of conservation tillage in which there is intensive soil preparation of a narrow strip approximately 60 cm wide and 50 - 60 cm deep where planting is carried. The interstrip is left untilled to encourage water to run into the strip. Thus the strip will get more moisture even after a small amount of rain. The strips can be laid 1.5 m apart or even more depending on individuals management.

Beds and furrow system

- is a system in which raised beds of about 90 - 100 cm are prepared with furrows on either side of the bed. These furrows are spaced 1.5 m from furrow centres. The furrows are used for discharging excess water in cases of heavy rainfall. Crops are planted on raised beds 75 cm between rows.

Improvements and Modifications

- The first attempt was to study management practices. Then implements were modified and improved to suit management practices.

9.5.2 DEVELOPMENT OF THE STRIP CULTIVATION SYSTEM

Proto-type subsoiler

- The subsoiler was made by Vaderstad in Sweden. It came with a krall manure applicator. The applicator was fitted with an auger system to apply kraal manure. The problem with the design was that the kraal manure hopper was shallow and the manure tended to bridge on either side of the auger. Insufficient quantity of kraal manure was delivered through the spout.

Improvement and Modifications

1- Stanhay fertilizer hoppers were adapted to fit the subsoiler. Two hoppers in this case were used, one for kraal manure and the other for lime application. Kraal manure is applied in a band in the top soil, (20 cm) while calcium carbonate grit is applied at 4 different levels through the depth of the strip, (approx 25-55cm below the surface).

2- Applicator Drive Wheels - The original wheels were cumbersome and failed to always remain in operation. As the wheels were fixed to the main fraim of the implement, when the subsoiler rose in hard ground they disengaged from the soil and the fertilizer mechanism ceases to function. In addition the design stopped the ripper to reach full operating depth. The wheels were removed and replaced with a light and small diameter wheel, spring loaded so that the drive is maintained even when the subsoiler rises in hard ground. The drive to the hoppers is on sprokets and chain. This allows for different rate of fertilizer to be applied simply by changing the sizes of the sprockets.

3- Combining Operations: combining operations reduces traffic over the field. Attachment were made on the subsoiler to fit a soil moulder and residue collector or gatherer. These were attached onto the subsoiler and trailed behind but would remain in suspension when the subsoiler is lifted out of the ground, see illustration, figure 6.

4- Soil Moulder - This is used to form surface undulation for micro-catchment of rain water.

5- Residue Collector - This is used for gathering crop residues between the strips and line them in the rip line. This operation partially burries the crop residues. The burried crop residues will decompose during the dry period. Those on the surface will also rot with time as well as providing a mulch on the strip.

6- Blade Harrow - This implement is used for interrow cultivation as well as for the seedbed preparation. The cutting blades of the implement are in two sections shapped to fit the shape of strips. The blades are secured to a tool frame by means of clamps to enable the blades to be adjusted wide or narrow depending on the height of the crop.

7- Crop residue chopper - It is a roller with cutting blade. The residue chopper is used before ripping to chop down any standing or fallen crop residues in short pieces, which would easily be managed or burried with a residue gatherer. The stalk chopper is made from a bore hole casing which is filled with concrete to give it some weight. This can easily be pulled with a small tractor. The tractor should be driven fast so that the

Illustration 5. THE MODIFIED VERDESTAD DEEP RIPPER

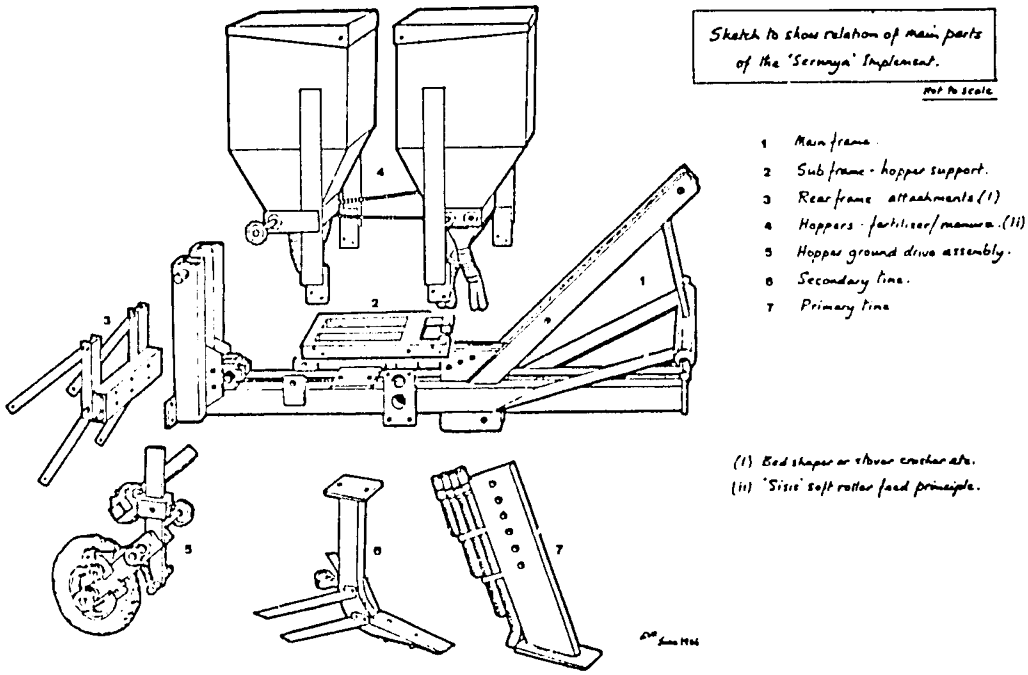
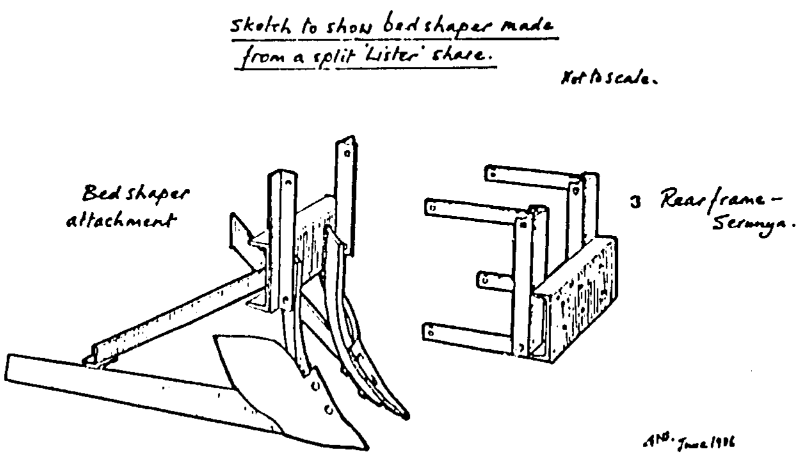


Illustration 6. THE BED FORMING 'FREE FLOATING' IMPLEMENT

Modified 'Serunya' Implement continued.



roller effectively cut the crop residues.

9.5.3 MANAGEMENT OF THE STRIP CULTIVATION SYSTEM

Deep Ripping/Strip Cultivation is done in winter after harvesting the crops. The advantage of ripping in winter is that the action of the ripper will shatter a bigger volume of soil (beyond the cultivation width of the subsoiler), unlike when the soil is wet, the loosening will be determined by the width of the tine of the cultivating implement.

OBJECTIVES

A trial was conducted to compare single autumn ripping and its modification with double ripping (Ripping in Winter and before planting) as methods of seedbed preparation.

Materials and Methods - A trial was carried out in Sebele using sorghum - Segaolane, Maize KEP, and Blackeye cowpeas. It was laid out as a split-plot design with four tillage treatments as main plots.

1. Single Autumn ripping - Rip in Winter (T1)
2. Double ripping - Rip in Winter and after rains before planting (T2)
3. Single Autumn rippping and discing - Discing at planting (T3)
4. Single Autumn ripping and moulding - Moulding at planting (T4)

Two planting treatments, dry (D) and wet (W) were included as subplots. All treatments were duplicated. The trial was planted in strips of 200 m length and 1.5 m wide. The variables observed were seedling establishment and yield.

Results and Discussion

Sorghum -

Seedling establishment

No significant difference was detected between the tillage treatments but the moisture regime at planting significantly affected seed establishment. The interaction approached significance at 10% (significant at 11.5%).

Yield -

Tillage treatments did not affect sorghum yields but wet planted plots yielded significantly higher than those dry planted.

Table 7. SORGHUM ESTABLISHMENT AND YIELDS

No. of Replication	Tillage Treatment	Planting	Popul. est/ha	Popul aft. Thinning	Yield Kg/ha	Yield g/plant
2	T1	D	8445	5835	532	49.1
2	T1	W	14085	8100	937	118.2
2	T2	D	9900	7530	601	79.8
2	T2	W	15885	9150	990	108.2
2	T3	D	8550	6690	575	86.0
2	T3	W	15780	8325	852	102.3
2	T4	D	6315	5310	468	88.1
2	T4	W	8835	6165	859	139.2

Table 7. ANALYSIS OF VARIANCE TABLES, SORGHUM

Table 7a. PLANT POPULATION ESTABLISHED

Source	D of F	Sum of squares	Mean square	F Value	Probability
Rep	1	20048006.25	20048006.250	2.72	.197
A	3	66948018.75	22316006.250	3.03	.193
Error	3	22129818.75	7376606.250		
B	1	114222656.25	114222656.250	108.01	.000
AB	3	12030468.75	4010156.250	3.79	.115
Error	4	4230225.00	1057556.250		

Coefficient of Variations 9.4%

Table 7b. YIELD

Source	D of F	Sum of Sources	Mean Square	Value	Prob
Rep	1	286920.91	286920.208	6.03	.079
A	3	36917.01	12305.672	0.29	
Error	3	125962.79	41987.598		
B	1	549080.94	549080.943	11.06	.029
AB	3	12570.03	4190.010	0.08	
Error	4	198558.82	49638.655		

Coefficient of Variations = 30.6%

Cowpea

Seedling establishment

1. No significant difference between the tillage treatments but there was significant between the wet and dry plantings at better than 1% level.

2. The interaction is approaching signficant at 10%.

Yield

Yield was not significanty effected bytillage treatment but there was a significant difference between the wet and dry plantings at better than 1% level. Interaction was significant at 5% level.

Table 8. COWPEAS ESTABLISHMENT AND YIELD

No. of Replication	Tillage Treatment	Planting	Popul Estab	Popul after Thinning	Yield kg/ha	Yield/ Plant (g)
2	T1	D	6330	5610	9.3	1.7
2	T1	W	7695	6330	247.2	39.1
2	T2	D	5760	5190	13.0	2.5
2	T2	W	7200	5760	158.2	27.5
2	T3	D	7290	5985	32.2	5.4
2	T3	W	9465	7290	187.0	25.6
2	T4	D	9030	7560	5.2	0.7
2	T4	W	9240	8040	242.3	30.0

Table 9 ANALYSIS OF VARIANCE TABLES, COWPEAS

Table 9a. ESTABLISHMENT

Source	D of F	Sum of Squares	Mean Square	F Value	Prob
Rep	1	756900.00	756900.000	0.13	
A	3	17875125.00	5958375.000	1.02	.492
Error	3	17462250.00	5020750.000		
B	1	6734025.00	6734025.000	41.14	.003
AB	3	1977525.00	659175.000	4.03	.105
Error	4	654750.00	163687.500		

Coefficient of Variation 5.2%

Table 9b. YIELD

Source	D of F	Sum of Squares	Mean Square	Value	Prob
Red	1	7406.32	7408.324	12.41	.038
A	3	4413.96	1471.321	2.47	.230
Error	3	1790.09	596.698		
B	1	150129.13	150129.128	281.81	.000
AB	3	7709.02	2569.672	3.11	.050
Error		3303.95	825.737		

Coefficient of Variations 25.70%

Maize

Seedling establishment

There was significant difference between the tillage treatment at the 10% level. Again there was a strong significant effect between wet and dry planting conditions.

Yield -

It wasn't possible to analyse the results, because the late planted maize did not yield anything.

Table 10. MAIZE ESTABLISHMENT AND YIELDS

Tillage Treat	Planting	Population Establ/ha	Population after Thinning	Yield kg/ha	Yield g/plant
T1	W	6615	5925		
T1	D	8190	6615	137.4	20.8
T2	W	9840	6775		
T2	D	13500	9840	189.7	19.3
T3	W	12465	9555		
T3	D	16215	12465	106.5	8.5
T4	W	10260	8940		
T4	D	12885	10785	120.7	11.2

Table 11. ANALYSIS OF VARIANCE TABLE FOR MAIZE ESTABLISHMENT

Source	D of F	Sum of Squares	Mean Square	F Value	Prob
Rep	1	1768900.00	1768900.000	0.35	
A	3	98097825.00	32699275.000	6.40	.080
Error	3	15319350.00	5106450.000		
B	1	36300625.00	36300625.000	100.06	.002
AB	3	3032325.00	1010775.000	2.79	.211
Error	3	1088350.00	362783.333		

Coefficient of Variation = 5.38%

COWPEA VARIETIES

A crop of two varieties of short season cowpeas was planted on 3rd March 1987 in the strips where maize had failed. A blade harrow was used to prepare the seed bed. The cowpeas were grown on total of 54.2 mm rainfall. Two short season varieties were used, ER7, IT 82D881, light showers were concentrated in the first 23 days from day of planting. No rain at flowering until harvesting. Heavy infestation of aphids and hopper nymphs reduced the yield.

Table 12 COWPEAS ESTABLISHMENT AND YIELDS

Tillage treatment	Variety	Popul. establ.	Yield kg/ha
T1	ER7	21450	65.9
T2	"	23625	89.45
T3	"	23835	109.5
T4	"	23595	85.5
T1	IT82D881	16125	54.8
T2	"	16395	51.45
T3	"	18957	104.4
T4	"	15795	58.95

Table 13 COWPEA ESTABLISHMENT

Table 13a ANALASIS OF VARIANCE

	Degrees of Freedom	Sum of squares	Mean square	F Value	Prob
Rep	1	26001.56	26001.56	0.02	
A	3	14010342.19	4670114.062	2.74	.214
Error	3	5104279.69	1701426.563		
B	1	159232851.56	15923285.562	20.62	.010
AB	3	6074479.69	2024826.563	0.25	
Error	4	30893231.25	7723307.813		

Coefficient of Variation = 13.92%

Table 13b. ANALYSIS OF COWPEA YIELD

Source	Degrees of Freedom	Sum of squares	Mean square	F Value	Prob
Red	1	4241.27	4241.266	21.42	.019
A	3	4952.39	1650.795	8.34	.057
Error	3	594.14	198.046		
B	1	1630.14	1630.14	5.78	.074
AB	3	667.98	222.661	0.79	
Error	4	1128.65	282.164		

Coefficient of variation = 13.92%

9.5.4 OBSERVATIONS MADE DURING EQUIPMENT DEVELOPMENT

(1) Season 1

(a) Collapsing of soil in the strips when rainfall exceeded 20 mm.

(b) Weeds were establishing everywhere (in the rip lines and between strips).

(c) Clods - very difficult to break mechanically with light implements. These had to be wetted by rain water before the seedbeds can be prepared.

(2) Season 2

(a) The collapsing of soil in strips was reduced.

(b) Weeds established more thickly in the strips than between strips.

(c) Clods partially broken with a light disc. (in the dry state).

(3) Season 3

(a) The collaps of soil in strips had stopped. This may have been due to kraal manure and crop residues added in Season 1 & 2. It was assumed that the addition of kraal manure and crop residues had benefitted the soil and stabilized its structure.

(b) Weeds established mostly in strip and very few managed to establish in the interstrip zone. It is hoped that with further compaction of soil between the strips, the weeds establishment will further be reduced.

(c) Clods in their dry state were easily broken with a light disc, soil moulder, residue collector or disc opner of a planter.

9.5.5 CONCLUSIONS

(1) The seedbed preparation methods used, single autumn ripping (T1); double ripping (T2); single autumn ripping + discing at planting (T3); single autumn ripping and soil moulding + remoulding at planting (T4), did not influence seedling establishment of maize sorghum and cowpeas.

(2) Yields were not different except for dry planted crops. (yield were lower with dry planting than wet planting). The major difference has been due to date of planting. Dry Planting was delayed because of wet weather conditions. It was only possible to dry plant in early December.

(3) Deep Ripping System uses $^1/_3$ of fuel that is required for mouldboard ploughing, 6 and 18 litres of diesel/ha respectively, a big saving for the farmer.

(4) Land can be prepared (i.e. subsoiled) during the dry period, remained in a condition ready to receive the first rains and does not slump when the system has been implemented after three seasons.

Section 10. ENTOMOLOGY

SUMMARY

Aphids are among the important pests of sorghum in Botswana. Field populations fluctuate from low levels to high densities in different seasons. Factors responsible for these population fluctuations are not well understood. An experiment to evaluate the role of natural enemies on field populations of sorghum aphids Schizaphis graminum (Rondani) and Melaphis sacchari (Zehntner) was carried out at the Goodhope Research Station. S. graminum population increased on caged plants but was suppressed on plants with unlimited access to natural enemies. Xanthogramma aegyptium (Weird) (Piptera: Syrphidae) and Leucopus sp (Diptera: Chamaemyiidae) were the most important predators of sorghum aphids. M . sacchari population increased despite the activity of these natural enemies.

A Sorghum germplasm screened for seedling resistance to the sugarcane aphid, Melanaphis sacchari (Zehntner) revealed that resistance is readily available. Sorghum lines with resistance to M . sacchari will be used to develop aphid resistant cultivars.

10.1 SUPPRESSION OF SORGHUM APHIDS BY NATURAL ENEMIES

Three species of aphids, Melanaphis sacchari (Zehntner) (MS), Rhopalosiphum maidis F. (RM) and Schizaphis graminum (Rondani) (SG) are associated with sorghum in most of the SADCC countries. Only M. sacchari is considered economically important in Botswana. R. maidis often builds large populations in the plant whorl and may interfere with normal development and pollination. Low populations of S. graminum are always found on sorghum plants throughout the growing season in many sorghum growing areas. The incidence of S. graminum on plants under field conditions is very high but population buildup has not been observed in the field. In many parts of the world S. graminum is a key pest of sorghum (Young and Teetes 1977). The work reported here was undertaken to determine the factors, especially natural enemies, responsible for the suppression of S. graminum populations on sorghum under field conditions in Botswana.

10.1.1 METHODS AND MATERIALS

A field study of sorghum aphids and their natural enemies was carried out at the Goodhope Research Station. A local sorghum cultivar, Segaolane, in the boot stage, was sampled on the 19th March 1987 and fortnightly thereafter. All aphid species, and natural enemies were visually counted on 100 plants selected randomly from a one hacter field. Sixteen field cages were used to enclose single plants from which all but 10 S. graminum aphids were removed. Eight of the cages had two large holes on the sides to allow free access by natural enemies into the cages. Every 2 weeks, the cages were removed and aphid and natural enemy counts were taken again. Counts were also made on 100 randomly selected plants from the same field.

10.1.2 RESULTS AND DISCUSSION

Schizaphis graminum (SG) was the only aphid recorded on sorghum during the first sampling date March 19, 1987. Low populations of M.

sacchari and R. maidis were found on plants during subsequent sampling dates. Table 1 shows counts of aphids and natural enemies made every two weeks. All development stages of natural enemies were found on sorghum and the most important were Xanthogramma aegyptium (Weid) (Diptera:Syrphidae) and Leucopus sp (Diptera: Chamaemyiidae). Other species recorded were various lady beetles and lace wings. X. aegyptium was closely associated with S. graminum and it was common to find X. aegyptium egg/s oviposited among small colonies of SG. Leucopus larvae were also found on S. graminum colonies but became numerous as M. sacchari population increased on sorghum.

Table 1. POPULATIONS OF APHIDS AND THEIR NATURAL ENEMIES ON CAGED AND UNCAGED PLANTS UNDER FIELD CONDITIONS

Sampling date	Aphid counts M. sacchari			S. gramimum 3/.			x. aegyptimum			Leucopis sp.			Others		
19/3	0F	0F	0F	38F	100	10C	6F	-0	-C	7F	-0	-C	7F	-0	-C
02/4	8	8	0	24	143	145	18	0	1	12	0	0	44	15	2
15/4	30	0	0	20	58	177	1	0	0	10	0	0	10	8	1
23/4	41	0	0	7	23	940	0	0	3	12	1	0	6	1	2

1. Counts of larval and egg stages of natural enemies of aphids on sorghum. F = field counts; 0 = opened cage counts; C = closed cage counts.

2. Species of natural enemies of aphids on sorghum; x = Xanthogramma aegyptium L = Leucopis sp. 0 = Other species = lady beetles, Synmnus sp, Chrysop sp.

3. All aphids were removed from field cages except for 10 aphids of mixed stages of S . graminum .

Field populations of S. graminum remained stable on sorghum up to six weeks following initial sampling whereas they increased inside caged plants. S. graminum multiplied from 10 to 940 aphids per plant inside closed cages whereas 143 aphids was the highest population reached inside open cages. Population of M. sacchari increased late into the season as sorghum matured.

The number of natural enemies, especially Leucopus sp., lady beetles, Scymnus sp. and lace wings, increased as the population of M. sacchari increased. A decline in populations of S. graminum and M. sacchari was observed late in the season in the field and inside open cages, whereas no such decline was taking place inside closed cages.

Alates of S. graminum and R. maidis appear on sorghum early in the season to establish field populations. The most important natural enemy early in the season is X. aegyptium and it attacks both S. graminum and RM, however, only S. graminum population is suppressed. R. maidis populations buildup within the whorls where they remain until head-excertion. Although M. sacchari appear on sorghum throughout the season populations tend to increase during the grain filling stage. According to Van Rensburg (1973), M. sacchari population regulation is brought about by joint action of plant condition, aphid dispersal and the action of natural enemies.

10.1.3 CONCLUSIONS

Of the three species of sorghum aphids only *S. graminum* appeared to be under biological control and the most important agent was *X. aegyptium* . A further study of sorghum aphids and their natural enemies is planned.

10.2 Sorghum germplasm screening for resistance to the sugarcane aphid

10.2.1 INTRODUCTION

Three species of aphids, *Melanaphis sacchari* or sugarcane aphid; *Rhopalosiphum maidis* or maize leaf aphid; and *Schizaphis graminum* or greenbug, attack sorghum in most SADCC countries. In Botswana, *M. sacchari* is economically important while *R. maidis* occassionally builds up large populations which may cause poor head exsertion and poor pollination. *S. graminum* does not buildup populations and is believed to be under biological control. Insecticide are often used to control *M. sacchari* but because of poor timing and low yield levels, they are considered uneconomical. A program was initiated sometime back to find sources of sorghum resistance to *M. sacchari* . Preliminary studies indicated that resistance was available (Manthe et al 1984). As part of the sorghum improvement program in Botswana, resistance to the sugarcane aphid is considered an important component. The objectives of the sorghum resistance to the sugarcane aphid are as follows:

- to screen sorghum lines for sources of resistance
- to examine mechanism of resistance
- to determine the inheritance of aphid resistance

This paper reports on the progress achieved with screening and results of other objectives will be forthcoming.

10.2.2 METHODS AND MATERIALS

Resistance was determined in the seedling stage under greenhouse conditions. Sorghum lines were planted in rectangular plastic pots in a soil mixture containing field soil, sand and compost in a 3:1:1 ratio. A small amount of compound fertilizer was mixed with the growth media at planting time. When the seedlings were about 3 days old, they were artificially infested with *M. sacchari* aphids of mixed developmental stages. To infest the plants, aphids were brushed onto the soil surface and allowed to establish on the seedlings. A resistant check, TAM 428, and a susceptible check, Segaolane, were included with each trial of 100-150 entries. When the susceptible check showed evidence of aphid damage, other lines were evaluated. Normally, damage symptoms appeared within seven days after infestation and evaluations were carried out until entries were heavily infested with aphids and susceptible check was killed by aphids. Resistance determination was based on a visual ranking of damage levels in comparison with the susceptible check and the resistant check. The following damage rating scheme was used:

1.0 = 0 - 10% leaf kill
2.0 = 11 - 25% leaf kill
3.0 = 26 - 40% leaf kill
4.0 = 41 - 60% leaf kill
5.0 = 61 - 100% leaf kill and dead plant

In the screening phase, 20 seeds of each entry were planted in rows and thinned to 10 seedlings after germination. Only 2 replications of each entry are planted. The entries selected during the screening phase are tested for resistance in replicated experiments. Only results of the screening phase are reported here.

10.2.3 RESULTS AND DISCUSSIONS

Table 2 shows sources and numbers of sorghum lines available for screening. Botswana materials involved breeding lines and local cultivars. The entire Botswana sorghum collections will be screened as soon as it is received from ICRISAT/India.

A number of lines have been selected for further evaluation as sources of resistance to the sugarcane aphid (table 3). Particularly interesting are entries of the Zera Zera group in that they exhibit high levels of resistance to the sugarcane aphid. TAM428, which is a resistant check, causes mortality to aphids feeding on it. This resistance has been varified in mature plants growing in the field. Sorghum lines received from South Africa were selected in the basis of known performance against aphids. According to Teetes (personal communication) some of the SA aphid resistant lines were developed from TAM428.

It was observed that certain lines showing resistance to the sugarcane aphid were susceptible to the greenbug under greenhouse conditions. Since both aphid infest sorghum in the field, it will be necessary to select only lines with resistance to both aphids for use in breeding programs.

Table 2. SORGHUM LINES AVAILABLE FOR SUGARCANE APHID RESISTANCE SCREENING

Source	Number of entries
USA	736
ICRISAT/Bulawayo	1,125
South Africa	7
Botswana	67 1/

1/ Includes locally collected lines, adapted cultivars and commercial hybrids of South Africa origin.

Table 3. SORGHUM LINES SELECTED FOR FURTHER EVALUATION FOR RESISTANCE TO THE SUGARCANE APHID

Entry Number	IS Number	SC Number	Sorghum group	Resistance 1/ designation
5	12558C	38	DUR	MR
6	12566C	51	CAUKAU	MR
9	12611C	91	PARA	MR
10	12611C	111	ZZ	R
11	2416C	101	SUMAL	MR
13	2553C	121	CAU	MR
16	12637C	146	CANUIG	MR
17	12661C	170	ZZ	R
21	1366C	210	DUR	MR
27	5188C	245	ROX	R
39	6962C	352	CAU	R
44	1144C	451	DUR	R
52	6426C	497	NAND	MR
59	7864C	541	CONSP	MR
63	7333C	553	MEMB	MR
145	-	464	DUR	MR
183	1215C	984	ZZ	R
242	1598C	214	DOC	R
282	12609C	109	ZZ	R
283	12610C	110	ZZ	R
286	12645C	154	DURBIC	R
288	12664C	173	ZZ	R
291	12677C	186	CAUDIR	R
300	1133C	202	DUR	R
301	1134C	203	DUR	R
302	1139C	205	DUR	R
340	5887C	248	ROX	R
343	6389C	489	NAND	R
428	TAM428	-	ZZ	R
738	SA1469	-	-	R2/
739	SA1470	-	-	R
740	SA1471	-	-	R
748	Marupantse	-	-	R3/
752	PNR8537	-	-	R
760	233	-	-	R
764	237	-	-	R
773	246	-	-	R

1. Resistance evaluation based on damage to seedlings and aphid ability to multiply. Damage to seedlings was rated visually and scored as follows: 1.0 = 0 - 10% leaf kill; 2.0 = 11 - 25% leaf kill; 3.0 = 26 - 40% leaf kill; 5.0 = 61 - 100% dead plant. Damage was determined 14 to 21 days after artificial infestation of seedlings with aphids and was based on two replications. TAM423 = resistant standard Segaolane = susceptible check.

2. Sorghum lines with SA numbers are entries from South Africa.

3. Botswana cultivar.

SUMMARY

Population dynamics of the root-knot nematodes (Meloidogyne SPP.) was studied on different crop varieties under field conditions. Jugo beans (local variety), and two cowpea varieties (Blackeye and ER7) were found to support high popultions of root-knot nematodes while sorghum (VAR. Segaolane), sunflower (VAR. Russian No. 4) and cowpea (VAR. Tswana) supported reproduction to a lesser extent. Populations of the root-knot nematodes declined on millet (VAR. Serere 6A), tepary beans (Local variety), groundnut (VAR. Sellie) and maize (VAR. Kalahari Early Pearl). Other nematode genera (Tylenchorhynchus, Rotylenchulus, Pratylenchus and Criconemoides) were also found associated with various crops tested.

In another study, several local and introduced cowpea varieties were tested for resistance to cowpea aphid-borne mosaic virus in the field under supplemental irrigation. Four sources (Blackeye, TVu 410, UCR 237 and B027) were identified.

11.1 Population Studies of Root-knot Nematodes Under Various Crops.

INTRODUCTION

The problem caused by root-knot nematodes (Meloidogyne spp.) in Botswana has long been established (FAO, 1972, Anon 1981). Field surveys have indicated that root-knot nematodes have a wide host range and damage on field crops such as cowpeas and sunflower has been observed (Anon 1982, De Mooy, personal communication). The fact that root-knot nematodes attack even weeds poses a potential problem in designing suitable crop rotation systems for their control. Information on survival of the root-knot nematodes under field conditions is lacking and it is therefore essential to establish which crops might be good in maintaining or reducing the root-knot nematode populations. Such information combined with appropriate agronomic practices will be useful in designing crop rotation systems which would be useful for nematode control.

The present study was aimed at monitoring populations of root-knot nematodes under different crops throughout the growing season.

Materials and Methods

A site with a known history of root-knot nematodes infestation was chosen at the Goodhope Experimental Station, thus artificial inoculations were not necessary.

Ten different crop varieties were tested. These were Jugo beans (local variety), millet (Serere 6A), tepary beans (local variety), sorghum (Segaolane), sunflower (Russian No. 4), groundnuts (Sellie) maize (Kalahari Early Pearl) and three cowpea varieties (ER 7, Tswana, Blackeye).

The varieties were planted in 10-metre 4-row plots (75 m spacing between rows and 20 cm spacing between plants). Each treatment was replicated twice and the treatments were completely randomised within each replicate.

The trial was managed conventionally and soil samples were collected 60, 100 and 140 days after planting. At sampling composite soil samples (10 cores each 2.5 cm in diameter and 30 cm deep) were collected from the middle two rows in each plot and 500 cm^3 of the soil was processed for determination of nematodes. The number of nematodes per soil sample was determined by the combined sieving-floatation centrifugation method (Zuckermann, et al). The root fragments recovered during sieving were placed on Baermann funnels for four days. Nematodes recovered from soil and roots were counted using a stereomicroscope and counts from both portions were combined to determine the total number of nematodes per 500 cm^3 of soil from each plot.

At the end of season the plants were examined for galls and the severity of galling measured.

Results and Discussion

The trial got well established and root-knot nematodes were found to be present in all plots at the initial sampling. Although the trial had been specifically designed to study population dynamics of the root-knot nematodes, other genera were found to be present in the soil. These included the stunt nematode (*Tylenchorhynchus* sp), reniform nematode (*Rotylenchulus* sp), Lesion (*Pratylenchus* sp) and ring nematode (*Criconemoides* sp). Table 1 shows only those nematodes that appeared to be in large numbers.

The nematode host status of any crop can be based on that crop's ability to support reproduction of the nematode. Accordingly all good hosts will have a final population being greater than the initial population.

Root-knot nematodes continued to increase throughout the season on Tswana and Jugo beans with the latter having a higher reproduction index (Table 1). On Segaolane, Russian No. 4, ER 7 and Blackeye the population at the second sampling was higher than that at third sampling and this could be due to crops being past physiological maturity such that there were limited feeding sites for nematodes on the senescing roots. Tepary beans, Groundnut CV.Sellie, maize and millet can be placed in this group. Millet was the only crop where the populations declined to zero level implying that it might be a non-host, however, this is only a preliminary study and the host status has to be confirmed further.

TABLE 1. POPULATIONS AND REPRODUCTION OF DIFFERENT PLANT PARASITIC NEMATODES ON DIFFERENT CROPS

	Root-Knot					Stunt					Reniform				
TREATMENT	P1	P2	P3	P2/P1	P3/P1	P1	P2	P3	P2/P1	P3/P1	P1	P2	P3	P2/P1	P3/P1
Jugo beans	435	2825	4065	6.50	9.34	80	85	125	1.06	1.56	68	100	70	1.47	1.39
Millet	639	0	0	-	-	103	810	770	7.86	7.47	103	1769	790	17.17	7.71
Tepary	3605	1170	865	0.32	0.24	45	300	195	6.67	4.33	50	200	305	4.00	1.52
Segaolane	60	135	125	2.25	2.08	137	199	255	1.45	1.86	80	442	540	5.52	6.75
Russian No. 4	441	955	830	2.16	1.88	25	80	415	3.20	16.60	36	35	535	0.97	15.41
Tswana	350	422	620	1.21	1.77	406	180	165	2.25	0.41	75	75	95	1.00	1.46
ER 7	240	5661	1230	23.59	5.13	63	325	20	5.16	0.31	20	20	60	1.00	0.42
Blackeye	220	6057	1990	27.53	9.04	110	470	135	4.27	1.22	45	59	75	1.31	1.67
Sellie	55	50	35	0.90	0.63	69	70	30	1.01	0.43	20	165	20	8.25	1.00
Maize	50	19	5	0.38	0.70	300	2680	3190	8.93	10.63	140	1825	1410	13.03	10.07

P1 = Population per 500 cm^3 soil at 1st sampling (60 days)
P2 = Population per 500 cm^3 soil at 2nd sampling (100 days)
P3 = Population per 500 cm^3 soil at 3rd sampling (140 days)

The susceptibility of the plants to damage by the root-knot was assessed by the incidence and severity of galling on the plants (Table 2). It can be assumed that plants that show no galling probably would not suffer any pathological effects from root-knot nematodes but they might still be effective in maintaining the nematode population at low levels thus posing a threat to any subsequent susceptible crops. Concerning the crops that exhibited galling, pathological studies under controlled conditions need to be done in order to assess economic thresholds.

TABLE 2. INCIDENCE OF GALLED PLANTS AND GALLING INDEX ON VARIOUS CROPS

Treatment	Percentage of plants with galls	Severity of galling *
Jugo beans	60	1.4
Millet	0	0
Tepary beans	39	1.0
Segaolane	0	0
Russian No. 4	46	0.7
Tswana	76	2.1
Sellie	0	0
ER 7	100	3.1
Maize	0	0
Blackeye	94	2.7

* Galling index - 0 = no galls on roots
1 = occasional galls of r ,s
2 = few galls, less than 25% of roots affected.
3 = moderate galling, 25-49% of roots affected.
4 = severe galling >50% roots affected.

CONCLUSIONS

From the foregoing study it can be concluded that crops like maize, millet and groundnuts might be useful in rotation systems where root-knot nematodes are a problem. These findings need to be confirmed by further studies under controlled conditions. The fact that other nematodes like the stunt and reniform were also present in large numbers in some crops (Table 1) poses another potential problem. Further work especially regarding surveys of plant parasitic nematode in field crops needs to be carried out.

11.2 Cowpea Aphid-borne Mosaic Virus

INTRODUCTION

Cowpea aphid-borne mosaic virus is a major disease of cowpeas in Botswana. The disease is a problem particularly at Sebele probably due to intensive cowpea production. Previous studies (Molefe 1983, deMooy 1985) showed the virus to be seed-borne, sap transmissible and also transmitted in a non-persistent manner by the groundnut aphid, *Aphis crassivora*. Disease spread is favoured by high humidity and, may therefore reach epiphytotic levels in wet years and under irrigation.

Most local cowpea varieties are susceptible to the virus but some sources of resistance have been identified (deMooy, 1985). The present study is a continued effort to identify further sources of resistance and confirm the known ones.

Materials And Methods

Fifty-one local and exotic Cowpea varieties were planted in 10-metre single rows (rows were 75 cm apart and plant spacing was 20 cm within the row). The trial was planted as a randomised block with two replicates at three locations (Sebele, Goodhope and Mahalapye). The trial at Sebele received supplemental irrigation while those at Goodhope and Mahalapye were dryland. All the plots were fertilized with single superphosphate at a rate of 250 kg/hectare.

Three plants (at the primary leaf stage) in each row were inoculated with virus infected sap mixed with a little celite. The plants were tagged in order to be evaluated separately for virus symptoms two weeks after inoculation. The rest of the plants (uninoculated) were examined for virus symptoms at the first trifoliate to determine any seedborne infection. The incidence of the virus symptoms was also recorded in each row four weeks after inoculation.

Results And Discussion

The trial at Mahalapye failed due to severe drought. At Goodhope there was good stand establishment but the plants later got moisture stressed. The incidence of virus symptoms at Goodhope was very low and the cowpeas were severely affected by root-knot nematodes (*Meloidogyne* SPP) and witchweed (*Alectra vogelii*). At Sebele, the plants grew well and virus symptoms were observed. Although very few aphids were seen at the site of the trial, virus spread was evident six weeks after planting (Table 3).

Table 3. DISEASE INCIDENCE ON COWPEA LINES AT SEBELE

ENTRY	% EARLY INFECTION a	Inoc Plants with symptoms b	Incidence (%) of virus a
UCR 237	0	0	0
TVu 410	0	0	0
BO 27	0	1	0
Blackeye	0	1	0
Vita 9	0	0	1
TVu 1000	0	0	3
TVu 645	0	0	3
B 111A	0	3	3.5
UCR 236	0	0	4.5
TVx 1999-01F	0	2	4.5
TVu 2755	0	3	4.5
UCD 84-857	5.34	0	5.5
IT 82D 881	0	3	6.0
IT 82D 885	0	0	6.5
IT 81D 1137	0	2	6.5
TVu 408	0	0	6.5
IT 82D 889	0	2	6.5
8055	0	1	7.0
7964	0	2	7.5
Magnolia Blackeye	0	3	7.5
BO97	2.47	0	8.0
TVu 1185	4.26	0	10.0
IT 709	6.25	3	10.5
IT 880	0	1	11.0
UCR 264	0	4	12.5
B 163	0	2	14
B163	0	2	14
IT 82E-70	0	0	14
B 127	0	5	15.5
IT 82D 785	0	4	16
UCR 207	2.23	0	16
Mississippi white	3.53	1	16.5
IT 82E-60	1.52	0	19.0
BO 16A	0	5	19.5
UCR 193	0	0	20.5
PI 293505	4.06	1	21.5
TVu 801	0	6	21.5
B 171	0	1	21.5
IT 82D 640	6.25	1	22.5
TVu 652	0	2	23.5
TVx 3236-01G	3.03	3	26.5
UCR 194	0	3	27.0
IT 82D 755	0	2	28.0
BO 55	0	4	30.5
TVu 347	0	3	31.5
BO 57	5.75	3	32
TVx 3236	3.34	2	35.5
B 232	5.41	6	35.5
IT 82D 641	16.0	1	35.5
ER 7	3.03	4	37.5
PI 471521	1.41	2	50.0
B201	9.84	3	51.5

a = average of 2 replications
b = actual number of plants infected out of the 6 inoculated

The most common symptoms in the plants were the common mosaic (light green patches on dark green background and some vein banding), but some plots had yellow mosaic with severe leaf distortion while others had verinal necrosis. When sap from leaves of plants with different types of symptoms was tested on Tswana, ER7 and Blackeye, there were no differences in symptoms within any one variety, a strong indication for varietal differences in symptom expression.

The innoculated plants did not always show virus symptoms even in highly susceptible varieties. Therefore it is doubtful if the inoculation method alone can be reliably used to assess resistance to the virus. For example IT 82E-60 and UCR 193 did not show any symptoms when inoculated but had high virus incidence at time of assessment.

Early infection (possibly seed-borne) was observed in several varieties tested (Table 3). In all the varieties, with one exception (IT 82D 641), the incidence of early infection was less than 10%. It was later learnt that the varieties used in the study were not from virus free sources (Dr. de Mooy, personal communication). Except for UCD 84-857, all the varieties that had early infection showed an increase in cincidence of virus infected plants later in the season.

There were no virus symptoms observed in the varieties: TVu 410, UCR 237, B027 and Blackeye (except for one inoculated plant in each ofthe latter two varieties) so these could be good sources of resistance. Several varieties showed high levels of resistance (less tan 10% of plants infected) but most of the varieties were susceptible (Table 3).

Although previously reported as resistant to cowpea aphid-borne mosaic virus (deMooy 1985, 1986), P1 471521, IT 82D 885, and IT 82D 889 were found to be very susceptible to the virus in the present study. There are up to three strains of the virus (Molefe 1983, deMooy, 1985), and thus different strains might be involved in the different studies. This is especially true since the strains cannot be easily differentiated using field symptoms. All the above sources of resistance need to be evaluated under controlled conditions to get more meaningful results. It is only after the three strains have been evaluated separately that the results can be viewed with certainty. In the present study there were three possible sources of the virus:- the inoculated plants, seedborne (early infection) virus and an external source from the aphids. The possibility of more than one strain being involved can therefore not be ruled out.

CONCLUSIONS

Four possible sources of resistance to CAMV have been identified in the study. These are TVu 410, UCR 237, B027 and Blackeye. These however need to be tested using all the known strains of the virus.

The inoculation method cannot alone be used to determine resistance since susceptible varieties often failed to show symptoms when inoculated.

Section 12. WEED RESEARCH

SUMMARY

Work continued on the development of control measures for the perennial grass Cynodon dactylon, the cereal witchweed Striga asiatica, the legume parasite Alectra vogelii and annual weeds of field crops in Southern Region, in particular Datura ferox.

Two passes with a mouldboard plough, one on an early rain and the second at planting provides an effective method of reducing C. dactylon regrowth in the season of implementation and during the subsequent season. Where infested land had been double ploughed for two consecutive seasons, almost complete control was maintained for a following residual season.

The 'SAR' - Striga asiatica resistant - lines of sorghum, provide a source of resistance to the parasite. Nine accessions including four SAR and four local lines were selected for future trials.

One greenhouse pot trial was used to evaluate the susceptibility of six S. hermonthica tolerant maize lines from West Africa to S. asiatica. Low levels of parasite emergence were recorded on two lines and the local variety Khalahari Early Pearl.

A field trial confirmed the resistance of the local cowpea accession B359 to A. vogelii. A further 156 local accessions and 311 introduced lines were screened.

A range of arable and fodder crop species were evaluated as hosts and stimulant producing false hosts of A. vogelii and S. asiatica. The fodders Dolichos Lalab abd Siratro (Alectra hosts), fodder sorghums and Columbus grass (Striga hosts) could cause a build up of infestation levels to the detriment of following cowpea and sorghum crops respectively. Pearl Millet is resistant to S. asiatica. but stimulates suicidal germination of A. vogelii. Other species including Proso (Panicum miliaceum), Rhodes Grass (Chloris guyana) and cowpea are potentially useful false hosts of S. asiatica.

Field studies confirmed that a mixture of terbuthylazine with metolachlor (1284.5 and 387.5 g/ha) was the most appropriate chemical for D. ferox control in sorghum.

A custom built tractor mounted cultivator bar sprayer proved an appropriate method of obtaining timely weed control with reduced herbicide costs. Excellent control of D. ferox was obtained.

Field trials investigated herbicides for use in maize and groundnuts and applicatiion techniques including knapsack sprayers and the Berki spinning disc sprayer. Hand weeding proved the most reliable method of weed control in sunflower. The effect of the post emergence application of various herbicides on Pearl Millet was assessed in a greenhouse trial.

12.1 Cultural control of Cynodon dactylon

BACKGROUND

The rhizomatous perennial grass Cynodon dactylon (L.) Pers infests lands areas in many parts of Botswana. The species is reported as a particular problem in areas of Southern region (Bacon and Marsh, 1987), while in a survey of arable farming problems in Kgatleng, 49% of farmers reported their fields to be infested (Opschoor, 1981). The weed was reported to result in portions of fields remaining unploughed and in severe cases led to fields being abandoned.

The traditional practice of broadcast planting on a single shallow mouldboard ploughing, merely fragments the Cynodon stolon/rhizome system, which quickly become re-established to cause severe competition to the emerging crop.

It has been noticed that where farmers plough twice in the spring prior to planting Cynodon growth, is reduced, for the immediate season at least.

A trial was established at two farmer-field sites during the 1984-85 season with the objective of quantifying the degree of control which may be achieved by double ploughing.

METHODS

In the season prior to the trial both sites, which had visually uniform infestations of Cynodon had been planted by broadcasting on a single pass with an ox drawn plough.

The following treatments have been implemented at each site:

1984/85	1985/86	1986/87
Single plough	Single plough	Single plough (Control)
Single plough	Double plough	Single plough
Double plough	Single plough	Single plough
Double plough	Double plough	Single plough

These allowed an assessment of the effect of double ploughing carried out for one season or two seasons running as well as the residual benefit of the practice over the following two seasons. Two replicate plots per treatment 8m wide and 40m long in two blocks were laid out at each site. The first ploughing on double ploughed plots was carried out with a two furrow reversible plough to a depth of approximately 25cm, in each season. Apart for the 1984/85 season when a single furrow animal drawn plough was used, second plough pass on double ploughed, and the only plough pass on single ploughed plots was effected by a tractor mounted two furrow one-way plough.

For the 1986/87 season the single ploughing was carried out at both sites on all plots on 10th December.

The effect of tillage on Cynodon was assessed by recording the dry weight of Cynodon aerial growth (leaf and stolons) in eight 2 sq.m quadrats per plot. Quadrats were placed on eight transects laid at random positions across the trial. Records were made at 140 days after the planting tillage.

For an-alysis the data of both sites has been combined to give a randomised block design with two blocks per site (i.e. 4 replicates). Data was subject to loge (x+1.1) transformation prior to analysis.

RESULTS AND DISCUSSION

A residual effect of double ploughing for the first time in 1985/86 was found one season after the resumption of the traditional tillage practice of single ploughing (Table 1). The reduction in Cynodon regrowth to 23% of that following continuous single ploughing was similar to the reduction in regowth recorded at harvest of the 1985/86 season following double ploughing only in 1984/85 (Anon 1987).

Table 1: THE RESIDUAL EFFECT OF TILLAGE FREQUENCY ON C. DACTYLON REGROWTH. MAY 1987. (DATA FROM TWO SITES COMBINED)

Tillage Regime 1984/85	1985/86	1986/87	Dry Matter g/m2	Transformed Data (loge(X+1.1))
SP	SP	SP	29.9	3.31
DP	SP	SP	19.4	2.61
SP	DP	SP	7.0	1.93
DP	DP	SP	0.9	0.57
LSD (0.05)				0.72
S.E.D (3 d.f)				0.23
C.V.				21.4%

Excellent control was maintained on plots which had been double ploughed in both 1984/85 and 1985/86, the Cynodon having been virtually eradicaed.

However, there was considerable regrowth of Cynodon on plots which had been double ploughed for one season only in particularly at Site 1 (Table 2). Reseaonable control was maintained at Site 2, however.

Table 2: CYNODON REGROWTH (May 1987) FOLLOWING VARIOUS PLOUGHING TREATMENTS COMPARED TO CONTINUOUS SINGLE PLOUGHING.

Tillage Regime 1984/85	1985/86	1986/87	Site 1	Site 2
SP	SP	SP	100%	100%
DP	SP	SP	81%	26%
SP	DP	SP	18%	37%
DP	DP	SP	4%	0%

Draught animals are often in poor condition following the dry season, so in many cases animal traction users would have to hire a tractor to carry out the initial tillage pass, if double ploughing were to be adopted as a means of Cynodon control. Monitoring of the trial sites should be continued to indicate the rate at which Cynodon recolonises following double ploughing, particularly where this has been carried out for two seasons. The loss of control in the second season after one year's ploughing at Site 1 could indicate the need for double ploughing every second season. Based on the

Accelerated Rainfed Arable Production ploughing subsidy scheme price of P50/hectare for contract ploughing, and 1987 B.A.M.B. prices, a total of 354kg per hectare increased sorghum yield would be needed over a four year period to cover the cost extra tillage passes, if double ploughing was to be used every second year or for two seasons in succession. This is equivalent to 89kg per hectare each year.

12.2 Striga Research

12.2.1 SELECTION OF RESISTANCE TO S. ASIATICA IN SORGHUM

BACKGROUND

The red flowered cereal witchweed *Striga* asiatica (L.) Kuntze is found throughout many of the cultivated area of Botswana (Musselman and Riches, 1985). Sorghum is the major crop host although maize is also parasitised. The S. asiatica problem in Botswana is discussed in more detail in Anon (1980; 1982) and Musselman and Riches (1985).

Work on the selection of sorghum genotypes with resistance to the parasite began in the 1985/86 season. These studies aim to provide the sorghum breeding programme with sources of resistance for incorporation into agronomically superior lines. Resistance sorghum varieties, including the red grain type Radar, were developed from sorghum germplasm collected in South Africa (Saunders, 1942). More recently a breeding and selection programme at ICRISAT Center resulted in the identification of sorghum lines with stable resistant in India (Rao, 1983). These S.A.R. lines (*Striga asiatica* resistant)were developed with resistance to the white flowered morphotype of the parasite found in India. In Southern Africa cereal crops are parasitised by a red flowered morphotype.

Two screening trials were planted during 1986/87. In the first a range of germplasm including SAR lines and local sorghum accesions collected in Botswana were planted for a second season to confirm the levels of susceptibility recorded in 1985/86. Accessions from the Botswana colletion not previously screened were evaluated in a second trial.

SCREENING TRIAL METHODS

A pot techique was used involving growing test entries in 6.5kg capacity polythene propogation bags, filled with artificially infested soil sunk into the ground. Approxomately 400 seeds of *S. asiatica* collected at Sebele in May 1985 were added to each pot from a volumetric measure. The seed was mixed into soil in the bottom one third of the pot. Three replicate pots were grown of the first two for the initial screen of local accessions. A single test plant was established in each pot. As sorghum plants matured the pots removed from the ground and the root mass shaken out from the soil to allow a count of *Striga* number per plant. Each trial included accessions of differing maturities. All remaining plants were harvested at 16 weeks after sowing.

TRIAL 1

ENTRIES

A total of 90 accessions were evaluated for a second season. The composition of the trial was:

19 'SAT" lines ex ICRISAT Centre, with known resistance to the white flowered morphotype of S. asiatica found in India.

38 S.D.S. accessions ex Matopos (SADCC/ICRISAT Sorghum Improvement Programme) selected for inclusion in the Botswana Sorghum Programme;

29 accessions ex the Botswana Sorghum Colletion;

3 varieties released in Botswana;

1 variety Radar selected for resistance to S. asiatica in South Africa.

RESULTS AND DISCUSSION

A range of susceptibility to the parasite was found among the entries. The SAR sorghum lines appear to provide a source of resistance to S. asiatica in Botswana (Table 3).

Table 3: THE NUMBER OF SORGHUM ACCESSIONS SUPPORTING VARIOUS LEVELS OF S. ASIATICA - MEANS OF TWO SEASONS DATA.

Striga No. per plant	All accessions (n=90)	SAR lines only (n=19)
up to 2	2	2
5	22	9
10	49	8
15	10	
15	7	
Trial mean Striga /entry	8	4.2

Overall 46% of the accessions with less than 5 parasites per plant (emerged and subterranean parasites) tested over two seasons were SAR lines. Only one SAR line exhibited greater susceptibility than the overall trial mean of 8 parasite attachments per plant.

The only entries supporting a mean of no more than two S. asiatica attachments per plant were SAR 13 and SAR 24. These were also the only accessions tested with a total of five or less parasite attachments per plant in the most heavily infested replicate in either season of evaluation. While 76% of entries supported no more than 10 emerged Striga by more than 10 parasites per plant in total (emerged and non-emerged parasite attachments) - Table 4.

Table 4: <u>THE NUMBER OF SORGHUM ACCESSIONS SUPPORTING VARIOUS LEVELS OF S. ASIATICA -MOST HEAVILY INFESTED REPLICATE IN TWO SEASONS OF TRIALS</u>

Striga No. per plant	Emerged parasites only	Total parasites
5	38	2
10	31	11
15	16	19
+15	5	58
Trial mean (Striga/plant)	7.2	18.5

As well as SAR 13 and 24, lines SAR 30 and 34 all supported less than a mean of five _S. asiatica_ attachments in total with one emerged parasite in either season. Four local accessions, PM 64, PM 70, POK 144, PSA 159 and SDS 2819 ex Matopos supported up to five parasite attachment of which no more than three emerged.

Adaptability trials of this resistant germplasm should now be conducted at infested field sites across Botswana. Work completed in 1985/86 indicated genetic hereogeneity between collections of S asiatica from different areas of Botswana on the basis of a differential response of sorghum varieties to the parasite. Multilocational trials are needed to ensure selected resistance is stable (Anon, 1987).

Radar, which showed complete resistance in the first season of the trial supported a mean of 5 emerged and total of 9 _Striga_ per plant in 1986/87. This variety had previously been reported as having lost resistance due to outcrossing (Grobbelaar, 1952). The locally availble varieties Kanye Standard, Marupantse and Town supported a mean of 7.0, 7.4 and 8.3 parasite attachments over the two seasons of the trial. Each were attacked by 15 or more parasites in the most heavily infested replicate.

TRIAL 2

A total of 117 accessions from the Botswana collection of local sorghum germplasm were screened. Although three replicates were established, the assessment of _Striga_ attacked was limited to two replicates only. The third block was abandoned, the plants having become droughted early on in the season despite suppplementary irrigation.

RESULTS AND DISCUSSION

This initial observation indicated low susceptibility to _S. asiatica_ for many locally colleted accessions. More than 50% of entries supported a mean of 5 or less _Striga_ per plant:

Mean Total *Striga* per Plant		No. of Entries
	0	14
up to	5	47
	10	7
	15	15
over	15	14

Trial mean (*Striga* /plant) 6.7
Segaolane (check) 15.0

Only 28 accessions supported more than 5 emerged *Striga* plants per sorghum plant in the most heavily infested replicate as shown below:

Striga per plant		No. of Entries with: Emerged *Striga*	Total Striga
	0	32	14
up to	5	57	37
	10	19	23
	15	6	16
over	15	3	27
Trial mean (*Striga* /plant)		3.4	9.9
Segaolane (check)		17.0	30.0

The majority of accessions under test were considerably less susceptible than Segaolane. There were 51 accessions suppoting no more than 5 *Striga* plants per sorghum host plant in the most heavily infested replicate. These should be tested further with increased replication.

12.2.2 SUSCEPTIBILITY OF MAIZE TO STRIGA

BACKGROUND

During seasons of favourable rainfall, maize is grown on approximately one third of the area planted to cereals in Botswana, (e.g. 35% in 1981; Anon, 1981). *Striga asiatica* causes severe stunting of maize in Botswana and damages the crop elsewhere in Southern Africa.

Maize varieties showing resistance to *Striga hermonthica* , a widespread problem in the crop in West Africa, have been developed at the International Institute of Tropical Agriculture. A single greenhouse pot experiment was conducted during the winter of 1987 to investigate the susceptibility of these varieties to *S. asiatica* from Botswana.

METHODS

IITA supplied seven maize varieties for screening. Khalahari Early Pearl was inclued as a local check and sorghum cv Segaolane as a further check. The trial comprised the following nine entries:

	Variety	Pedigree	Origin
1.	8322-13	T2i3xT2i12	IITA
2.	8321-18	T2i3xT2i15	IITA
3.	8428-19	T2i3xT2i9	IITA
4.	8338-1	T2i9xT2i10	IITA
5.	8329-15	T2i18xT2i25	IJTA
6.	8425-8	T2i18x2i25	IITA
7.	8505-13	8329015xT2i25	IITA
8.	Khalahari Early Pearl	Open pollinated local	SMU,Botswana

No. 1-3 and 5-7 selected at IITA for resistance to S. hermonthica. 8338-1 is highly susceptible to S. hermonthica in West Africa.

Five replicates (two plants per pot) were grown of each entry in a Randomised Block Design. Plants were grown in 6.5kg capacity polythene propogation bags, filled with standard potting soil infested with approximately 1000 Striga seeds per pot. An even infestation level between pots was obtained by mixing the total amount of soil and parasite seed needed for the trial in a cement mixer prior to potting. Striga seed had been collected at Sebele in June 1985 (23 months prior to the trial) from plants parasitising sorghum. Fertilizer as 2:3:2 (6.3%N; 9.4%P; 6.3%K with 0.5%Zn) was added at planting at 0.17g per kg soil. Liquid fertilizer was appled at 35 days after sowing at 200ml per pot of a solution containing 0.44g N; 0.073g P and 0.057g K/litre. Mean maximum air temperature during the trial was 34.7°C. With a mean minimum of 15.6°C. Night temperature fell below 15°C (but never 11°C) from 38-63 days after sowing.

Counts of Striga emergence were made at two day intervals following the first parasite emergence. The trial was harvested at 80 days after sowing when a count was made of the number of emerged Striga plants and the total number of Striga plants per pot. Host roots were washed free of soil to allow a count of subterranean Striga shoots. Stems of the five most developed (i.e. longest) Striga plants in each pot were measured.

RESULTS AND DISCUSSION

Little Striga had emerged on the local maize variety Khalahari Early Pearl by the time the trial was harvested. Parasite stems emerged in only two pots of this variety compared to at least four pots for all other entries. First Striag emergence tended to be later for Khalahari Early Pearl, 8338-01 and 8322-13. The period to the emergence of 50% final emerged shoot number was also longer for 8338-01 and Khalahari Pearl than for other entries, as shown below:

Variety	Mean Days to: First *Striga* Emergence		50% of Final Emergence		No. of Pots with Emerged *Striga*
8329-15	55	+5.2	70.5	+6.3	4
Segaolane	60	+6.6	67	+8.2	5
8425-08	61.2	+8.2	65.8	+5.5	5
8505-13	61.3	+8.2	68	+4.5	4
8321-18	62.2	+5.4	66.8	+5.8	5
8428-19	63	+7.4	75	+3.3	4
8322-13	65.5	+7.2	73.2	+7.1	4
8338-01	69.3	+9.9	76	+2.8	4
Khalahari Early Pearl	69.5	+2.5	76	+4.0	2

- Based on pots in which emergence occured only
+ Standard deviation.

While *Striga* emergence was significantly less on 8338-1, 8322-13 and Khalahari Early Pearl there was little difference in the total number of *Striga* plants developing on the maize entries when the experiment was harvested.

Table 5: MEAN EMERGED STRIGA NUMBER PER POT OF TWO HOST PLANTS

Variety	*Striga* No. Log$_{10}$ (x+1.1)	Actual No.
8428-19	1.06	10.4
8321-18	0.98	8.5
8505-13	0.82	5.5
8329-15	0.82	5.5
8425-8	0.80	5.2
Segaolane	0.71	4.0
8338-1	0.35	1.1
8322-13	0.34	1.1
Khalahari Early Pearl	0.25	0.7
Standard Error	0.17 (32 d.f.)	
LDS 0.05	0.34	
CV	39.25%	

The local sorghum check did however support fewer parasite attachments than the three most heavily infested maize varieties.

Table 6: MEAN TOTAL STRIGA NUMBER PER POT OF TWO HOST PLANTS

Variety	*Striga* No. Log$_{10}$	Actual No.
8428-19	1.95	89.1
8329-15	1.83	67.6
8338-1	1.67	46.7
8321-18	1.59	38.9
8425-8	1.56	36.3
8322-13	1.55	35.5
8505-13	1.53	33.9
Khalahari Early Pearl	1.46	28.8
Segaolane	1.18	15.2
Standard Error	0.21 (32 d.f.)	
LSD 0.05	0.42	
CV	20.6%	

As well as supporting fewer emerged *Striga* plants, the varieties 8322-13 and Khalahari Early Pearl appeared in this trial to be poorer hosts for parasite development than the other maize entries. The five longest *Striga* shoots were in total lees than 200mm on these compared to between 250 and 450mm on other varieties. This difference in total shoot length was significant in the case of 8322-13 and all maize entries other than Khalahari Early Pearl. Five maize varieties supported more developed *Striga* plants than Khalahari Early Pearl. *Striga* development was also less rapid on Segaolane sorghum compared to most of the maize varieties under test.

Table 7: MEAN LENGTH OF THE FIVE MOST DEVELOPED STRIGA PLANTS PER POT OF TWO HOST PLANTS

Variety	Mean total length (mm) Log$_{10}$	Actual length
8428-19	2.61	409
8329-15	2.52	333
8505-13	2.51	325
8321-18	2.50	318
8425-08	2.48	303
8338-1	2.41	258
Khalahari Early Pearl	2.26	183
Segaolane	2.26	183
8322-13	2.18	152
Standard Error	0.08 (32 d.f.)	
LSD 0.05	0.16	
CV	5.01%	

Of the maize varieties in the trial which were selected for resistance to *S. hermonthica* in West Africa, only 8322-13 showed any degree of resistance to *S. asiatica* from Botswana. This differed from the other varieties in supporting slower parasite development and less emergence but was not less susceptible in terms of total parasite number. Inerestingly, Striga development was also slower and less emergence was supported by 8338-1, the variety susceptible to S. hermonthica in West Africa.

There was no attempt in this initial trial to investigate any varietal difference of the effect of the parasite on host plant growth and development. The level of attack on 8322-13, 8338-1 and Khalahari Early Pearl may prove sufficient to cause yield reductions in the field despite reduced or delayed parasite remergence.

These three varieties should be tested further under infested and uninfested conditions, with the trial taken to yield.

12.3 Aleutra Research

The root hemi-parasite Alectra vogelii Benth hss a similar distribution in Botswana to S. asiatica . Cowpea is the major cultivated host of the parasite throughout the country.

The introduced cowpea of work on the A. vogelii problem has been the identification of cowpea germplasm resistant to the parasite.

12.3.1 FIELD TRIALS WITH SELECTED COWPEA LINES

BACKGROUND

Fourteen local accessions and the introduced variety ER7 were planted at an infested field site to allow evaluation of their performance on A. vogelii infested land. The local accessions had previously been evaluated in a series of pot trials which had indicated promising levels of resistance (Anon, 1986). These lines originated from single plant selections made at infested sites. This was the second season the trial had been planted.

METHODS

A prliminary screening plot design (Rao et al., 1982) previously used elsewhere for Striga research was used. The layout involves plots of test entries planted around a plot of a susceptible check and was adopted because of likely heterogeneity of parasite seed distribution in the field.

One replicate of the trial with 16 entries would appear as follows:

T	T	T	T	T	T
T	T	T	T	T	T
T	T	T	T	T	T

A, B = susceptible check
T = test entry

Parasite infestation of a particulr entry may be expressed as a percent of the infestation on the nearest susceptile check. Where a check plot escapes attack, adjacent test plots are likely to be on uninfested soil.

Three replicate block of test entries were planted, with one susceptile check plot to eight entries. Plots consisted of 4 rows by 4m. Cowpeas were thinned to 20cm in the row. As the cowpeas senesced, 10 plants frome the two centre rows of each plot were dug to allow a count of the number of <u>A. vogelii</u> parasitising each plant. The trial produced negligible yields due to the drought.

RESULTS AND DISCUSSION

A summary of the trial results over the past two seasons is presented below:

Cowpea entry	Mean percent 1985/86		infestation 1986/87	
B359	4	(1)	0	(1)
B319	13	(3)	0.6	(2)
B126	9	(2)	32	(5)
B116A	23	(6)	35	(6)
B315	26	(7)	41	(9)
B305	29	(8)	47	(12)
B357	40	(11)	45	(11)
ER7	43	(12)	41	(9)
B301	51	(13)	40	(8)
B302	30	(9)	62	(13)
B332	65	(14)	36	(7)
BSMU 18	38	(10)	71	(14)
Blackeye	100%		100%	

() = ranking of susceptibility in ascending order.

B359 remained parasite free on all plots this season and was also the least susceptible entry in 1985/86. The six most resistant accessions supporting a maximum of 35% the <u>A. vogelii</u> infestation on the Blackeye check plots occupied similar ranks in both season.

The resistance of B359 has now been demonstrated in a number of pot trials (Riches, 1987) and in the field. It is lated maturing - flowering at approximately 70 days after planting - in common with the majority of local germplasm collected in Botswana, B359 does, however, provide a good source of resistance for use in future cowpea breeding programme.

12.3.2 PRELIMINARY SCREENING OF COWPEA GERMPLASM

In an attempt to broaden the genetic base of resistance germplasm available in a future cowpea breeding programme, screening of the Botswana Cowpea collection was initiated in 1985/86. In the first season 201 accessions were screened. A further 156 accessions were evaluated this season. In addition 311 introduced accessoins from various parts of the world, held in the Botswana Cowpea collection were also screened.

METHODS

The screening trials used the "pot in the ground" technique described for striga screening earlier in this report. Approximately 800 seeds of *A. vogelii*, collected in 1985, were mixed into the soil in each pot. Three replicate were grown of each accession, using one cowpea plant per replicate pot.

Early maturing accessions were harvested as plants senesced. All remaining plants were harvested 100 days after planting for the local accession trial and 80 days after sowing in the case of the introductions. At harvest each pot was removed from the ground, the cowpea root system shaken free of soil and a count made of *A. vogelii* attachments.

RESULTS AND DISCUSSION

Of the local accessions evaluated during the season, 25 supported no more than a mean of two *A. vogelii* per plant (Table). These should e further evaluated under infested consitions with greater replication. The majority of accessions were less susceptible than the susceptible check Blackeye, while 48% of entries supported higher parasite numbers than the trial mean.

Table 8: THE NUMBER OF LOCAL COWPEA ACCESSIONS SUPPORTING VARIOUS LEVELS OF *A. VOGELII*

A. vogelii /plant	No. of accessions
0	7
up to 2	17
5	57
10	49
11+	26
Blackeye - susceptible check (*A. vogelii* /plant)	14
B359 - resistance check	0
Trial mean	6

The resistant check 359 remained parasite free in both trials. A maximum of five parasites per plant developed on 32.5% of introduced accessions (Table 9).

Four accessions were not attacked in this trial. A further 32 supported a maximum of five parasites in the most heavily infested replicate of each entry. The 36 least susceptible accessions should be tested further under parasite infested conditions to confirm the resistance shown in this initial observation. These include a number of lines from West Africa which are earlier in maturity than the resistant selections made from local germplasm to date. The accessios showing "resistance" in this preliminary observation also include a number of Blackeye types from collectins in USA. A resistant Blackeye cowpea would have obvious potential in Botswana.

Table 9: THE NUMBER OF INTRODUCED COWPEA ACCESSIONS SUPPORTING VARIOUS LEVELS OF A A. VOGELII (MEAN PARASITE NO.PER ACCESSION)

A. vogelii /plant	Number of lines
0	4
up to 5	97
10	146
15	54
+15	10
Blackeye - suscejptible check (A. vogelii /plant)	7.3
B359 - resistance check	0

12.4 Studies on the host range of A. vogelii S.& asiatica

BACKGROUND

The seed of Alectra and Striga species germinate in response to root exudates of potential hosts development (Botha, 1948; Saunders, 1942). Successful attachment to a host and development of the parasite follows e.g. S. asiatica on susceptible varieties of sorghum. A number of species, however, stimulate parasite seed germination, but subsequently do not support parasite development. The use of such "false hosts" has been exploited in the technique of trap cropping. The trap crop causes suicidal germination of witchweed seed. Trap cropping of S. asiatica with Soyabean (Glycine max) or field pea (Pisum sativum) led to a steady increase in maize yields over a five year period in a field trial in USA as witchweed infestation levels fell (Robinson and Djowler, 1966).

A range of arable and fodder crops which are either currenlty grown in Botswana or which have been evaluated in research trial were assessed as hosts and as stimulant producing false hosts of both A.vkogelii and S. asiatica.

METHODS

For the evaluation kof crops as hosts, plants were grown in 15cm diameter plastic propogation bags in soil infested with both S. asiatica (2 year old seed collected at Sebele in June 1985) and A. vogelii (seed collected at Marapong in June 1985). Root systems were washed out of the pots at 65 days after sowing to allow an assessment of parasite development. The crops were tested for Alectra and Striga stimulant production by assessing the germinaion of parasite seed placed in a fiber glass filter paper sandwich at a depth of 7cm in the profile of 10cm diameter pots in which test plants were grown in sand. Germination counts were made 40 days after planting. No germination was recorded for seed maintained in pots in which no plants were grown.

RESULTS AND DISCUSSION

As well as grain sorghum - cv Segaolane and BOT79, maize - cv Khalahari Early Pearl and Cowpeas - cv Blackeye, a number of fodder species and arable crops suitable for introduction in Botswana, are hosts of either *Striga* or *Alectra* (Table 10). Columbus grass (*Sorghum almum*), fodder sorghums cv 'Gotcha','Haygrazer' and 'Trudan' (*Sorghum bicolor*) and Smuts Finger Grass (*Digitaria smutsi*) support the development of *S. asiatica* , while the foddr legumes Dolichos lablab (*Lablab purpureus*), Pigeon Pea (*Cajanus cajan*), Siratro (*Macropotilium atropurpureum*) are hosts of *A. vogelii* .

Table 10: GERMINATION STIMULATOR AND HOSTS OF A.VOGELII AND S. ASIATICA

Striga hosts — Germination of *Alectra*: Yes	*Striga* hosts — Germination of *Alectra*: No	*Alectra* hosts — Germination of *Striga*: Yes	*Alectra* hosts — Germination of *Striga*: No
Digitaria smutsi (++)	*Sorghum bicolor* -grain and fodder types	*Cajanus cajan* (+)	* *Cicer arietinum*
Zea mays (+)	*Sorghum almum*	*Macropotlium atropurpureum* (+++)	* *Glycine wightii*
		Lablab purpureus (+)	* *Lichardt dolichos*
		Vigna ungiculata (++)	
		* *Sesamum indicum* (+)	

Non-hosts which germinate

Alectra and *Striga*	*Alectra* only	*Striga* only
Barrel medic (+++);(+)	*Eragrostis curvula* (+)	*Panicum maximum* (+)
Chloris guyana (++);(++)	*Pennisetum americanum* (++)	*Panicum miliaceum* (++)
Helianthus annuus (+);(+)	*Medicago sativa* (++)	*Secale cereale* (+)
	Vigna subterreanea (+++)	*Setaria anceps* (+)
	Poa pratensis (+)	

Non-hosts with no germination stimulated

Antephera pubscens ; *Cenchrus ciliaris* ; *Eragrostis teff* ; *Onobrychis vicifolia*

(+) 0 to 25% (++) 26-50%; mean max. seed germination over 3 replicates.
* Poor parasite development.

When grown as break crops in an otherwise arable rotation, these fodder crops could cause a buildup of parasite infestation levels to the detriment of following sorghum or cowpea crops. By the time the experiment was harvested *A. vogelii* attachment to chickpea cv ICC-32 (*Cicer arietinum*), (*Glycine wightii*), *Lichardt dolichos* and Sesame cv 38-1-4 (*Sesamum indicum*) were poorly developed. Field trials under infested conditions are needed to indicate if the parasite will emerge and flower when parasiting theses hosts. If any varieties of Sesame or Chickpea are selected in future adaptability trials for introduction as a crop in Botswana they should first be screended for susceptibility to *A . vogelii* .

A number of species appear to have potential as trap crops. Of particular interest are crops already grown in Botswana. These include Pearl Millet - grain type cv Serere 6A and fodder type Babala - which is not susceptible to *Striga* but is a false host of *Alectra* . Bambara, a false host of *Alectra* , may be grown on *Alectra* infested soils as an alternative legume to cowpea. although a host of *A . vogelii* Blackeye cowpea also stimulated germination of *S . asiatica* . Cowpea varieties which are resistant to *A . vogelii* may be useful in a rotation at *S . asiatica* in South Africa (Hattingh, 1956). The current trial also indicated the crop cv Russian No. 4 caused limited germination of both parasite species. Proso (*Panicum milaceum*) and Rhodes Grass (*Chloris guyana*) would be useful false host fodder grasses for inclusion in rotations at parasite infested sites.

12.5 **Weed control in sorghum**

SUMMARY

A range of chemicals were screened in field trials forthe control of *D . ferox* in grain sorghum. The results obtained show that a mixture of terbuthylazine and metolachlor (1284.5 and 437.5 g/ha) was consistently the most effective.

METHODS AND MATERIALS

Based or the results from the previous season and the glasshouse screening st... two on farm sites were established to further test various post emergence ...icides against *D . ferox* .

The trials were laid out on an incomplete latin square design. The herbicides were applied using a CP 15 knapsack sprayer, delivering 260 l/ha spray solution. The same sprayer and trial design was used for all other crop trials, unless otherwise stated.

At six days after spraying a visual assessment of treatment efficacy was made. At 20 and 35 days weed counts per square metre for each treatment were made.

RESULTS AND DISCUSSION

The band-spraying of chemical over the crop row whilst hand-hoeing between the crop row effectively reduced chemical use by up to sixty percent. *D . ferox* numbers within the crop row were significantly reduced.

Table 11. THE EFFECT OF DIFFERENT WEED CONTROL METHODS ON WEED SURVIVAL 1987

TREATMENT	(g/ha)	NO. OF DAYS AFTER SPRAYING: 6 (% control) I *	6 (% control) II	20 (No. of D. ferox/sq. m.) I *	20 II	35 I	35 II
Terbuthylazine + metolachlor	1284.5 437.5	94.5 (92.5)	98.3 (100)	0.18 (0.0)	0.09 (0.0)	1.11 (2.05)	1.04 (3.0)
Terbuthylazine + metolachlor	917.5 312.5	93.6 (86.2)	97.6 (100)	1.09 (3.7)	0.75 (3.0)	1.99 (10.0)	1.74 (13.7)
Terbuthylazine + metolachlor banded + 25 days	1284.5 437.5	71.7 (72.5)	88.2 (92.5)	1.45 (5.6)	0.09 (0.0)	2.25 (10.0)	0.84 (3.75)
Terbuthylazine + metolachlor banded + 25 days banded + 25 days	917.5 312.5	39.6 (36.2)	82.9 (83.7)	3.41 (30.0)	0.83 (5.0)	3.02 (26.5)	0.43 (4.4)
Bromofenoxim + atrazine + terbuthylazine	375 242 242	71.6 (71.2)	100.0 (100.0)	2.34 (13.7)	0.09 (0.0)	2.41 (19.4)	0.84 (4.4)
Bromofenoxim + atrazine + terbuthylazine	250 161.3 161.3	70.6 (63.7)	98.4 (92.5)	2.24 (22.5)	0.09 (0.0)	2.57 (35.0)	0.72 (2.5)
Bromofenoxim + atrazine + terbuthylazine + 25 days	375 242 242	41.9 (42.5)	91.1 (86.2)	1.99 (11.9)	1.1 (2.5)	2.23 (21.9)	1.41 (6.2)
Atrazine + terbuthylazine	242 242	76.8 (80.0)	87.1 (83.7)	3.03 (20.6)	0.77 (7.5)	2.97 (38.7)	1.49 (8.8)
Bromoxynil + M.C.P.A.	337.5 400	91.7 (92.5)	98.3 (100)	1.84 (6.9)	0.39 (0.6)	2.70 (38.1)	0.61 (1.9)
Bromoxynil + M.C.P.A.	225 200	92.2 (92.2)	84.1 (91.2)	0.92 (4.4)	0.39 (0.6)	2.38 (11.2)	0.99 (3.1)
Weed at 25 days		97.9 (100.0)	102.4 (91.2)	2.70 (13.7)	0.09 (0.0)	3.25 (0.0)	1.41 (1.8)
Weed at 25 and 50 days		92.9 (100.0)	77.1 (81.2)	3.30 (13.7)	1.19 (4.4)	0.09 (0.0)	0.69 (0.0)
No weed control		-5.3 (0.0)	-4.8 (0.0)	3.86 (48.7)	2.7 (26.8)	2.34 (28.7)	1.9 (19.4)
C.V.:		31.1%	8.2%	47.4%	74.9%	65.8%	98.9%
S.E.D. (29 df):		8.26	2.72	0.40	0.34	0.60	0.42
Significance level of treatments:		0.10%	0.10%	1.00%	1.00%	n.s.	n.s.

NOTE: All data loge (x + 1.1) transformed. Percent control data based on pre-transformed data scale. * indicates means adjusted in accordance with incomplete latin square methodology. Data in brackets is original data.

Table 12. GRAIN SORGHUM YIELDS (TONNES PER HECTARE) .

Treatment	(g/ha)	Yield Site 1 *		Yield Site 2	
Terbuthylazine	1284.5	0.73	(0.82)	0.57	(0.68)
Terbuthylazine + metolachlor	917.5 312.5	0.55	(0.77)	0.24	(0.18)
Terbuthylazine + metolachlor banded + 25 days	1284.5 437.5	0.51	(0.70)	0.42	(0.45)
Terbuthylazine + metolachlor banded + 25 days	917.5 312.5	0.53	(0.62)	0.22	(0.15)
Bromofenoxim + atrazine + terbuthylazine	375 242 242	0.55	(0.38)	0.50	(0.59)
Bromofenoxim + atrazine + terbuthylazine banded + 25 days	375 242 242	0.37	(0.68)	0.21	(0.13)
Atrazine + terbuthylazine	242 242	0.41	(0.70)	0.43	(0.49)
Bromoxynil + M.C.P.A.	337.5 400	0.41	(0.55)	0.78	(1.08)
Bromoxynil + M.C.P.A.	225 200	0.40	(0.44)	0.23	(0.16)
Weed at 25 days		0.52	(0.84)	0.15	(0.07)
Weed at 25 and 50 days		0.69	(0.21)	0.34	(0.01)
C.V.:		36.36%		187%	
S.D.:		0.18		0.67	
S.E.D. (29 df):		0.07		0.26	
Significance level of treatments:		n.s.		n.s.	

NOTE: All data loge (x + 1.1) transformed. * indicates means adjusted in accordance with incomplete latin square methodology. Data in brackets is original data.

At both rates the bromoxynil with M.C.P.A. gave rapid effective control of all _D_. _ferox_ present. Neither of terbuthylazine with metolachlor treatments gave as rapid kill of te _D_. _ferox_ seedlings, but did significantly reduce weed re-growth. This property commends this chemical to _D_. _ferox_ control. Bromoxynil with M.C.P.A. is however more appropriate for use in soil of less than 10% clay. The hand weeding treatments gave poor control of the _D_. _ferox_.

Yield data was obtained (Table 12). On the control plots a markedly reduced yield was obtained. the terbuthylazine with metolachlor treatment (1284.5) and 437.5 g/ha) gave consistently higher yields than the majority of other treatments. The treatments that utilised band spraying had reduced yields in comparison to those treatments which were broadcast sprayed.

CONCLUSIONS

Good control of _D_. _ferox_ may be obtained with terbuthylazine and metolachlor, sprayed at the recommended rate. Weed re-growth later in the season is significantly reduced through the use of this chemical.

12.6 **Related Field Trials**

2.6.1 USE OF PRE-EMERGENCE HERBICIDE TREATMENTS FOR WEED CONTROL IN SORGHUM

Summary

An on-farm trial was established to test any potential the pre-emergence herbicide metolachlor may have when used in a combination with a variety of recommeded post-emergence herbicides. Testing was also carried out of the relative merits of applying the metolachlor using a spinning disc applcator, the "Berki" sprayer.

The trial results highlighted the problems associated with the use of pre-emergence herbicides. The post-emergence herbicides were applied for te purpose of studying their effect on the weed flora.

METHODS AND MATERIALS

The trial was laid out on a split plot design, treatments are as detailed. The pre-emergence treatments were applied using either a "Berki" spinning disc sprayer, applying 20 l/ha spray solution, or a CP 15 knapsack sprayer fitted with a blue "polijet" and applying 260 l/ha spray solution. A hybrid seed was used (CG 766) which had been previously treated with a safener, Concep, to allow for the safe application of pre-emergence chemicals.

All post-emergence spray treatments were applied using the same CP 15 knapsack sprayer.

The post emergence treatments were applied using the same CP 15 knapsack sprayer.

The post emergence treatments were applied 25 days after planting. Routine assessments of weed numbers present were carried out or up to 68 days after the first treatment application.

RESULTS AND DISCUSSION

i) PRE-EMER GENCE SPRAY APPLICATION

The predominant weed species present were noted as D. ferox, Eleusine indica and Amaranthus thunbergii.

The results do not indicate a significant difference in either treatment or treatment application techniques. No rain fell for 9 days after the pre-emergence herbicide was applied, hence failing to activate the herbicide's active ingredient.

Table 13. EFFECT OF PRE-EMERGENCE TREATMENT AND APPLICATION METHOD ON NUMBERS OF EMERGING WEEDS

Treatment	g/ha	Percent control of weeds 21 days post application	
Berki Sprayer:			
I) metolachlor	720	35.00	(2.0)
II) metolachlor	720	45.00	(2.33)
III) metolachlor	1056	65.00	(3.00)
IV) metolachlor	1056	76.60	(3.66)
Knapsack sprayer:			
I) metolachlor	720	45.00	(2.33)
II) metolachlor	720	26.60	(1.66)
III) metolachlor	1056	71.60	(3.66)
IV) metolachlor	1056	71.60	(3.66)
Control I		26.60	(1.66)
Control II		71.60	(3.66)
	C.V.:	48.8%	
	S.D.:	26.3	
	S.E.D.(g df): of treatments:	11.76 n.s.	

NOTE: All data transformed to percent values on a pre-transformed rating scale. Data in brackets is original data.

Table 14: EFFECT OF POST EMERGENCE HERBICIDES APPLIED TREATMENTS ON WEED NUMBERS

Treatment	g/ha	Percent control of weeds Days post applicantion 14		28	
Berki Sprayer:					
Metolachlor	720	73.3		81.6	
Terbuthylazine	1284.5		(3.33)		(3.66)
+ metolachlor	437.5				
Metolachlor	720	81.6		93.3	
Terbuthylazine	917.5		(3.66)		(4.33)
+ metolachlor	312.5				
Metolachlor	1056	88.30		85.0	
Bromofenoxim	375		(4.33)		(4.0)
+ atrazine	242				
+ terbuthylazine	242				
No weeding		35.0		0.00	
			(2.0)		(0.0)
Knapsack sprayer:					
Metolachlor	720	85.0		71.66	
Terbuthylazine	1284.5		(4.0)		(3.66)
+ metolachlor	437.5				
Metolachlor	720	71.60		93.30	
Terbuthylazine	917.5		(3.33)		(4.33)
+ metolachlor	312.5				
Metolachlor	1056	85.0		63.30	
+ handweeded 25 days post planting			(4.0)		(3.66)
Metolachlor	1056	75.0		66.60	
Bromofenoxim	375		(3.66)		(3.33)
+ atrazine	242				
+ terbuthylazine	242				
No weeding				55.0	
53.3					
C.V.:		32.7%		39.6%	
S.D.:		23.73		27.8	
S.E.D (9 df):		10.6		12.43	
Significance level of treatments:		n.s.		5%	

NOTE: All data transformed to percent values on a pre-transformed rating scale. Data in brackets is original data.

ii) POST EMERGENCE TREATMENTS

Following the application of the post-emergence chemicals good broad-leaved weed control was achieved. There was no significant differences observed between any of the treated plots.

The hand-weeded plots gave good weed control, notably of the D . ferox However, hand-hoeing was a lengthy operation and over the larger areas of the Barolong region would not be regarded as being a suitable method for weed control.

CONCLUSIONS

The results indicate that the use of pre-emergence herbicides for weed control is not to be recommended.

Any merits of the use of the Berki Sprayer were not apparent. As long as pre-emergence herbicides are not recommended for weed control in the Barolong region further investigations into the relative merits of the unit are likely to be less than fruitful.

The use of a knapsack sprayer to apply chemicals post-emergence offers the potential for good and timely weed control.

12.6.2 THE EVALUATION OF HERBICIDES FOR WEED CONTROL IN MAIZE

SUMMARY

A range of herbicides recommended in South Africa for both pre- and post-emergence application in maize were applied in field trials at the recommended rate for 0-15% clay content soils. A range of mechanical weeding treatments were included to investigate the comparative advantage of intra or inter-row weeding and early with late weeding.

Good weed control was obtained throughout the season by use of atrazine with terbuthylazine and metolachlor at the recommended rate.

METHODS

One trial site was established.

A weed assessment was made 7 days after the application of the pre-emergence treatments. The post emergence treatments. The post emergence treatments were applied 25 days after crop planting.

Table 15. EFFECT OF DIFFERENT CONTROL METHODS ON WEED NUMBERS IN MAIZE

Treatment	g/ha	*D. ferox* numbers/sq. metre at days after treatment application: 7 days post pre-emergence	7	28	42 (% control) *
Atrazine + terbuthylazine + metolachlor	656.25 656.25 437.5	1.44	0.64 (33.5)	0.57 (5.0)	85.0 (10.0)
Atrazine + terbuthylazine + metolachlor	468.75 468.75 312.5	1.13	0.29 (15.0)	0.21 (1.5)	87.0 (1.5)
Atrazine + cyanazine	335.0 666.6	1.02	1.29 (23.0)	1.24 (44.5)	27.0 (29.0)
Alachlor + atrazine	1536.0 98.0	1.26	0.47 (24.5)	0.34 (2.5)	94.0 (2.0)
Metolachlor + atrazine + terbuthylazine + bromofenoxim	1056.0 266.2 266.2 375.0	1.13	0.04 (23.5)	0.81 (0.0)	80.0 (14.0)
Metolachlor + atrazine	750.0 750.0	1.39	1.43 (30.0)	1.24 (37.0)	7.0 (21.5)
Weed inter-row 30 days		1.34	1.28 (24.5)	1.17 (36.0)	13.0 (23.5)
Weed overall 30 days		1.25	0.48 (30.5)	0.87 (11.5)	40.0 (18.5)
Weed overall 30 days		1.01	0.55 (30.5)	1.16 (11.5)	40.0 (18.5)
Control, no weeding		1.24	1.47 (34.5)	1.37 (44.5)	7.0 (28.0)
C.V.:		38.6%	70.9%	61.4%	47.3%
S.D.:		0.463	0.52	0.50	25.71
S.E.D. (35 df)		0.356	0.33	0.32	16.26
Sig. level of treatments		n.s.	0.1%	1.0%	0.1%

NOTE: Data in column "*" transformed from original scores on pre-transformed rating scale. All other data log (x+1.1) transformed. Original mean values in brackets.

RESULTS AND DISCUSSION

Despite rain falling within 7 days of the application of the pre-emergence treatments there was no significant difference in the levels of broad-leaf weed control obtained. Following the application of the post-emergence treatments good D. ferox control was obtained, notably with the atrazine, terbuthylazine and metolachlor and atrazine, terbuthylazine and bromofenoxim combinations (see Table 15).

The hand-weeding treatments were all effective in controlling weeds 30 days after crop planting, although there was rapid re-growth of the weeds. The treatment requiring weeding overall at 30 and 60 days after planting reduced weed numbers effectively. The second pass to control weeds was slow, taking up to 6 man-days per hectare to clear the area, the earlier weeding having taken an equivalent of 5 man-days per hectare.

CONCLUSIONS

The use of chemical combinations containing atrazine, terbuthylazine and metolachlor and atrazine, terbuthylazine and bromofenoxim resulted in good weed control being obtained for up to 42 days after crop planting.

The use of pre-emergence treatments for grass and broadleaved weed control is not recommended. Hand weeding offers a method of weed control most appropriate to small holdings.

12.6.3 BROAD-LEAF WEED CONTROL IN GROUNDNUTS

SUMMARY

A range of pre and post-emergence chemicals were compared for the control of *Datura ferox* (L.) in groundnuts. A number of hand-weeding regimes were tested to evaluate the effect of timely control on weed numbers.

Good control of *D. ferox* was achieved using post-emergence applications of herbicides, as well as through timely hand weeding. Aerial crop dry matter obtained with all the treatments that had controlled *D. ferox* throughout the season.

METHODS AND MATERIALS

Two on-farm trials were established.

Weed assessments were carried out at 25 and 45 days after crop planting. Plant aerial matter was harvested at each site 105 days after planting. The material was oven dried for 4 days at 65 C to obtain dry weight figures.

Table 16. THE EFFECTS OF DIFFERENT WEED CONTROL METHODS ON WEED SURVIVAL AND PLANT DRY MATTER PRODUCTION

Treatment produced	g/ha	No. of days after planting (nos. of *D. ferox* /sq.m) 25		45		Dry matter produced (t/ha)	
SITE		I	II	I	II	I	II
Metolachlor + bendioxide	1056 1200	0.88 (17.5)	0.70 (45.0)	-0.17 (4.0)	-1.38 (37.5)	2.70 (4.36)	1.45 (3.16)
Metolachlor + acifluorfen	1056 480	0.85 (12.5)	0.92 (13.0)	0.58 (31.0)	1.46 (3.32)	1.62 (2.34)	1.03 (2.24)
+ Alachlor + acifluorfen	1740 480	0.10 (6.25)	0.72 (33.5)	0.68 (38.0)	1.00 (26.5)	2.70 (5.16)	1.87 (2.94)
Cynmethylin	503.4	2.90 (160.0)	2.43 (103.5)	2.12 (54.5)	2.57 (121.8)	-0.60 (0.92	-0.65 (0.4)
Trifluralin	360	2.44 (78.75)	2.21 (102.5)	1.16 (29.5)	1.65 (71.1)	-0.17 (1.55)	-0.24 (0.42)
Acifluorfen	480	0.68 (41.25)	1.27 (45.0)	0.07 (7.5)	1.47 (40.0)	1.28 (3.74)	1.09 (2.14)
Bendioxide	1200	1.18 (17.50)	1.45 (37.0)	-0.28 (6.5)	0.63 (19.5)	1.90 (3.84)	0.85 (2.14)
Clean weeded		-8.85 (0.00)	2.44 (119.5)	1.24 (13.5)	1.20 (34.5)	1.26 (3.04)	1.21 (2.33)
Weed 25 days		-0.18 (18.75)	1.41 (64.5)	0.56 (13.0)	1.34 (24.5)	1.01 (3.50)	0.79 (1.96)
Weed 25 and 50 days		-0.41 (2.50)	2.57 (130.5)	1.42 (11.5)	1.18 (28.0)	1.93 (4.0)	1.19 (2.38)
No weeding		3.59 (196.25)	2.68 (196.0)	3.01 (91.5)	2.71 (125.5)	-0.38 (0.9)	-0.25 (0.46)
C.V.:		50.8%	16.1%	43.9%	21.6%	29.7%	41.7%
S.D.:		0.27	0.27	0.44	0.32	0.37	0.34
S.E.D. (35 df)		0.11	0.11	0.19	0.13	0.16	0.14
Significance level of treatments:		0.1%	0.1%	0.1%	0.1%	0.1%	0.1%

NOTE: All data log (X+1.1) transformed. All means adjusted in accordance with incomplete latin square methodology. Data in brackets is original data.

RESULTS AND DISCUSSION

Following the application of the pre-emergence herbicides no rain fell until 10 days after application (9.8mm). It is extremely unlikely therefore that any of the pre-emergence applied herbicides were activated. Further testing for crop susceptibility to cynmethalin will be required.

The split applications (metolachlor with bendioxide, metolachlor with acifluorfen and alachlor with acifluorfen) all gave adequate control *D. ferox*. The bendioxide treated plots were almost totally weed free. Good control of *D. ferox* was obtained on all plots treated with acidfluorfen. However large numbers of *D. ferox* germinated subsequent to treatment application. The hand weeding regimes gave excellent weed control, though considerable weed re-growth occured.

The amount of crop aerial dry matter produced does not correlate with potential yield. The metolachlor with bendioxide and alachlor with acifluorfen treatments did have significantly higher amounts of plant dry matter than any of the other treatments.

CONCLUSIONS

The use of pre-emergence herbicides in groundnuts is not recommended.

Hand-weeding of the crop no later than 25-30 days post planting is the most appropriate weed control method on holdings up to 5 hectares in size. On larger holdings good broad-leaved weed control may be achieved by the use of acifluorfen or bendioxide, both sprayed at the label recommended rate.

12.6.4 BROAD-LEAVED WEED CONTROL IN SUNFLOWERS

SUMMARY

The range of chemicals available for the selective control of broad-leaved weeds in sunflower is very limited. Hand labour is the principle method of effecting weed control. Studies have centered around the use of pre-emergence herbicides in comparison with various hand weeding regimes.

It was found to be more appropriate to hand weed sunflowers than use chemicals. All hand weeding should be carried out no later than 25-30 days after crop planting.

METHODS AND MATERIALS

Two on-farm trials were established. Treatments are as detailed. Weed assessments were carried out at 25 and 60 days after crop planting.

No yield data was obtained.

RESULTS AND DISCUSSION

Table 17. THE EFFECTS OF DIFFERENT WEED CONTROL METHODS ON WEED NUMBERS

Treatment	g/ha	Days after crop planting (*D. ferox* nos. per square m)			
		Site I *	Site II *	Site I *	Site II *
Alachlor	1536.0	2.01 (44.4)	1.99	96.9	1.26
Alachlor banded + Weeded inter row 25 days post pltg.	1536.0	-1.06 (0.0)	-0.65	22.5	1.46
Cynmethylin	503.4	2.96 (122.5)	1.44	86.2	2.06
Trifluralin	480.0	2.77 (125.6)	0.99	57.5	0.59
Hand weed 25 day post planting		-0.97 (0.0)	-0.70	39.4	1.17
Hand weed 25 + 50 day post planting		-1.01 (0.0)	-0.77	16.9	-1.00
No weeding		2.80 (101.8)	1.67	100.0	1.26
C.V:		26.0%	40.3%	43.6%	45.7%
S.D.:		0.279	0.26	-	0.44
S.E.D (16 df)		0.15	0.14	-	0.24
Sig. level of treatments:		0.1%	0.1	n.s.	1.0%

NOTE: All data in columns marked * log (x+1.1) transformed. Means in columns marked "*" adjusted in accordance with incomplete latin square methodology. Data in brackets is original data.

After the completion of the pre-emergence treatments 6.8 mm rain fell within 7 days of application activating the alachlor, cynmethylin and trifluralin. Nevertheless extremely poor weed control was obtained. No adverse effects of cynmethalin on the developing crop were noted.

The hand-weeded plots were, subsequent to treatment application, rapidly inundated with re-growth. However, timely hand weeding no later than 25 days post planting is the most appropriate method of obtaining good broad-leaf weed control in sunflowers.

CONCLUSIONS

Preplant or pre-emergence chemicals did not give adequate weed control. Effective weed control may be obtained by a single timely weeding 3-4 weeks after planting.

Further studies are required to test the effects of different weed control methods on both grass weed numbers and final crop yield obtained.

12.6.5 THE SUSCEPTIBILITY OF SUNFLOWERS TO POST EMERGENCE APPLIED PENDIMETHALIN

SUMMARY

Studies were initiated to consider the effect of post emergence application of pendimethalin on Russian No. 4, a sunflower variety commonly grown in Botswana.

When the chemical was applied to the seedlings seven days after planting there was a significant increase in percent leaf damage and in seedling height and dry weight was reduced. When the chemical was applied 14 and 28 days after planting a similar increase in leaf damage was noted. However there was not such a marked effect on seedling height and weight.

The use of pendimethalin as a post emergence applied chemical for broad-leaved weed control in sunflowers is not recommended.

METHODS

Three studies were carried out;

1) the effect on Russian No. 4 seedlings of chemical application at 7 and 14 days after crop planting,

2) the effect on Russian No. 4 seedlings of chemical application at 14 and 28 days after crop planting and

3) the effect on three variety seedlings of chemical application at 14 days after crop planting.

For each study the same basic method was used. Seed of the sunflower varieties to be used was planted in soil filled pots. The herbicides were applied at a range of doses (tables below). Chemicals were applied using a knapsack sprayer delivering 260 l/ha spray solution.

RESULTS AND DISCUSSION

Pendimethalin caused unacceptable levels of damage to the crop when applied post-emergence, at any time up to 28 days after planting. Trifluralin, also recommended for pre-emergence application did not cause such significant levels of damage as pendimethalin.

When applied 7 days after planting pendimethalin caused a significant increase in leaf damage compared to seedlings similarly sprayed at 14 days after planting (Table 18). The leaf damage to seedlings sprayed with trifluralin at 7 days after planting was not as severe as that caused by the pendimethalin treatments.

Table 18. CHEMICAL DAMAGE TO RUSSIAN NO 4 SEEDLINGS

Treatments		% leaf damage				Plant height (mm)				Plant weight (g)	
Day sprayed:		7		14		7		14		7	14
Day assessed:	g/ha	21	35	21	35	21	35	21	35	35	35
1) Pendimethalin	750	10	10	8	20	191	379	194	360	1.3	1.3
2) Pendimethalin	1000	10	31	11	20	189	347	199	338	1.0	1.2
3) Pendimethalin	1250	15	35	13	25	182	313	183	298	1.1	1.0
4) Pendimethalin	360	10	21	10	21	205	417	212	246	1.2	1.3
5) Pendimethalin	480	10	30	10	23	208	373	217	409	1.3	1.2
6) Control		0	0	0	0	205	413	206	398	1.3	1.2
C.V.:		39.1% (21 days)				11.2% (21 days)					
		67.0% (35 days)				13.5% (35 days)				13.5%	
S.E.D (44 df)		2.20 (21 days)				14.1 (21 days)					
		8.34 (35 days)				31.7 (35 days)				0.10	
Significance level of treatments:		0.1% (21 days)				5.0% (21 days)					
		0.1% (35 days)				0.1% (35 days)				2.5%	

Table 19. CHEMICAL DAMAGE TO RUSSIAN NO 4 SEEDLINGS

Treatments		%leaf Damage				Plant height (mm)				Plant weight (g)	
Day sprayed:		14		28		14		28		14	28
Day assessed:	g/ha	21	42	21	42	21	42	21	42	42	42
1) Pendimethalin	750	33	6	-	13	264	498	-	550	1.6	1.6
2) Pendimethalin	1000	28	9	-	10	288	490	-	508	1.6	1.9
3) Pendimethalin	1250	33	36	-	10	239	382	-	519	1.2	1.5
4) Trifluralin	360	10	2	-	6	340	598	-	540	2.0	1.8
5) Trifluralin	480	25	8	-	8	299	516	-	554	1.7	1.5
6) Control		0	0	-	0	319	544	-	534	2.2	1.5
C.V:		83.8% (42 days)				13.3% (42 days)				18.7%	
S.E.D. (44 df):		4.76 (42 days)				43.6% (42 days)				0.19	
Significance level of treatments:		0.1% (42 days)				2.5% (42 days)				1.0%	

Table 20. CHEMICAL DAMAGE TO SEEDLINGS

Variety: 1) PNR 7204
2) SO 222
3) AS 543
Sprayed: 14 days post planting

Treatments		% leaf damage			Plant height (mm)			Plant weight (g)		
Day assessed:		21			42			42		
Variety:	g/ha	1	2	3	1	2	3	1	2	3
1) Pendimethalin	750	20	32	41	153	85	97	2.3	1.7	1.2
2) Pendimethalin	1000	20	21	30	136	91	106	2.7	1.6	1.8
3) Pendimethalin	1250	30	42	37	133	93	99	2.1	1.5	1.5
4) Control		0	0	2	155	95	104	3.1	2.0	1.7
C.V.:		67.9%			10.1%			23.3%		
S.E.D. (43 df):		9.81			7.14			0.28		
Significance level of treatments:		0.1%			n.s.			1.0%		

When pendimethalin (1250 g/ha) was applied to sunflower seedlings at 14 days after planting (table 19) leaf damage was significantly increased compared to the control plants. Other treatments, at both 14 and 28 days after planting did not significantly affect the seedlings' development.

A further three sunflower varieties were sprayed post emergence with pendimethalin. Percent damage to the leaves was increased when herbicide was applied. Seedling aerial dry weight was reduced, notably for cultivar PNR 7204 (Table 20).

CONCLUSIONS

The selective control of broad leaved weeds in sunflowers by use of post-emergence applied pendimethalin or trifluralin is not recommended.

When pendimethalin is applied to the crop at either 7 or 14 days post planting at rates as low as 750 g/ha, leaf damage occurs, as well as a reduction in plant dry matter produced. It is likely that this damage will have a detrimental effect on final crop yield.

When sprayed 28 days after planting the pendimethalin did not cause significant damage to the crop. Spraying of pendimethalin on PNR 7204, SO 222 and AS 543 at 14 days post planting caused unacceptable levels of leaf damage and reductions in seedling dry weight.

12.6.6 THE EFFECT OF POST EMERGENCE APPLIED HERBICIDES ON THREE MILLET CULTIVARS

SUMMARY

Glasshouse studies were initiated to screen ten compounds suitable for the control of *D. ferox* in millet. Chemicals noted for good control of *D. ferox* were tested on three locally available cultivars, Serere 6A, ICTP 8202 and ICTP 8203.

Acifluorfen, was found to adversely affect the developing millet seedlings. Its use for *D. ferox* control in millet is not recommended.

Control of *D. ferox* in the varieties tested is best achieved using terbuthylazine with metolachlor (1284.5 and 437.5 g/ha). Field trials will be required to consider any effect the chemicals may have on final crop yield.

METHODS

Seed of three locally available varieties of millet was planted according to variety in soil filled pots. A range of herbicides were applied to the seedlings at the recommended rate for the original crop and a reduced rate. At 42 days after planting seedling aerial plant matter was harvested and oven dried to constant dry weight.

RESULTS AND DISCUSSION

When used in groundnuts acifluorfen gives good control of *D. ferox*. When applied to Serere 6A, ICTP 8202 and ICTP 8203 severe leaf scorching was observed, leading to the death of the plants. Acifluorfen is not recommended for *D. ferox* control in millet.

Of the other chemicals tested only the bromoxynil with MCPA (337.5 and 400.0 g/ha) and atrazine with terbuthylazine (968.0 and 968.0 g/ha) combinations caused any leaf scorch of note, on ICTP 8203 and Serere 6A seedlings respectively. The spraying of MCPA should be avoided, although when sprayed in combination with bromoxynil in sorghum and maize this mixture is extremely effective for the control of *D. ferox*.

CONCLUSIONS

The majority of the chemicals tested had no effect on the seedling leaves. The exception, for the varieties tested, was acifluorfen which caused extreme leaf scorch. Many seedlings were killed.

All three varieties had reductions in aerial dry weights when treated with atrazine and cyanazine. This treatment had not caused significant visible damage to the seedlings. For effective *D. ferox* control in Serere 6A, ICTP 8202 and ICTP 8203 the most appropriate treatment is terbuthylazine with metolachlor (1284.5 and 437.5 g/ha).

Until field trials have been undertaken to evaluate any effects on crop yield extreme caution should be exercised in using chemicals to control *D. ferox* in millet.

Table 21. <u>THE EFFECT OF HERBICIDES ON SERERE 6A SEEDLINGS</u>

Treatment		Rate applied (g/ha)	Percent damage, days after spraying 7	14	Four plant aerial dry weight (g).
Terbuthylazine	*	1284.5/437.5	0.0	0.0	4.43
+ metolachlor		917.5/312.5	0.0	0.8	3.53
Bromoxynil	*	337.5	0.0	0.0	4.63
		225.0	3.3	0.8	4.80
M.C.P.A.	*	400.0	0.0	0.0	3.67
		200.0	0.0	0.0	4.30
Bromoxynil	*	337.5/400.0	0.8	0.8	3.57
+ M.C.P.A.		225.0/200.0	0.8	0.8	4.77
Atrazine	*	968.0/968.0	0.8	16.6	6.23
+ terbuthylazine		605.0/605.0	1.7	0.8	5.83
Bromofenoxim	*	500.0	0.8	0.0	5.70
		250.0	0.0	0.0	5.57
Atrazine	*	242.0/242.0/375.0	0.8	0.8	5.33
+ terbuthylazine		121.0/121.0/250.0	0.0	0.0	5.83
+ bromofenoxim					
Atrazine	*	562.5/562.5/375.0	0.8	0.0	3.83
+ terbuthylazine	*	375.0/375.0/250.0	0.0	0.0	4.20
+ metolachlor					
Bendioxide	*	1200.0	0.8	0.0	4.90
		960.0	0.8	0.0	5.43
Atrazine	*	1250.0	0.0	0.0	3.50
		960.0	0.0	0.0	4.75
Cyanazine	*	832.5/417.5	0.0	0.0	3.73
+ atrazine		500.0/250.5	0.0	0.0	4.03
Acifluorfen	*	240.0	50.0	90.0	3.63
		120.0	1.3	1.7	3.57
Control (no chemical)			0.0	0.0	6.10
C.V.:					20.03%
S.E.D. (48 df):					0.76
Significance level of treatments:			n.s.	n.s.	0.01%

Table 22. <u>THE EFFECT OF HERBICIDES ON ICTP 8202 SEEDLINGS</u>

Treatment		Rate applied (g/ha)	Percent damage, days after spraying 7	14	Four plant aerial dry weight (g).
Terbuthylazine	*	1284.5/437.5	0.0	0.0	4.16
+ metolachlor		917.5/312.5	0.0	0.0	3.96
Bromoxynil	*	337.5	0.0	0.0	4.46
		225.0	0.0	0.0	5.70
M.C.P.A.	*	400.0	0.0	0.0	3.86
Bromoxynil	*	337.5/400.0	0.0	0.0	4.40
+ M.C.P.A.		225.0/200.0	3.3	0.0	4.46
Atrazine	*	968.0/968.0	0.0	0.0	4.03
+ terbuthylazine	*	605.0/605.0	0.0	0.0	5.10
Bromofenoxim	*	500.0	0.0	0.0	4.63
		250.0	0.0	0.0	5.93
Atrazine	*	242.0/242.0/375.0	0.0	0.0	4.23
+ terbuthylazine	*	121.0/121.0/250.0	0.0	0.0	5.60
+ bromofenoxim					
Atrazine	*	562.5/562.5/375.0	0.0	0.0	4.26
+ terbuthylazine		375.0/375.0/250.0	0.0	0.0	4.40
+ metolachlor					
Bendioxide	*	1200.0	0.0	0.0	5.20
		960.0	0.0	0.8	5.13
Atrazine	*	1250.0	0.0	0.0	5.03
		960.0	0.0	0.0	5.03
Cyanazine	*	832.5/417.5	0.0	0.0	2.66
+ atrazine		500.0/250.5	0.0	0.0	5.37
Acifluorfen	*	240.0	45.3	89.6	2.83
		120.0	7.0	45.0	3.86
Control (no chemical)			0.0	0.0	4.96
C.V.:					19.16%
S.E.D. (48 df):					0.72
Significance level of treatments:			n.s.	n.s.	1.00%

Treatment		Rate applied (g/ha)	Percent damage, days after spraying 7	14	Four plant aerial dry weight (g)
Terbuthylazine	*	1284.5/437.5	0.0	0.0	3.76
+ metolachlor		917.5/312.5	0.0	0.0	3.83
Bromoxynil	*	337.5	0.8	0.0	5.23
		225.0	0.8	0.0	4.36
		200.0	0.0	0.0	4.43
Bromoxynil	*	337.5/400.0	6.6	7.8	3.53
+ M.C.P.A.		225.0/200.0	0.0	0.0	4.13
Atrazine	*	968.0/968.0	0.0	0.0	4.90
+ terbuthylazine		605.0/605.0	0.0	0.0	4.46
Bromofenoxim	*	500.0	0.0	0.0	4.96
		250.0	0.0	0.0	5.80
Atrazine	*	242.0/242.0/375.0	0.8	0.0	5.46
+ terbuthylazine		121.0/121.0/250.0	0.0	0.0	5.50
+ bromofenoxim					
Atrazine	*	562.5/562.5/375.0	0.0	0.0	3.20
+ terbuthylazine		375.0/375.0/250.0	0.0	0.0	4.33
+ metolachlor					
Bendioxide	*	1200.0	7.0	0.0	4.43
		960.0	0.0	0.0	4.50
Atrazine	*	1250.0	0.8	0.0	4.43
		960.0	0.0	0.0	4.96
Cyanazine	*	832.5/417.5	0.0	0.0	3.00
+ atrazine		500.0/250.5	0.0	0.0	4.46
Acifluorfen	*	240.0	64.6	96.6	2.20
		120.0	4.2	25.0	4.30
Control (no chemical)			0.0	0.0	5.30
C.V.:					21.62%
S.E.D. (48 df):					0.77
Significance level of treatments:			n.s.	n.s.	1.00%

12.7 The Development of the Cultivator Sprayer

SUMMARY

In the Barolong area are a number of farms greater than 20 hectares in size. In addition there a large number of farmers owning, or having access to tractors and tractor mounted cultivator-bars. Conventional spraying equipment is however found on only a few farms in the region.

In order that timely and effective control of weeds might be achieved on larger farms a simple spray device, mounted on a tractor drawn cultivator bar was designed and built.

METHODS

The sprayer was based around a commercially available, tractor mounted, spring tine (duck feet), cultivator bar. A cradle of flat mild steel bar was made bolted onto a cultivator bar. The cradle held a 450 litre purpose of supporting spray nozzles.

The sprayer solution was drawn out of the spray tank and through a small roller-vane pump mounted on the tractor's P.T.O. shaft. It then passed through a pressure regulating valve and either returned to the bottom of the spray tank or passed to the spray nozzles on the "boom". Each nozzle had its own on/off switch.

The sprayer was fitted with yellow "polijets", giving a spray output measured at not less than 250 litres per sprayed hectare. The cultivator-sprayer band sprayed terbuthylazine and metolachlor at the recommended rate of 1284.5 and 437.5 g/ha respectively.

RESULTS AND DISCUSSION

The spraying of terbuthylazine with metolachlor (1284.5 and 437.5 g/ha) at two field sites gave weed free bands within the crop row for up to 110 days after spray application. Subsequent to theinter-row cultivation there was some re-growth of D . ferox .

The hand weeding of two 0.25 hectare sites 25 days after planting was, on the large areas involved both slow and tedious. At one site extremely rapid re-growth of D . ferox occured. At both sides an area was sprayed using a knapsack sprayer. The terbuthylazine with metolachlor (1284.5 and 437.5 g/ha) gave good weed control, the sprayed area at one site remained free of D . ferox for 105 days after spraying.

In areas adjacent to the trial sites farmers mechanically weeded at 60 days after planting. One site was cultivated using a tractor mounted cultivator bar, the other was hand weeded. Mechanical cultivation left large numbers of weeds in, or close to, the crop row. The hand weeding was extremely slow. At both sites weed re-growth occurred. Extremely low yields were obtained (Table 24).

Table 24. SORGHUM YIELDS OBTAINED WITH DIFFERENT METHODS OF WEED CONTROL

Weed Control Method	Tonnes Per Hectare Site 1	Site 2
Cultivator - sprayer	1.10	0.84
Knapsack - sprayer	0.80	0.70
Hand weeded 25 days post planting	0.89	0.00
Hand weeded 60 days post planting	0.44	0.00

Despite high costs for mechanised weed control techniques (Table 25), where the cultivator sprayer was used the increased crop yields gave increased financial return (based on a 40 hectare holding operating a cultivator sprayer over 5 years). The low clay content soils in the Barolong region do give some cause for concern. In all cases where it is proposed to spray herbicide a thorough soils analysis of the area will be required.

Table 25. COSTS FOR USING DIFFERENT WEED CONTROL

Weed Control Method	Cost (P/ha)	Profit (P/ha) Site 1	Site 2
Cultivator - sprayer	34.07	277.23	203.65
Knapsack - sprayer	38.74	187.66	159.36
Hand - weeded 25 days post planting	11.00	240.87	0.00
Hand - weeded 60 days post planting	11.00	113.52	0.00

Grain sorghum price: P283/t. Costs based on a 40 hectare holding. No other inputs included in costings.

At the end of the season farmer interest in the cultivator sprayer was intense. The findings of the department have been passed on to the extension department for field implementation.

CONCLUSIONS

The cultivator sprayer is appropriate to farm size in the Barolong region, is relatively cheap to construct and offers the potential for timely, effective and profitable control of broad leaved weeds in sorghum.

Hand weeding is possible over smaller areas of D. ferox infestation. The lack of available man-power and the lengthy period of time involved in weeding large areas detract from making this a viable proposition on holdings larger than 5 hectares in size.

The knapsack sprayer is most appropriate for weed control on holdings of up to 10 hectares.

13.1 FARMER PERCEPTIONS

In 1985-86, 28 Francistown cooperator farmers identified what they felt were major factors attributing to their low yields (Table 1). This question was not designed to tell us what problems really exist, but what farmers perceive their problems to be. In 1986-87, we asked the same 28 farmers the same question (Table 2). This was to give us an idea of trends over time, if there were any. This data is limited, however, because of the small size of the data set. In mid-1987, 306 farmers were asked a similar question in conjunction with the Matsitama/Mokubilo Pilot Grazing Study (Table 3). The large size of this data set, will make the results more reliable.

Are there any trends over time and between locations? Definitely, poor rainfall is a major factor which farmers acknowledge as causing low yields. After that the results are more obscure. Bird damage appears to have been a problem for farmers in both the Francistown and Matsitama/Mokubilo areas this past season. Almost twice as many farmers as the year before pinpointed bird damage as a problem. Male headed households had more of a problem with birds then female headed households. Livestock damage was reported in both years by Francistown Cooperator farmers as being a problem.

Mostly farmers reported not having a problem with equipment, or labour. Specifically in the Francistown area, a lack of weeding labour was not a problem. Farmers perceptions of their problems are difficult to analyse, however, as they change with the weather so to speak.

Table 1: FACTORS WHICH PREVENTED FARMERS FROM GETTING GREATER CROP PRODUCTION (PERCENT), COOPERATOR'S SURVEY, FRANCISTOWN AREA, 1985-86

		VILLAGE:			SEX OF HEAD OF HHD:		CATTLE OWNERSHIP:				
	TOTAL	MATO	MATH	MARA	MALE	FEMALE	0	1-15	16-35	36-70	> 70
Poor Rain	100	100	100	100	100	100	100	100	100	100	100
Farmer Sickness	56	11	40	0	24	9	50	30	0	0	0
Insects	46	0	80	56	47	45	75	40	44	33	50
Poor Plant Establishment	46	20	70	56	62	27	50	41	56	0	100
Wild Animal Damage	43	56	20	56	47	36	0	40	56	67	50
Livestock Damage	43	11	70	44	47	36	100	30	56	0	0
Diseases	39	33	60	22	47	27	50	40	44	0	50
Birds	35	20	60	33	45	27	50	34	44	0	50
Lack of Labour	29	11	60	11	29	0	75	30	22	0	0
Lack of Draught	25	0	50	22	24	27	75	20	22	0	0
Too Many Weeds	21	11	20	33	29	9	25	20	33	0	0
Equipment Problems	11	22	10	0	12	9	0	10	22	0	0
Need More Land Destumped	7	0	20	0	6	9	25	10	0	0	0
Lack of Weeding Labour	4	0	10	0	6	0	0	10	0	0	0

Table 2: FACTORS WHICH PREVENTED FARMERS FROM GETTING GREATER CROP PRODUCTION (PERCENT), COOPERATORS' SURVEY, FRANCISTOWN AREA, 1986-87

FACTORS		VILLAGE:			SEX OF HEAD OF HHD:		CATTLE OWNERSHIP:				
	TOTAL	MATO	MATH	MARA	MALE	FEMALE	0	1-15	16-35	36-70	> 70
Poor Rain	100	100	100	100	100	100	100	100	100	100	100
Drought	79	100	67	67	83	70	75	82	87	100	0
Bird Damage	64	80	44	67	71	60	50	73	38	100	50
Livestock Damage	43	40	44	44	50	30	50	36	62	0	50
Too Many Weeds	32	20	0	78	33	30	0	55	12	22	50
Wild Animal Damage	29	20	22	44	33	20	25	36	25	0	50
Poor Plant Establishment	21	10	33	22	17	30	25	18	25	33	0
Farmer Sickness	21	20	22	22	33	0	25	27	12	0	50
Lack of Draught	18	0	22	33	11	30	25	27	0	0	50
Need More Land Destumped	14	0	0	44	11	20	0	18	25	0	0
Lack of Ploughing Lbr	11	10	0	22	11	10	0	9	25	0	0
Insects	7	0	0	22	6	10	0	9	0	33	0
Too Little Food To Work	7	0	0	22	11	0	0	9	25	0	0
Lack of Weeding Labour	4	0	0	11	0	10	0	9	0	0	0
Diseases	4	0	0	11	6	0	0	0	0	33	0
Lack of Harvesting Lbr	4	0	0	11	6	0	0	0	12	0	0
Not enough Seed	4	0	0	11	0	10	0	9	0	0	0
Equipment Problems	0	0	0	0	0	0	0	0	0	0	0

Table 3: FACTORS WHICH PREVENTED FARMERS FROM GETTING GREATER CROP PRODUCTION (PERCENT), MATSITAMA/MOKUBILO PILOT GRAZING AREA STUDY, 1986-87

FACTORS	TOTAL	AREA:		SEX OF HEAD OF HHD:		CATTLE OWNERSHIP:				
		MATS	MOKU	MALE	FEMALE	0	1-15	16-35	36-70	> 70
Poor Rain	56	69	35	58	54	57	64	59	39	66
Bird Damage	50	67	21	52	52	48	62	52	34	54
Insect Damage	44	64	11	44	50	48	54	46	24	48
Lack of Draught Power	39	57	9	38	48	60	46	35	24	26
Lack of Advice from GOB	33	52	0	24	37	40	36	29	23	36
Crop Diseases	29	46	0	30	37	38	39	23	17	24
Poor Plant Establishment	25	40	1	27	24	27	30	23	13	36
Too Little Seed	22	34	1	21	35	57	39	15	8	4
Equipment Problems	19	28	4	19	28	42	26	12	8	4
Poor Soils	18	26	4	18	30	32	32	13	5	6
Too Many Weeds	16	21	7	15	26	28	20	8	10	14
Lack of Labour	11	11	12	11	15	15	12	14	8	8

13.2 Farmer groups

13.2.1 FARMER GROUPS AS A TOOL IN ON-FARM RESEARCH

Working with groups of farmers, instead of individual farmers, is an approach currently being used by a number of on-farm researcher teams in Botswana. The different teams are using farmer groups for different reasons and different purposes.

The following is a discussion on how and why the use of farmer groups has evolved in Tutume Agricultural District. The advantages observed and issues arising are also briefly described. The discussion is excerpted from "1986-87 Farmer's Groups Technology Options Testing Trial", by. F. Worman et.al. , ATIP Progress Report F87-6.

It should be noted that while this paper describes progress to date, the methodology is still evolving. Also, it is recognized that the potential for using the group approach for conducting various types of research and extension activities is much broader than the specific purposes for which it has been used in Tutume Agricultural District.

Before the 1985-86 cropping season, the ATIP Francistown staff decided to intensify FMFI (Farmer Managed, Farmer Implemented) activities by forming a farmer's group in Matobo. The first year the group was limited to a single trial (double ploughing) and to the single village. The approach of recruiting interested farmers through a kgotla meeting was used to recruit 15 farmers. Twelve farmers planted trials and participated in the monthly meetings to discuss the trials and cropping problems in general. The AD from Matobo actively participated in the group meetings. The double ploughing trials were laid out in side-by-side comparisons with a traditional check plot. Both plots were relatively small, 10 metres by 50 metres. In addition to on-going monitoring through the monthly meetings, ATIP staff recorded dates of ploughing, planting, weeding, and harvesting, and weighed the resulting yield from both the trial plot and the traditional check plot. Mid-Season and End-of-Season Farmer Assessment Surveys were conducted to obtain a more formal farmer evaluation of the trials. Near the end of the growing season a field day was held with participation by extension personnel and farmers from the other two villages where ATIP worked. The field day was favourably received and there was a great deal of discussion among the farmers.

Following the favourable experience working with a group of farmers in Matobo, it was decided to expand the farmer's group concept both in terms of the number of technologies available for testing and to the other two villages. Thus at the beginning of the 1986-87 season kgotla meetings were held in all three villages and the previous years work was described. Dates were set for meetings of those interested in participating in farmer's groups and a total of 97 farmers chose to participate. An increased number of technologies were discussed and farmers were able to choose one or more for testing. Again ATIP staff helped stake the side-by-side comparison plots. Extension participation, both by ADs and by district and regional personnel continued to be good. Farmer's groups also became a forum for researchers and extension staff to discuss new ideas with farmers. Data collected included dates of operations, yield data, and Baseline and End-of-Season Surveys. Well attended field days were held in all three villages.

The two years had several characteristics in common. First, trials were laid out in side-by-side comparisons so that farmers could more easily compare results and so the yield data for comparisons would be more meaningful. Side-by-side comparisons are also advantageous for field day activities and the data can be analysed across locations using a paired t-test. Second, plots were kept small and the same size to reduce the farmer's risk and to facilitate implementation. Third, the active participation of extension staff (particularly ADs) and other researchers was encouraged. Finally, a basic set of data, including socio-economic data, was collected for each year.

The farmer's group approach as it has evolved in the Francistown area has several advantages:

(a).The farmer's groups are an integral part of the ATIP Francistown research strategy. Because of limited time for conducting researcher managed trials, the farmer managed and implemented trials conducted through the group format can be used to expand the number of technologies which can be researched. Those technologies which need very specific testing, or a great deal of data collection can continue to be handled as RM trials. Testing of items outside the primary research focus and items which have been researched and are ready for broader farmer managed testing can be presented to farmers through the group format. The group approach thus allows for an improved use of researcher time.

(b).The linkage of farmers, extension and research has increased communications among these groups. Farmers, through their choices of trials, provide valuable information on what technologies are of potential interest to farmers in general. Farmers can also give early and continuing feedback to extension and research on problems with technologies. Farmer participation also promotes the inclusion of farmer identified technologies in the research programme, and since farmers do continual research in their own fields, the inclusion of their experiences in the research-extension framework is advantageous.

(c).The inclusion of extension personnel in the research activities means that they have input on and are familiar with new technologies as they are developed, and so are in a better position to extend the technologies than if they were completely new.

(d).There are a number of advantages to farmer based field days. First, there is a great deal of interest when farmers describe their experiences and conclusions to other farmers. Second, inter-village competition can develop, lending an incentive to try new technologies. Third, extension and researchers can get added information, as farmers tend to ask more questions of other farmers. The use of side-by-side comparisons facilitates this discussion.

(e).The farmer's groups, as implemented in the Francistown Area, do not have an organization apart from the research programme. They have been established as a part of the overall research programme and as such will probably not continue beyond the life of that programme. In a basic sense the groups are new each cropping season. However, this does not preclude the inclusion of the group approach to research in extension activities or other formalized groups within the villages.

Several problems have developed in relation to the farmer's groups.

(a). Farmer's groups tend to serve as a focal point for extension and research to interact with farmers about subjects that are not part of the FMFI trials work. While this type of exchange is useful for all parties, it may become too extensive, and thus have a negative effect by taking time needed for actual trials work. The groups, because they are there on a regular basis, also become a focal point for allowing out-of-country visitors an opportunity to meet with a large group of farmers in one location. Again occasional visitors are helpful to the group, but too many detracts from the group activities.

(b). A continuing question is how much support, in terms of seed, equipment and other inputs, should be provided by researchers. It appears obvious that any new equipment, seed variety, or other input, which is not locally available, must be provided if farmers are to conduct appropriate trials. However, it may be argued that farmers should provide all locally available inputs. ATIP Francistown has taken the position that providing small quantities of measured seeds for standard sized trial plots provides better comparisons than having farmers provide their own seeds and determine the quantity sown. It also aids in trials analysis and seed quantities do not exceed 200 grams per plot for grains, and 1 kg per plot for large seeded legumes.

(c). A related question is when do farmers stop testing and start adopting? Farmers have indicated an interest in planting larger areas, with ATIP provided inputs. The problem then becomes one of determining when a farmer is conducting a large scale trial (which may deserve support) and when the trial is actually an adopted technology and should be fully farmer supported. There is an additional question of what to do when a piece of equipment is not locally available, but farmers wish to use it extensively.

(d). Results from FMFI trials handled through a group format, provide limited data which is not the best for in-depth analysis. There is thus a trade-off between obtaining farmer opinion and limited field data on a technology and obtaining the more detailed data provided by RM (Researcher Managed) trials which are amenable to more complex analysis. This question of how much data is necessary, is one reason why FMFI group work must be part of a larger research programme, so that questions needing more intensive analysis can be handled by RM research. The development of assessment tools and ways of collecting more statistically analysable data from the extensive FMFI trials are important methodological concerns.

(e). One of the problems associated with group trials is the desire of participants to have researchers visit the trial sites on a regular basis, as is done with RM trials. With a large number of farmers participating in groups, individual field visits by research and/or extension staff is impractical. Yet there is a strong desire for such visits on the part of the participants.

Farmer's groups will continue to be a part of the Francistown research approach. However, several changes are being considered for the third year of group work. First, farmers will be encouraged to continue planting side-by-side comparisons, which must be planted on the same day for best comparisons. Farmers wishing to make large scale comparisons of technologies on their own will be encouraged to do so. In some cases ATIP has seed from previous years which will be made available to farmers interested in planting large plot comparisons on a first come basis. Second, ATIP will support extension personnel in establishing farmer technology options testing groups in non-ATIP villages. These groups will probably be limited in the number of technologies considered (mostly technologies already promoted by extension) and in the number of farmers participating. The extension led groups will provide a trial of the usefulness of farmer's testing groups in the extension process. Finally, an attempt will be made to ascertain how many of the farmers in the original group in Matobo have actually adopted the double ploughing practice, and to what extent.

Section 14. AGRICULTURAL DEVELOPMENT NGAMILAND PROJECT (ADNP)

PREFACE

In this summary for the 1986/87 cropping season the focus will be entirely on irrigation. To begin with the background to why the ADN project decided to investigate irrigation. There is a discussion about what role irrigation could play for the project area. Finally the first experience obtained from the irrigation plot in Etsha 6 is presented.

14.1 Introduction

In the sixth National Development Plan emphasis is laid upon Rural Development. The strategy for rural development stresses the following objectives:-

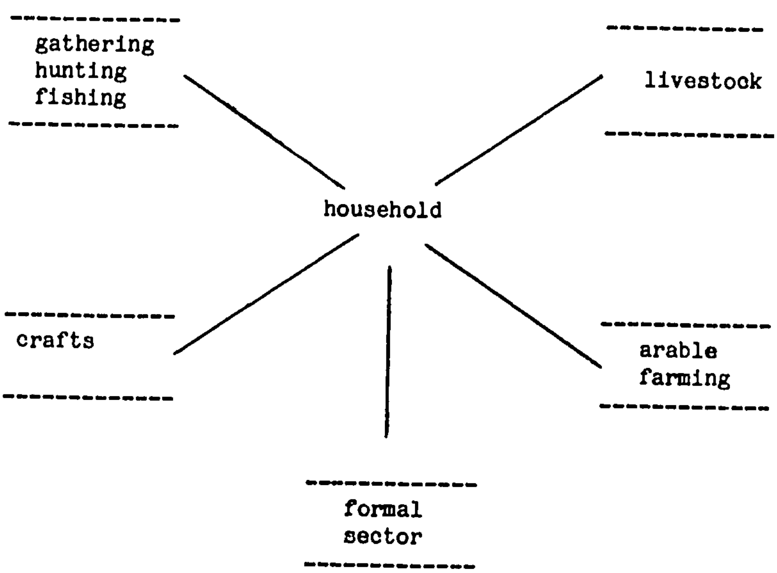
- development of cash earnings
- productive employment
- increased food production

It is hoped that this strategy will reduce reliance on food aid, and to provide an alternative to migration for employment to urban areas.

14.2 The Traditional Farming System vs Development Objectives.

The traditional farming system can schematically be divided into five main activities (fig. 1) each one contributing to the rural households subsistance.

Figure 1. THE RURAL HOUSEHOLD AND ITS SUBSISTENCE SOURCES.



It is of interest to study each one of the five "boxes", how their importance change with development, time and population growth.

14.2.1. LIVESTOCK

The livestock sector is without doubt by far the most important contributor to the rural households subsistance and a very important cash income source. It is however not likely that the livestock sector can sustain its relative importance. The decline in relative importance of the livestock sector is partly due to the rapid increase of the population. The major factor is however the livestock production system. The livestock production is not based on sustainability, it is depleting and destroying the resource it is based upon the pasture land.

14.2.2. GATHERING, HUNTING AND FISHING

In former times it is likely that this sector was the main contributor to the subsistance of the rural population. The relative importance of gathering (used as a common expression for the sector) is rapidly declining but it is still an important contributor, especially during drought years. There are many factors contributing to the decrease in importance of this sector. Population growth obviously ,the destruction of resources the sector is based on, destruction caused by an increasing pressure on the land both from people and from domestic animals. Lastly the break down of the traditional system to protect these resources.

14.2.3. CRAFTS

Under this heading comes crafts like baskets and other artifacts, also craftman's work like carpentry, traditional house building, the production of traditional tools and utensiles etc.

The importance of baskets and other artifacts has increased due to efforts made by different organisations. However the importance of traditional craftmanship is declining. Tools and utensiles traditionally made, can now be substituted with fabricated items, which are often more suited for their purposes.

14.2.4. ARABLE FARMING

Arable farming has not been and to some extent is still not as important as is often implicated by different authorities. By experience and tradition, rural households know that as the situation is they can not rely more on arable farming. The traditional arable farming system is developed and relied upon as much as natural constraints admit. It is an extensive system with minimal input that in good years will give a fair return and in bad years no return. The extensivity of the system ensures that the losses in bad years are kept at a minimum. It is obviously that an activity that regularly will hardly return anything for a number of consequtive years can not be relied upon to any greater extent.

14.2.5. THE FORMAL SECTOR

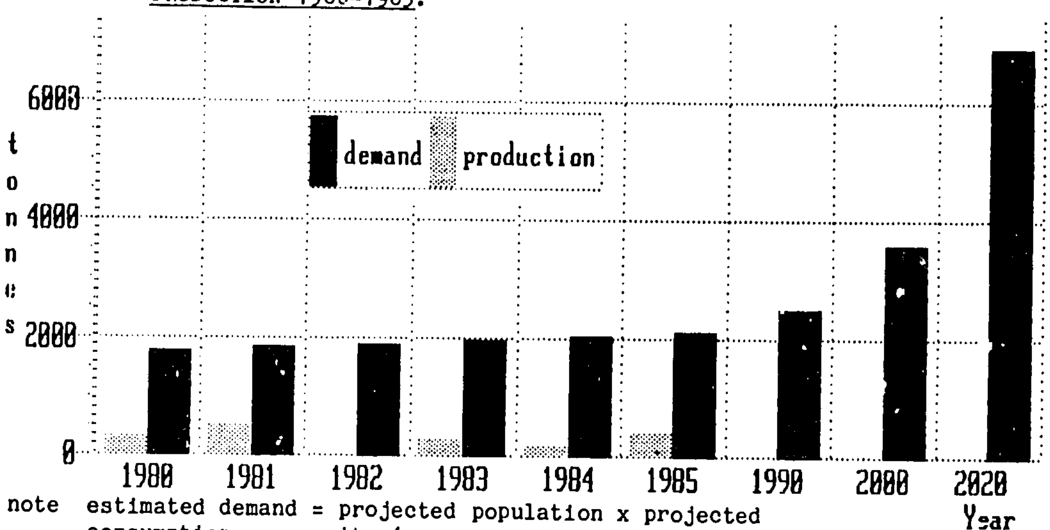
The formal sector is the sector that has increased most in significance. It is also the sector towards which rural households put their hopes and aspirations. It has an enormous magnetism since entering the sector means security plus an income and living standard that vastly exceeds what can be expected from the rural farming system. It is however obvious that most of the people aspiring to enter the formal sector will be dissapointed. They are left with the choice between unemployement in urban centres or return to the hardships of the rural dwelling life. More and more people are making the choice in favour of the first alternative.

14.2.6. CONCLUSIONS

With a situation with declining importance of the gathering/hunting sector, with a livestock sector that is close to collapsing, due to non existent grass land management and livestock control. A formal sector that can not keep up with population growth. Emphasis and hope have been put upon the arable sector to meet the objectives of employment creation, income generation and food security for rural households. It is doubtful if the traditional rainfed and molapo farming systems can be improved to an extent that is even close to what is required for any noticeable effect towards these objectives.

In Figure 2. the estimated demand of cereal food grains is projected and for the years 1980 - 1985 compared with estimated production.

Figure 2. FUTURE DEMAND FOR FOOD GRAINS COMPARED TO ESTIMATED PRODUCTION 1980-1985.



note estimated demand = projected population x projected consumption per capita (source SMEC Botswana Market for food grains at 1987 p B3)

note estimated production = average yield per planted area (Agric. Statistics) Maun Region x Arable lands areas

From Figure 2. it can be concluded that for the past six years the local production has been able to meet 20 percent of the demand. The present production has to be increased five times to meet the present demand, it has to be increased eight fold by the year 2 000 and eighteen times by the year 2020. On top of this the arable system must be able to overlap regular drought cycles of up to five years.

For the arable farming to have any major impact on the development objectives it is clear that, in this area with available water sources, irrigation could have such an impact.

14.3 Irrigated Arable Farming vs Development Objectives

14.3.1 INCREASED AND SECURED FOOD PRODUCTION

It is not likely or wished that irrigation should replace traditional farming. Irrigated arable farming should be a complement to and a backup of the traditional farming system. This function as complement and backup should not only be on a national basis. The best effect on rural development will be if irrigated farming and traditional farming complements each other on farm level. A farmer has his traditional land in dryland or molapo area in addition to that he has a portion of land that is developed for irrigation. In years of adequate rainfall for successful traditional farming, irrigation might not be carried out at all. If it is carried out it is only for one crop per year preferably during the winter season. In that way irrigation does not compete or interfere with the traditional farming system, which in good years is more cost effective than irrigation. In years with low rainfall or when other factors are causing crop failure, irrigation can be intensified. It is perfectly possible to harvest up to three yields per year.

14.3.2 RURAL EMLOYMENT AND INCOME GENERATION

The objective of increased food production will without doubt be reached in the most rapid way through large scale commercial irrigated farms. Such a development will also to some extent create employment for rural households. The number of employment opportunities will be affected since it is obvious that large scale commercial farms will have a higher degree of mechanisation than smaller farms. With a development towards large scale irrigation a number of factors should be considered. Most of the land suited for irrigation is already occupied by traditional farmers. In order to implement large scale farming these farmers have to move to areas with not so good soils, or more likely give up their land for employment on the new commercial farm. What is then created is a landless farm labour group in the society. Future possibilities for these farmers or their offspring to involve themselves in irrigated farming is lost.

ADNP is concentrating on irrigation systems that can be used by local small scale farmers. Together with traditional farming, it is believed that irrigation can provide enough employment and income to be an alternative to labour migration to urban areas.

14.4 The Etsha 6 Irrigation Plot

14.4.1 THE SET UP

In order to properly assess the viability of irrigation from the perspective of the small scale farmer, the ADNP decided to start to obtain practical experience and data on irrigation.

An 8 ha sprinkler irrigated plot was developed during 1986 and the first crop was planted in January 1987.

An additional irrigation plot is planned in the area known as the Nokaneng flats. The plot is planned to be in use during August 1988. By that time it is planned that the Thaoge Flow Restoration project under the department of Water Affairs will be able to provide a reliable water source into the area. On this plot emphasis will be on surface irrigation methods.

The eight hectare plot in Etsha is situated on sandy soil. Estimated water holding capacity is 80-100 mm/meter soil. The infiltration rate is high, more than 200mm/hour. (see ADNP Technical Report No. 2).

14.4.2 THE FIRST CROP

During January 1987 the following crops were planted:

Crop	Variety	Area planted
Maize	Kalahari Early Pearl	13 000m^2
"	Pioneer 473	7 000m^2
"	Saffola R0104	1 000m^2
Sorghum	Segaolane	7 000m^2
Groundnuts	Sellie/ 55-473	3 500m^2
Cowpeas	ER 7	3 000m^2
"	IT82D-641	1 000m^2
"	TVX3236-015	"
"	B 005-C	"
"	B 111-A	"
"	B 097	"
"	IT82E-9	"
Millet	Serere 6A	1 400m^2
Dollichos lablab		1 400m^2

The results from the first crop on the irrigation plot were disappointing, when considering the yields obtained. This was mainly due to unexpected infestations with pests and crop diseases. The irrigation equipment was also partly disappointing.

In this summary emphasis will be put on the results and experienses with maize, the irrigation method and on the irrigation equipment.

14.4.3 IRRIGATION METHOD

To estimate the crop water recuirement the Pan Evaporation Method as described in Crop Water Requirements by J.Doorenbos and W.O.Pruitt (197) was used. Which gives the crop evapotranspiration in the formula below

$$ETcrop = Kc * Kp * Epan$$

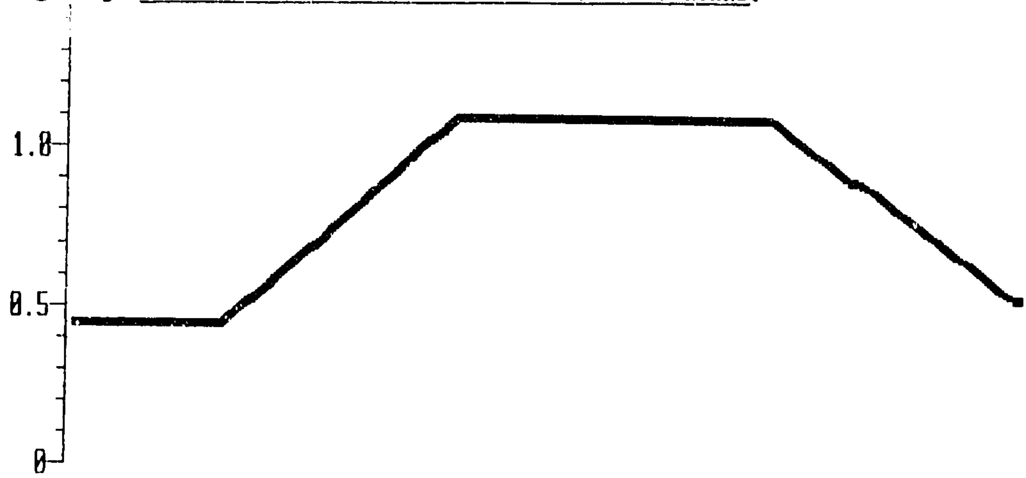
where ETcrop = Crop evapotranspiration
Kc = Crop coefficient
Kp = Pan coefficient
Epan = Pan evaporation in mm/day

As can be seen from the formula the crop water requirement as estimated with this method, depends on three factors. The crop coefficient, the pan coefficient and the pan evaporation.

14.4.3.1 CROP COEFFICIENT

The crop coefficients was calculated from the same publication. In figure 3 the crop coefficients for maize planted in January is presented.

Figure 3. CROP COEFFICIENTS FOR MAIZE PLANTED IN JANUARY.



14.4.3.2 PAN COEFFICIENT

The Pan coefficient is harder to determine. Its value varies with relative humidity, wind speed and the vegetation surrounding the Pan.

The Pan coefficient was with the help of the same source estimated to 0.6. Other sources indicate that values as high as 0.8 might be more correct for the area (SMEC 1937). It is very disturbing not to be able to determine the Pan coefficient more accurately. In table 1 the Pan evaporation readings in Etsha are presented for March to December 1987. The different potential evapotranspirations (ETp) obtained with different Pan coefficients are compared with average ETp for Etsha, calculated from Meterological data for Maun and Shakawe. (ADNP Technical Report No 2.)

Table 1. PAN EVAPORATION ETSHA 6 MARCH TO DECEMBER 1987, POTENTIAL ETP VALUES WITH DIFFERENT CROP COEFFICIENTS AND AVERAGE ETp FOR ETSHA. MM/DAY.

Month	Epan	Epan*0.6	Epan*0.7	Epan*0.8	ETp Etsha
Mar	7.5	4.5	5.2	6.0	5.9
Apr	8.4	5.0	5.9	6.7	5.3
May	6.5	3.9	4.6	5.2	4.3
Jun	5.2	3.1	3.6	4.2	3.5
Jul	7.5	4.5	5.2	6.0	3.7
Aug	6.8	4.1	4.8	5.4	4.8
Sep	7.0	4.2	4.9	5.6	6.3
Oct	7.0	4.2	4.9	4.9	7.0
Nov	8.9	5.3	6.2	7.1	6.7
Dec	6.5	3.9	4.6	5.2	7.0
Total mm	2181	1306	1526	1743	1671

As can be seen from Table 1, the Pan coefficient have quite significant impact when trying to estimate the crop evapotranspiration. In Table 2, the effect on the irrigation of a maize crop planted in September is presented.

Table 2. IRRIGATED AMOUNT ON MAIZE PLANTED IN SEPTEMBER DEPENDING ON WICH PAN COEFFICIENT THAT IS USED AND WITHOUT CONSIDERATION TO RAINFALL. APPLICATION EFFICIENCY IS 0.7.

Pan Coefficient	0.6	0.7	0.8	ETp Etsha
Crop Water Demand	457	531	603	684
Irrigation mm	653	758	862	977

The disadvantage with the inaccuracy in determining the Pan coefficient is quite big. The difference in irrigated amount of water between a Pan coefficient of 0.6 compared to 0.8 is 2 000 m^3 per hectare. Losses in yield by using to low coefficient is impossible to predict, but can be of considerable amounts.

14.4.3.3 PAN EVAPORATION

A Class A Pan was used to measure Pan evaporation. The Experience is that it is very hard to read the Pan accurately. In addition to this, after each good rain the pan is full and the reading is lost. The very rough readings of the pan evaporation together with the unceartainty in estimating the pan coefficient, raise the question if it would not be as good to use meteorological data that are available for Maun and Shakawe. In table 1 and 2 potential evapotranspiration and crop water recuirements are compared, when using pan evaporation and meteorological data.

14.4.3.4 WATER BUDGET

The Crop Evapotranspiration rates were used together with rainfall data in a water budget in order to estimate the available soil moisture for the crop. With the help of the water budget, irrigation intervalls and water requirements were estimated.

How much to irrigate was decided with the help of estimated rooting depth and application efficiency. The rooting depths was checked by digging pits and by neutron probe readings. A rule of thumb for maize appears to be: The roots goes as deep as the crop is high but stops at about 1.0 to 1.3 meters. In addition to the water budget, tensiometers and neutron probe readings were used to estimate soil moisture. Even though quite an effort was put into both these methods neither of them produced any convincing data. This can partly be explained by the poor distribution from the sprinklers (see 14.5.3).

14.4.3.5 APPLICATION EFFICIENCY

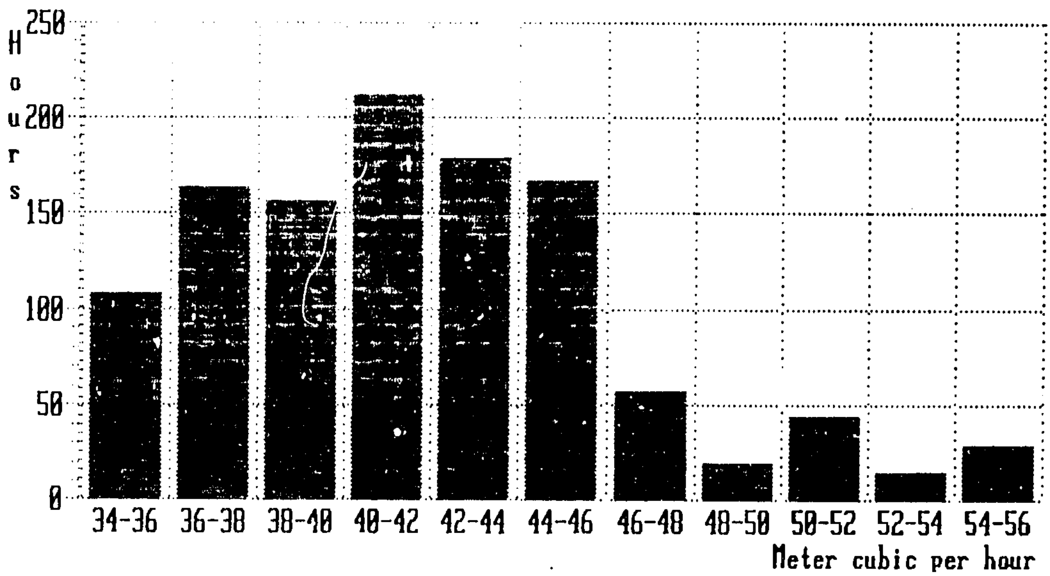
To estimate the application efficiency is a bit more difficult. Measurements carried out indicates a rate of 70 percent, meaning that when irrigating 10mm, 3mm are lost in the air. However rates between 60 and 95 percent have been measured during the same day. This indicates that there is a large potential water saving through night irrigation.

14.5 **Irrigation equipment**

14.5.1 ENGINE AND PUMP

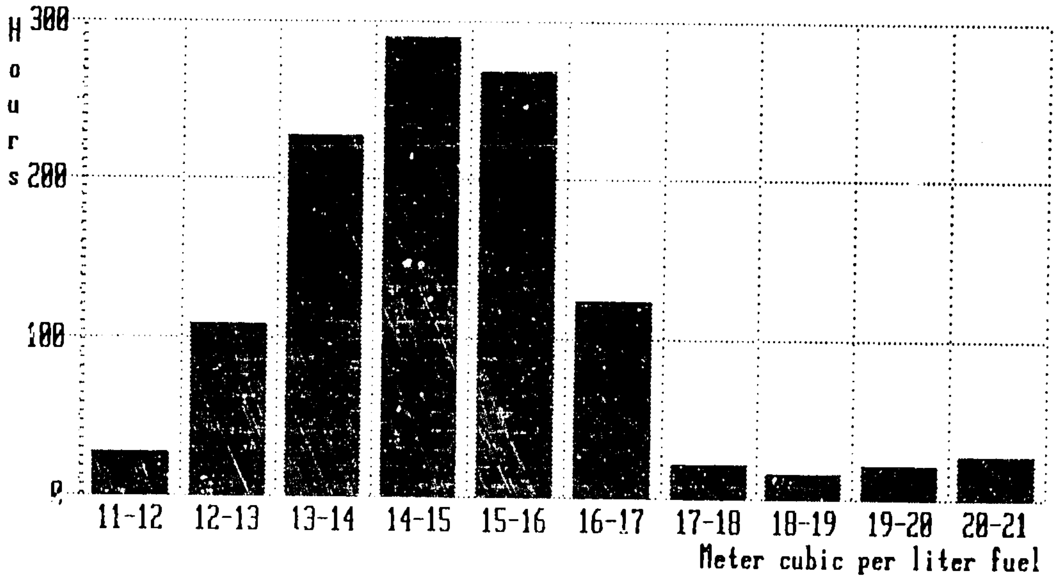
A two cylinder Lister Diesel engine powers a Centrifugal pump. The unit is fixed on a concrete foundation placed about 1,2 meters above the water surface. Initially the unit did not perform even close to expectation. The problem was caused by the footvalve installed severely obstructing suction. This was replaced with an ordinary gate valve fitted after the pump. What is most surprising is the variation in performance of the unit, in respect to both the fuel consumption and amount of water pumped per hour. In figure 4.a histogram of the performance in cubic meters water pumped per hour is presented.

Figure 4. ENGINE AND PUMP PERFORMANCE. METER CUBIC OF WATER PUMPED PER HOUR.



The average amount of water pumped per hour is 41.8 m^3 . But as can be seen from Figure 4 it is equally possible to get anything between37-45 m^3/hour. This of course makes it hard to predict how many hours to irrigate in order to apply a certain amount of water. It is also of economic interest. In Figure 5. the amount of water pumped per liter of fuel consumed is presented.

Figure 5. ENGINE AND PUMP PERFORMANCE. METER CUBIC OF WATER PUMPED PER LITER OF FUEL CONSUMED.



The average amount of water pumped is 15.1 m^3 per liter fuel consumed. Even though the relationship between the amount of water pumped and fuel cuncumption is stronger than the relationship to time, it does vary quite a lot. The difference in pumping $16m^3$/liter fuel and 14 m^3/liter fuel is 89 liters of fuel for one hectare of maize. For an irrigated area of eight hectares, two crops per year and a fuel price in Etsha of Pula one per litre, this means a difference in fuel costs only, of Pula 1 400 per year. In addition to this comes increased maintenance and depreciation costs. The economic significance is perhaps best expressed as follows. To obtain on average one additional meter cubic of water pumped per liter fuel consumed, justifies an investment of P 10 000. The question is why does the performance of the engine and pump vary so much? In Figures 4. and 5. variations caused by factors that are obvious, such as dirt in the impeller or slipping belts, are excluded. Two factors that have been possible to check is difference between pumping at day or at night, and difference in suction height caused by changing water level in the lagoon from where the water is pumped. Neither of these two factors could satisfactory explain the differences in performance. A third factor that needs to be investigated is air temperature and humidity.

14.5.2 THE CONVEYANCE SYSTEM

The conveyance system, which is the pipeline between the pump and the water distribution equipment on the field, has worked satisfactory. A water meter was installed for research purpose. In practise the water meter has been very useful as an indicator of the condition of the engine and pump. This use alone justifies the additional investment of Pula 400 for the water meter.

14.5.3 LATERALS AND SPRINKLERS

The laterals are 70 mm Irrilock pipes, that are handmoved every day. A set of 32 sprinklers and a total length of pipe of 438 meters covers an area of 0.7 hectares. Two men moves the set in 2,5 to 3 hours, depending on how high the maize crop is. The hand moved sprinkler and lateral system has worked smoother than expected. No damage to pipes or sprinklers have occured during ten months of use. This experience contradicts a statement in the Southern Okavango Integrated Water Development Phase 1 report, where the consultant states about hand moved sprinkler systems. "... the practical problems associated with moving sprinkler lines through mature maize render these systems inappropriate for use with broad area crops." One problem however is when long risers are fitted on the sprinklers. The risers that are used are made from ordenary three quarter inch water pipe, wich is heavy. A lateral with a two meter riser and sprinkler becomes quite unmanagable. There are however light weight risers available, and a set of these will be purchased.

The big disappointment in the whole irrigation system is the sprinklers. The sprinklers used are the Salen sprinklers model 430/1770. The sprinkler, which is appealing due to its simplicity and strength, does not perform as expected. The problem is poor distribution of the water. This was first noticed by irregular growth in the crop. Distribution tests were carried out by placing out 35 tins in a three by three meter pattern. These tests confirmed what was seen in the crops. In table 3 the test results are presented together with results from laboratory tests carried out by the Division of Agricultural Enginering, Department of Agriculture,RSA.

Table 3. TEST RESULTS OF THE SALEN 430/1770. KRISTIANSENS DISTRIBUTION COEFFICIENT= Cu.

	Field Test Etsha		Laboratory test	
Nozzle	Pressure	Cu %	Pressure	Cu %
Yellow (2.5*4.0)	265 kpa	62.5	200 kpa	86.66
			300 kpa	84.47
Orange (3.0*4.0)	230 kpa	64.7	200 kpa	80.69
Green (4.0*4.0)	140 kpa	65.8	250 kpa	83.04

The poor distribution results in substantially dryer areas in between the laterals. Kristiansens coefficient is a rather rough way of expressing the distribution. A distribution efficiency of 65 percent means that some areas recieve as much as four times the amount of water as other areas.

14.6 **The First Maize Crop**

At the end of January three plots of 7 000 m^2 each was planted with maize. Two plots were planted with Kalahari Early Pearl and one plot with the hybride PNR 473. A plant population of 55 000 plants per hectare was aimed for, using 40-45 kg of seed per hectare. In the seedbed 40 kg of nitrogen and 38 kg of phosphate was applied per hectare. An additional 120 kg of nitrogen was applied applied in three applications, 15, 30 and 50 days after planting.

14.6.1 PESTS AND DISEASES

14.6.1.1 Stalk Borer

The maize was attacked by Stalk borer. An estimated 15 percent of the plants were infested. Monocrotophus was sprayed 35 days after planting, at the rate of 200 ml per hectare. The treatment was successful even though some plants had already died.

14.6.1.2 Streak Virus

About one month after planting, plants infected with Streak virus started to appear. An attempt to stop the virus by pulling out infected plants did not seem to have any effect. Four thousand plants per hectare were pulled out 40 days after planting. Approximately 40 percent of the plants were finally infected, most of these plants did not produce any cobs. The occurrence of Streak virus is quite serious. The crop can not be treated when it has been infected. Preventive treatment has to be done into the seedbed at planting. To treat one hectare the cost of pesticide is about Pula 300. This disease alone raises the break-even point by nearly one tonne. Another practical problem is how to apply the pesticide into the seed bed. What is required is some kind of applicator that can be fitted on an animal drawn planter.

14.6.1.3 American Bollworm

After emergence of the silks the crop was infested with the American bollworm. At that time it was decided, concidering the allready poor state of the crop not to treat against the pest. For small scale irrigation the American bollworm will cause concern.

14.6.2 SUMMARY

The first crop of Maize is summarised in Table 4.

Table 4. MAIZE CROP PLANTED JANUARY 1987, SUMMARY.

	Variety		
	K.E.P.	PNR 473	RO 104
Plot size m^2	6 000	7 000	7 000
Seed rate kg/ha	43	43	43
Plant population 50 days after planting per ha	40 400	?	54 800
Fertilizer P kg/ha	20	?	37
N kg/ha	160		160
No of irrigations	16	16	18
Irrigated mm	585	590	650
with 70 % application eff.	409	413	455
Rain mm	60	60	60
Total available water mm	469	473	515
Days planting to harvest	120	120	125
Pesticides			
Monocrotophus ml/ha	200	200	200
Yield kg/ha	2 700	2 740	2 200

Spraying has to be carried out with a knapsack sprayer and at this stage the crop is quite high. All recommended insecticides against the American bollworm are highly poisonous (poison group I or II). As can be seen in the Table the yields obtained were very low. To present a lengthy economic analysis is hardly of any use. In short it can be said that the break even point is calculated to be 3,4 tonnes per hectare. With the occurrence of Streak virus and with the costs involved to control the virus, the same calculation gives a break even point of close to 4,5 tonnes per hectare.

14.7 CONCLUSIONS

The experience from the first crop under irrigation indicates some neccessary changes regarding irrigation method, equipment and crop husbandry. The Pan coefficient will be changed from 0.6 to 0.75. Under section 14.4.3.2 it was argued that the use of meteorological data provided by the meteorological service might be as usefull as readings from an evaporation Pan. The class A Pan will continue to be in use in order to obtain more information to support or deny the argument.

The crop husbandry will concentrate on pest control. It is believed that the change in irrigation method together with improved pest control will enable yields required to reach the break even point. Unless such yields are achieved it is of little use to carry out trials regarding fertility, varieties, etc.

The irrigation equipment will be monitored with the hope of identifying the causes for the encountered variations in performance. Regarding the sprinklers, discussions are ongoing with the supplier in order to solve the problem. If this is unsuccessful another type of sprinklers have to be used.

14.8 **Irrigation and the Local Small Scale Farmers**

It is unlikely that local farmers in any greater extent will be involved in irrigated farming within the near future. The farmers in the area in Etsha as well as in the Nokaneng flats have very little knowledge about crop husbandry. Their present results in the traditional farming system are entirely based on experiences. For example, by experience they know that too high a plant population often results in crop failure, which is correct. The explanation for this is however wrong. A common belief is that the air in between the plants goes bad when there are to many plants. This example shows that experiences and explanations that the local farmers have, though not detrimental in the traditional arable system, would be so if transferred to an irrigated system.

In order to make it possible for local farmers to get involved in irrigated farming a considerable extension effort has to be done in crop husbandry. Such an extension effort should be aimed at the present farmers as well as those who will be farmers ten years from now.

The Etsha 6 irrigation plot is under the title of the local Village Development Committee (VDC), wich also holds the water right. The VDC helps with the recruitment of workers on the plot. This ensures that the jobs are circulated within the community, and at this time most of the adults in Etsha 6 have worked and seen what is going on at the plot. At present discussions with the VDC are going on, about the VDC taking over the management of a part of the irrigation plot. In such a case the VDC would get assistance from the ADN project. Initially the project would also take the risks. This arangement would enable the VDC to obtain practical experience and an insight into the problems with irrigation.

Section 15. MELAPO DEVELOPMENT PROJECT

15.1 Location and Natural Conditions

INTRODUCTION

The aim of the Molapo Develoment Project (MDP) is to assist the smallholders in the Boro-Shorobe area in their traditional flood recession cultivation. The floodplains (melapo) at the south easterly fringe of the Okavango are seasonally inundated and the farmers plant (mainly maize) following the receding water.

These floodwaters of the Okavango have raised an increasing interest towards irrigated agriculture on the part of private investors, but also of the Botswana Government. A consultant (Snowy Mountains Engineering Corporation, Smec) was hired to assess the potential of the lower Boro region, including Laka Ngami, for large scale irrigated agriculture and other developments (like water supply to Orapa diamond mines, fisheries, Maun water supply).

Soils and topography

The Boro-Shorobe floodplains are an ondulating area with a general slope of about 30 cm/km, intersected by the seasonally flowing Boro river and the now defunct Santantadibe and Gomoti rivers. Its boundaries are the Kunyere fault to the northwest and the Thamalakane fault to the southeast. The latter acts as a collector drain for the forementioned rivers and is the projected reservoir basin.

During high floods the depressions fill up with water, leaving the higher parts as scattered islands. The division between the treeline, apparently an ecological boundary. The islands have a shrub and the tree except for their commonly central depressions, that are small salt pans.

The soils are poor sands, calcaric and are of no interest for arable farming.

The floodplains have a grass vegetation and are sandy loams to sandy clay (loams) with poor or no structural development. The clay content of the soil is higher in the lower parts of the floodplains and apparently related to flood frequency and duration. An increasing clay content of the soil with depth is common, reaching between 30 and 50 percent at 1-2 m depth.

The soils that are most interesting for arable farming were classified by FAO's "Soil mapping and advisory service project" as Eutric Gleysols, Eutric Fluvisols and Gleyic Luvisols.

Evaluation of the laboratory data leads to the following conclusions:

1. The soils are, in absolute terms low in organic carbon, although the content is high for Botswana soils.

2. The potassium (K) content of the soil is high.

3. The phosphorous content (P) is high, especially so in areas that are fequently inudated.

4. The exchangeable sodium percentage (ESP) is generally low (about 3), but shows a slight increase in the relatively drier (= higher) parts

   of the floodplains.

5. The Boro water is low in salinity (electrical conductivity ranging between 70 and 100 micromhos/cm) and the adjusted Sodium Adsorption Ratio (SAR-adj) is calculated at 0.41, which is low.

If used as irrigation water it may have a tendency to dissolve lime from the soil as the actual pHc value of 8.6 is just over the threshold value of 8.4. On the other hand the residual sodium carbonate and bi-carbonate (RSC) is calculated at 0.236 meq/1. This value being less than 1.25 is classified as "harmless".

It is concluded that the laboratory analyses do not raise any concern about irrigability of the melapo with Boro water.

However, one should bear in mind the observed tendency of the soils towards increased structural development, increased salinity and especially increased sodicity with decreased inudation. This indicates that exclusion of prolonged flooding and irrigating with shallow depths of water may introduce a salinity/sodicity hazard (Rhebergen, personal communication).

One of the issues examined by Smec is a reservoir in the Thamalakane basin, upstream of the Boro influence and re-opening of the Xasanara channel. This concept was referred to as the 'Master Bund' and the molapo system that is here under discussion. Details and conclusions pertaining to the Masterbund are beyond the scope of this report. However, if the Masterbund concept is being implemented it must be considered as a major contribution to the agricultural potential of the area. This is explained as follows:

The inundation of the floodplains takes place between July and September and is therefore out of phase with the cropping season, that extends from November to April. It can therefore be regarded as a pre-irrigation that leaves the soil wet at onset of the rains. This gives the molapo farmers a headstart with planting and although the crop is still dependent on subsequent rainfall, it has additional water available, amounting some 150 mm. Another advantage of molapo farming as compared with sandvelt cultivation is the higher soil fertility of the floodplains.

However, the main drawback for molapo farmers is the erratic flood extent of the Okavango and the difficult water management of the saucer shaped fields. As a result the Boro-Shorobe molapo belt may dry up completely and result in a severe water deficit in the soil, even during the rainy season, as experienced since 1981. On the other hand consecutive high floods may turn the melapo into swamps with aquatic vegetation, as during the period 1974-77. Extensive bunding and water flow regulation at molapo level, as done by the MDP aims at stabilizing the hydrology to some extent, mainly by cutting the top and the tail of high Okavango floods. The Masterbund would have a similar effect on a larger scale, but in addition create the possibility to back up the water in the Thamalakane reservoir.

In short the advantage of the Masterbund are:

1. extended flood protection of the lower Boro-Shorobe melapo.

2. extended areas under inundaton, especially during low floods.

3. Water storage during the cropping season, bringing flood water availability in phase with the cropping season.

The last item is of particular interest as it creats water storage facilities for supplementary irrigation to standing crop during the cropping season.

It should be borne in mind that this irrigation potential pertains to a fairly narrow strip of land (say 2 km) bordering the water source for pumping. Further considerations are the soil type and topography, which are discussed in section 15.3.

Slopes of up to 3% are common, but small fields can be found that are relatively flat. The relevance of this topography for the selection of irrigation methods is attended in section 15.4.

15.2 Agronomic studies of the cropping season

INTRODUCTION

After becoming operational in 1983 the Molapo Development Project has conducted field trials and demonstrations to optimize flood recession agriculture in the extensive melapo system North West of Shorobe. Within it's first phase the project's activities concentrated on a 300 ha pilot area at Xhwaa and Mazanga melapos.

Within the constraints of low-inputs and risk-minimizing strategies the objectives have been as follows:

- to investigate agronomic problems
- to identify potential practices
- to verify on true scale the practicability of promising research results
- to demonstrate improved practices to farmers
- to gain farmer's interest and confidence
- to train farmers on those practices
- to test the acceptability and adaptability of recommended methods

The trials were sited within the Mazanga and Xhwaa group fences. The flood plain soils are alluvial deposits of sandy to sandy/clay loams with a sandy organic rich top layer of approx. 20 cm. The soils are slightly below neutral pH at the surface, becoming alkaline with depth. Salinity ratings ratings in the alluvial plains are generally low. In the lower parts of the frequently flooded areas the nutrient availability is highest, however the availability of phosphorous generally remains low.

The available moisture holding capacity has been estimated to be in a range of 110-160 mm/m.

GROWING CONDITIONS

The 1986 flood was again much below average and none of the bunded area was innundaded.

According to table 1 the rainy season started very promising in October and November with above average rainfall.

Table 1. RAINFALL DATA IN 1986/87 CROPPING SEASON AT 3 LOCATIONS (mm)

Month	Decade	Maun	Xhwaa	Mazanga
OCT	1	5	-	-
	2	30	34	36
	3	-	13	1
	total	35 (206)	47 (276)	37 (218)
NOV	1	32	25	20
	2	3	-	2
	3	16	24	38
	total	51 (93)	49 (89)	60 (109)
DEC	1	22	30	30
	2	22	17	11
	3	21	-	16
	total	65 (81)	47 (59)	57 (71)
JAN	1	22	30	30
	2	25	22	7
	3	18	4	9
	total	49 (40)	35 (29)	32 (26)
FEB	1	9	14	8
	2	33	30	22
	3	15	17	2
	total	57 (50)	61 (53)	32 (28)
MAR	1	-	-	-
	2	22	6	11
	3	-	19	15
	total	22 (30)	25 (34)	26 (35)
APR	1	-	-	-
	2	-	-	-
	3	-	-	-
	total	0	0	0
TOTAL		279 (56)	264 (53)	244 (49)

() = deviation from Maun long term average in percent.

However, starting from December, the rainfall was much below average, and during January and February only about one third of the normal rainfall fell in the pilot area. There occurred periods of 4 weeks with rainfall less than 10 mm, which resulted in very poor crop establishment and often in a total failure. Most of the plantings even failed to emerge, while the surviving plants suffered the whole season from water stress. Only in slight depressions, where run-off water was collecting, plants managed to produce considerable heads and cobs respectively.

On top of that the stressed plants were attacked by termites, grasshoppers and corncrickets, and in a later stage by Queleas.

Farmers ploughed and planted from beginning of December until end of January. In February it appeared already, that there would be little chance of obtaining a yield, and some farmers abandoned their fields, rather shifting to other activities. It has been estimated that only 10-15% of the total ploughed area has produced some yield, while the rest failed completely.

CROP/VARIETY TRIALS

Crop/variety trials were carried out to demonstrate different crops and pre-selected varieties and to investigate their performance under molapo conditions. The different sides included light (Mazanga), medium (Xerexere), and heavy (Xhwaa) molapo soils.

The variety trials at Mazanga and at Xerexere were planted on 6/12/86 and on 10/12/86 respectively, and emergence was satisfactory at both sides.

About 4-6 weeks after planting the plants were thinned to the desired plant population and weeded first, using an animal drawn cultivator between the rows and hand weeding on the rows. Because of the unfavourable weather conditions also weed growth was suppressed, so that a second weeding was only partly necessary. Crop specific treatments like pest control will be dealt with in the following sub-paragraphs.

CEREALS

Pre-selected varieties, which have proved their performance already on research stations, were planted at three different locations. Two maize varieties (KEP, PNR 473), six sorghum varieties (Segaolane, 65-D, 8-D, Town, PNR 8311, Tshabatsie), and one millet variety (Serere 6 A) were included in the tests.

After thinning maize and sorghum were treated with Carbofuran against stalkborers, and in a later stage the maize had to be sprayed twice with Chlordane against the heavy attack of termites. During ripening sorghum and millet required bird scaring.

The summarized results are presented in table 2.

Under the very dry conditions maize produced considerably less than sorghum, and KEP showed more drought resistance than the hybrid PNR 473. The short sorghum varieties (65-D, 8-D, PNR 8311) proved to be very drought resistant and outyielded Segaolane, while the local Tshabatsie yielded mediocre. Millet failed to produce enough heads and yielded less than sorghum.

Table 2. RESULTS OF CROP/VARIETY TRIALS, CEREALS, NONFLOODED MELAPO

Location	Variety	Plant. date	Emerg. pl/sqm	Pl. pop. pl/sqm	Heads /pl.	Yield kg/ha	Plots sqm	Harvest date
Mazanga (light soil)	KEP	6/12		2.1	0.4	165	226	
	PNR 473	6/12		2.2	0.2	161	226	
	Segaolane	6/12		2.9	0.8	98	226	
	65-D	6/12		3.3	0.9	213	226	10/3
	8-D	6/12		3.0	0.6	126	226	10/3
	Town	6/12		3.7	Nil	Nil	226	
Xerexere (medium soil)	KEP	10/12	3.3	1.8	0.1	137	67	26/3
	PNR473	10/12	4.6	1.9	0.2	45	67	26/3
	Segaolane	10/12	6.6	3.1	0.8	?	67	
	65-D	10/12	4.5	2.2	0.6	283	67	16/3
	8-D	10/12	6.8	2.8	2.0	741 x	67	16/3
	PNR8311	10/12	6.3	2.5	1.0	833 x	67	16/3
	Tshabatsie	10/12	4.3	1.9	1.4	470	67	16/3
	Serere 6A	10/12	23.9	2.8	1.4	146	67	26/3
Xhwaa (heavy soil)	KEP	15/1				Nil	96	destroyed
	PNR473	15/1				Nil	96	by cattle
	Segaolane	15/1		2.4	1.3	65	96	16/4
	65-D	15/1		2.3	1.7	290	96	16/4
	8-D	15/1		1.4	1.4	292	96	16/4
	Town	15/1				Nil	96	16/4
	PNR8311	15/1		2.0	1.1	508	96	16/4
	Tshabatsie	15/1		2.0	1.2	385	96	16/4
	Serere 6A	15/1		1.5	1.4	92	96	16/4

x = slight depression, benefited from run-off water

BEANS

Three cowpea varieties (ER7, Blackeye, Tswana) were planted at 3 locations. At Xerexere other beans like Mungbeans, Velvet beans, and white Sword beans were included in the test, however, the varieties have not been known. The Velvet beans and the Sword beans had to be planted by hand, because of their enormous size. With a spacing of 0.8 m x 0.25 m the plant population of all beans was aimed at 50 000 plants per ha.

The cowpeas wer sprayed with Monocrotophos against beanfly and flowerbeetles, whilst the other beans did not require any treatment. Velvet beans were found to be a runner type, and after been supported with poles, they climbed up until a height of more than 2 m. Planted on the 10/12/86 this beans started flowering only middle of March.

The results are shown in table 3.

Table 3. RESULTS OF CROP/VARIETY TRIALS, BEANS, NONFLOODED MELAPO

Location	Variety	Plant date	Emerg. pl/sqm	pl.pop. pl/sqm	Yield kg/ha		Plots sqm	Harvest date
Mazanga	ER7	6/12		3.3	18		226	
	Blackeye	6/12		3.8	Nil		226	
	Tswana	6/12		3.4	44		226	
Xerexere	ER7	10/12	13.5	4.0	342		67	13/2-18/3
	Blackeye	10/12	10.5	4.0	375		67	25/2-18/3
	Tswana	10/12	11.3	3.9	537		67	25/2-18/3
	Mungbeans	10/12	30.3	4.0	935	x	67	25/2-18/3
	Velvetbeans	10/12	7.7		Nil		67	
	Swordbean	10/12	8.8	3.7	771	x	67	30/4
Xhwaa	ER7	15/1			Nil		96	
	Blackeye	15/1			Nil		96	

x = slight depression, benefited from run-off water

At Xhwaa, representing the heavy molapo soil, the cowpeas even failed to establish, although the emergence was satisfactory. At Mazanga yields were negligible, while the best yields were obtained on the medium textured soil at Xerexere. Mungbeans and Swordbeans yielded very good, however, it must be mentioned, that these plots were located in a slight depression. No yield was obtained from the Velvet beans. They showed a huge vegetative growth, but started flowering, when the cowpeas were already harvested.

OIL CROPS

Three groundnut varieties (Sellie, 55-437, 7333) and two sunflower varieties (Russian 4, S0209) were cropped at two locations. The groundnuts were thinned to a spacing of 0.8 m x 0.25 m, corresponding with a plant population of 50 000 plants per ha. The results are presented in table 4.

Table 4. RESULTS OF CROP/VARIETY TRIALS, OIL CROPS, NONFLOODED MELAPO

Location	Variety	Plant date	Emerg. pl/sqm	Pl.pop. pl/sqm	Yield kg/ha		Plots sqm	Harvest date
Xerexere	Sellie	10/12	4.8	2.9	256	x	67	15/4
	55-437	10/12	10.8	5.2	232	x	67	15/4
	7333	10/12	5.3	4.3	196	x	67	15/4
	Russ.4	10/12	5.0	2.3	652		67	7/4
	S0209	10/12	3.5	1.6	339		67	7/4
Xhwaa	Sellie	15/1			26	x	96	
	55-437	15/1			Nil		96	
	Russ.4	15/1			248		96	
	S0209	15/1			Nil		96	

x = shelled

The spacing of the sunflowers was 0.8 m x 0.45 m, aiming at a plant population of 28 000 plants per ha. No pest control was required this season, although the termites did some damage on the groundnuts. The slightly better yield of Sellie might have been caused by the poorer crop stand, and thus the more economic water use. Russian 4 seems to be more drought resistant than the hybrid S0209, which generally formed very small heads.

Date of planting trials

Under rainfed conditions the date of planting is a very crucial factor with regard to crop establishement and further development. Planted at the wrong time, i.e. too late, too early, unfavourable conditions, the crop may never be able to catch up.

In order to demonstrate early planting vs. later planting to farmers, the main crops used in the area were planted at different dates.

XHWAA

After the first promising rains at beginning of November, maize, sorghum, millet, cowpeas, and groundnuts were planted on the 7/11/86. On the same molapo level the trial was dublicated approx. 4 weeks later on the 10/12/86. Since both plantings were done after nice showers, the crops emerged well on both sides, but were later affected by long dry spells. The crops suffered a lot from water stress, and with both plantings the sensitive crop development stages (flowering, heading) happened to be during dry spells.

The results are presented in table 5.

Table 5. RESULTS, DATE OF PLANTING TRIALS, XHWAA, NONFLOODED MOLAPO

Crop (Variety)	Plant date	Emerg. pl/sqm	Pl.pop. pl/sqm	Heads /pl	Yield kg/ha	Plots sqm	Harvest date
Maize	7/11	1.5	1.0	0.3	215	144	10/3
(KEP)	10/12		1.9	0.6	342	144	27/3
Sorghum	7/12	14.7	2.8	0.8	35 x	144	10/3
(Segaolane)	10/12		2.8	0.8	871	144	10/3
Groundnuts	7/11	7.4	4.4		12	144	23/3
(Sellie)	10/12		1.9		Nil	144	
Cowpeas	7/11	3.5	2.6		77	144	21/1-26/2
Millet	7/11	5.3	3.0	1.8	90	144	23/3
(Serere 6A)	10/12		2.5	1.3	160	144	27/3

x = bird and game damage

In order not to cover the effect of the different planting dates, no crop protection measures were undertaken. Stalkborers and grasshoppers did some damage on maize and sorghum, termites attacked the groundnuts and the maturing maize, sorghum was seriously damaged by Queleas, and the cowpeas had the usual pests like beanfly, flowerbeetles and podborers, while the later planted plot was almost eaten up by a duiker.

With regard to pest infestation no difference between the early and late planted crops could be observed. As stated before, both plantings suffered a lot from long dry periods, however, the second planting faced slightly better conditions than the early planting.

NXAMATHAMA

The Nxamathama pool is located outside the flood protected pilot areas, and because of it's low level it cannot be cultivated in years of normal floods; then the water receeds only in February/March. With the low 1986 flood the water just reached the Nxamathama pool in July, but receeded already end of August. Since the topsoil had tried up already, the pilot was planted after some rains on the 22/10/86.

Four rows of each crop (maize, sorghum, millet, cowpeas) received about 200 kg/ha compound fertilizer (2:3:2), applied with the planter, while another four rows were planted without fertilization. Maize was treated with Dipterex (stalkborers) and sprayed with Chlordane (termites). Cowpeas were sprayed with Monocrotophos against beanfly and podborers.

The late-planting plot had to be ploughed a second time, because of excessive weed growth (mainly Sesbania, which may have acted as green manure) and was planted on the 8/1/87. The layout was a repetition of the early planting (same crops, fertilized and nonfertilized). The crops had to be treated with the same insecticides as the early planted.

The late planting was done about 4 months after flood recession, however, during the whole cropping season the former flood line (max. flood level) was distinctly indicated by crop and weed growth. Above the flood line the crops suffered from the very beginning and failed to produce flowers and heads.

The results of the early and late plantings are presented in table 7.

Due to their rooting system sorghum and millet obviously benefited from the residual soil moisture, even when planted mid January, which was about 4.5 month after flood recession. This effect could be less observed with maize and least with cowpeas.

The application of 200 kg/ha 2:3:2 fertilizer did not result in a clear yield response, neither with the early planting, nor with the late planting.

Table 7. YIELDS OF DIFFERENT CROPS, EARLY AND LATE PLANTING, FERTILIZED AND NONFERTILIZED, ON PRE-FLOODED MOLAPO

Crop (Variety)	Plant date	Fertilizer kg/ha	Plant population pl/sqm	Heads /pl.	Yield kg/ha	Harvest date
	22/10	0	2.2	1.0	1925	4/2
Maize		200	2.2	0.8	2009	
(KEP)	15/1	0	1.7	1.0	521	6/5
		200	1.1	1.0	1175	
	22/10	0	2.1	4.2	1852	21/1
Sorghum		200	2.1	3.6	2148	
(Segaolane)	15/1	0	2.3	3.0	2940	27/4
		200	2.3	2.7	2700	
	22/10	0	2.7	4.3	1947	15/1
Millet		200	1.8	5.9	1164 x	
(Serere 6A)						
	15/1	0	3.0	2.8	1125	6/5
		200	2.8	3.5	1718	
	22/10	0	2.4		1000	10/1-19/1
Cowpeas		200	4.0		819	
(Blackeye)						
	15/1	0	3.1		553	29/3-16/4
		200	2.1		381	

x = bird damage

FERTILIZER TRIALS

Molapo soils are naturally rich in K, Ca, Mg, and organic C, P is relatively good, but still too low for high crop yields. On regularly flooded soils Na remains low and salinity does not occur. However, little is known about long-term effects of permanent fertilization on molapo soils, i.e. change of pH, salinity build up, fertility. Therefore fertilizer trials have been conducted since the project got operational in 1983.

MAZANGA

Maize, sorghum, millet, and cowpeas were planted on the 5/12/86. One block received no fertilizer, while on two blocks compound fertilizer was harrowed in before planting, at a rate of 200 and 400 kg/ha respectively. The crops were thinned and weeded once, using a donkey drawn cultivator. Cowpeas were sprayed with Monocrotophos against podborers, and maize had to be treated with Chlordane against termites.

The yields are presented in table 8.

Table 8. GRAIN YIELD OF VARIOUS CROPS AND DIFFERENT FERTILIZATION ON NONFLOODED MOLAPO

Crop (Variety)	Plant date	Fertilizer kg/ha	Plant Population pl/sqm	Heads /pl.	Yield kg/ha	Harvest date
Cowpeas (ER7)	5/12	0	2.6		240	10/2
		200	3.2		96	
		400	2.8		166	
Maize (KEP)	5/12	0	2.1	0.6	40	
		200	1.5	0.0	Nil	
		400	1.9	0.3	42	
Maize (KEP)	5/12	0	2.1	0.6	40	
		200	1.5	0.0	Nil	
		400	1.9	0.3	42	
Sorghum (Segaolane)	5/12	0	2.8	0.8	Nil	16/3
		200	2.6	0.2	20	
		400	2.0	1.0	32	
Millet (Serere 6A)	5/12	0	2.8	1.2	182	16/3
		200	2.8	0.2	40	
		400	2.9	1.2	260	

Due to long dry spells crop establishment was generally poor, and desired stand of crops could not be achieved. Yields were very low, and neither a positive nor a negative effect of fertilization could be observed.

An application rate of 200 kg/ha 2:3:2 fertilizer has been applied for 3 years, but is still not reflected by the soil chemical properties. Generally K, Ca, Mg, and C are satisfactory, Na remains low, while P is at a low level.

XEREXERE

This trial was planted with the same crops (maize, sorghum, millet, cowpeas) on the 9/12/86. On two blocks 2:3:2 fertilizer was applied before harrowing at a rate of 200 and 400 kg/ha respectively, while one block was kept nonfertilized. The crops were thinned by hand and interrow cultivated using a donkey. Maize had to be treated with Chloridane against termites, and cowpeas were sprayed with Monocrotophos against flowerbeetles. Maize was damaged by straying cattle, but there was no cob development anyhow. Cowpeas were occassionally eaten by a duiker, which was impossible to avoid, because they feed during night. Crops suffered soon after emergence from the dry spell mid December until mid January.

Yields and details are presented in table 9.

Table 9. GRAIN YIELD OF VARIOUS CROPS UNDER DIFFERENT FERTILIZATION ON NONFLOODED MOLAPO AT XEREXERE

Crop (Variety)	Plant date	Fertilizer kg/ha	Plant Popul. pl/sqm	Heads /pl.	Seedw. gr	Yield kg/ha	Harvest date
		0	4.8		117	324	13/2
Cowpeas	9/12	200	3.7		123	147	-26/2
(ER7)		400	3.7			+	
		0	1.6	0.1		Nil	
Maize	9/12	200	1.4	0.4		Nil	
(KEP)		400	1.5	0.0		Nil	
		0	2.3	1.3	17	66	23/3
Sorghum	9/12	200	4.5	2.0	19	771 *	-30/3
(Segaolane)		400	1.5	0.7	22	23	
		0	2.3	1.3	17	66	23/3
Sorghum	9/12	200	4.5	2.0	19	771 *	-30/3
(Segaolane)		400	1.5	0.7	22	23	
		0	3.8	1.3	8	162	
Millet	9/12	200	2.6	1.0	8	225	26/3
(Serere 6A)		400	0.5	0.2	9	19	

+ = eaten by duiker
* = located in slight depression

Due to very poor and erratic rainfall yields were at a very low level, and crops responded rather to the heterogenaity of water supply (micro topography) than to fertilization. Until end of cropping season the undissolved fertilizer could still be found in the soil.

Data from soil analysis indicate, that after been fertilized for two seasons P is still lacking, while cations are adequate with a low level of Na.

CROPPING PATTERN TRIALS

Cereals and legumes have been mono cropped and rotated since 1984, and first time this season inter-cropping has been added. Inter-cropping legumes into cereals is a common practice in the humid tropics, but still has to prove it's success in arid climates, where competition for water, nutrients, less for light, is restrictive. But in a low-cost, risk minimizing orientated cropping system, it may prove successful in the long run, particularly on pre-flooded melapos.

Since row planting and interrow cultivation for weed control has only recently been introduced to the farmers, a new intercropping system should not interfere with those practices. Therefore it was decided to inter-crop the legumes on the cereal rows, rather than between the rows, where they would have prevented mechanical weeding. The legumes were supposed to be inter-planted by hoe, after the first weeding and thinning of the cereals.

Maize (KEP) and sorghum (Segaolane), cowpeas (ER7) and groundnuts (Sellie) have been mono-cropped on one block, while another block has been rotated with the following sequence: cowpeas-maize-groundnuts-sorghum.

The spacings and desired plant populations for the sole cropping have been:

maize	(0.8 m x 0.6 m)	= 21 000 plants/ha
sorghum	(0.8 m x 0.4 m)	= 31 500 plants/ha
cowpeas	(0.8 m x 0.25 m)	= 50 000 plants/ha
groundnuts	(0.8 m x 0.25 m)	= 50 000 plants/ha

The spacings and desired plant populations for the inter-cropping on the third block have been:

Maize	(0.8 m x 0.8 m) = 15 600		
+ Cowpeas	(0.8 m x 0.8 m) = 15 600	=	31 200 plants/ha
Maize	(0.8 m x 0.8 m) = 15 600		
+ Cowpeas	(0.8 m x 0.8 m) = 15 600	=	31 200 plants/ha
Sorghum	(0.8 m x 0.6 m) = 20 800		
+ Cowpeas	(0.8 m x 0.6 m) = 20 800		
Sorghum	(0.8 m x 0.6 m) = 20 800		
+ Groundnuts	(0.8 m x 0.6 m) = 20 800	=	42 600 plants/ha

XEREXERE

The crops on the mono-cropped and rotated parts, and the cereals of the inter-cropped part were planned on the 9/12/86. After first weeding and thinning, it was tried to inter-plant the legumes for several times, but the plants failed to establish due to lacking rainfall. Maize was sprayed with Chlordane against termites, and cowpeas were treated with Monocrotophos against flowerbeetles. Because the different blocks were next to each other, no difference in pest infestation between monoculture and crop rotation could be observed.

With this low yield levels no significant difference between the different cropping pattern systems could be observed with cereals. Other impacts, like difference in soil or topography might have influenced the yield more, than the previous crop. However, the cowpeas, which are the most sensitive crop against monoculture, seem to respond positive on the crop rotation.

The very low yields of the cereals on the inter-cropped part are explainable because of the wide spacings. The inter-cropped legumes could not establish and no yield was obtained.

Yields are given in table 10.

Table 10. YIELDS AND DETAILS OF VARIOUS CROPPING PATTERN SYSTEMS AT XEREXERE, NONFLOODED MOLAPO

Cropping pattern	Crop	Previous crop	Plant pop. pl/sqm	Heads /pl	Yield kg/ha	Harvest date
Monoculture	Maize	Mono	1.8	0.2	315	26/3
since 84/85	Sorghum	Mono	2.2	2.0	498	23/3-30/3
	Cowpeas	Mono	3.7		145	13/2-19/3
Planted 9/12	Groundnuts	Mono	2.7		60	27/4
Rotated	Maize	Cowpeas	1.7	0.2	377	26/3
since 84/85	Sorghum	Groundnuts	2.6	0.6	311	23/3-30/3
	Cowpeas	Sorghum	3.6		322	13/2-18/3
Planted 9/12	Groundnuts	Maize	3.6		70	27/4
Intercropped	Maize	Cereals	1.4	0.3	175	26/3
since 86/87	+ Cowpeas		Nil		Nil	
Cereals	Maize	Cereals	1.4	0.3	175	26/3
planted 9/12	+ Groundnuts		Nil		Nil	
Legumes	Sorghum	Legumes	2.1	1.2	185	23/3-30/3
failed	+ Cowpeas		Nil		Nil	
	Sorghum	Legumes	2.1	1.2	185	23/3-30/3
	+ Groundnuts		Nil		Nil	

XHWAA

The trial was planted on 20/12/86, as a duplicate of the Xerexere trial. After thinning and first weeding, the inter-planting failed as well, because of long dry spells and marginal soil moisture. No chemical pest control was required, but the cowpeas were considerably damaged by game.

The yields are presented in table 11.

Table 11. YIELDS AND DETAILS OF VARIOUS CROPPING PATTERN SYSTEMS AT XHWAA, NONFLOODED MOLAPO

Cropping pattern	Crop	Previous Crop	Plant pop. pl.sqm	Heads /pl	Yield kg/ha	Harvest date
Monoculture	maize	mono			365	
since 83/84	sorghum	mono	3.1	0.7	733	23/3-30/3
	cowpeas	mono	3.7		78 +	26/2
planted 20/12	groundnuts	mono	nil		nil	
Intercropped	maize	cereals			864*	
since 86/97	+cowpeas		nil		nil	
Cereals	maize	cereals			864*	
planted 20/12	+groundnuts		nil		nil	
Legumes	sorghum	legumes	2.6	1.7	78	23/3-30/3
failed	+cowpeas		nil		nil	
	sorghum	legumes	2.6	1.7	786	23/3-30/3
	+ groundnuts		nil		nil	

+ = damage by game
* = located in depression

As compared to other trials, the yields of sorghum are relatively high, but no difference between monoculture and rotation is shown, although the trial has been in it's 4th year. With this heavy soil at Xhwaa, the establishment of crops always have been difficult. Because the wilting point of the soil is relatively high, light showers are not effective, and it needs a high soil moisture content after planting to let the seeds germinate and the emerging plants establish. But after that, good yields can be obtained, probably because of the better fertility as compared to lighter soils.

ACTUAL WATER CONSUMPTION BY CROPS

Maize (KEP) was planted at Xhwaa on the 7/11/86 after nice rains. Although there was sufficient rainfall before planting, the emerging crop suffered from the dry spell mid November, resulting in excessive spacings, and only a poor plant population got established. The maize was sprayed once with Chlordane against termites.

To assess the actual water consumption, the soil moisture was continuously measured during growing season. The first month after planting a profile of 70 cm depth was measured, which was then extended to 90 cm depth, measuring 20-30 cm layers, using a neutron probe. The last measurement was taken about 2 weeks before harvest. Rainfall was monitored with a rain recorder.

The actual water consumption was calculated from the soil water balance:

$$ETa = P - Ro - Dr - dS - dG$$

ETa = actual Evapotranspiration

P = Precipitation
Ro = Run-off
Dr = Drainage
dS = Change in Soil Moisture
dG = Change in Ground Water

An influence of ground water can be excluded, because the ground water level was always deeper than 5 m, and deep drainage can be neglected, because the measured profile never came close to field capacity, although some losses might have occured trough cracks of the shrinking soil. The effect of run-off water was neglected.

So the formula was reduced to:

$$ETa = P - dS$$

The results are presented in table 12.

Table 12: <u>ACTUAL WATER CONSUMPTION OF MAIZE AT XHWAA, NONFLOODED MOLAPO</u>

Sampl. date	10/11 24/11	24/11 03/12	03/11 22/12	22/12 29/12	29/12 05/01	05/01 22/01	22/01 02/02	02/02 16/02	16/02 25/02	Total
Days	14	9	19	7	7	17	11	14	9	107
P (mm)	10	14	18	0	0	31	4	22	13	112
Sampl. depth (cm)	70	70	70	90	90	90	90	90	90	
Actual soil moist. (mm)	166	174	167	153	150	153	146	150	151	
	174	167	104	150	153	146	150	151	150	
dS (mm)	+8	-7	-63	-3	+3*	-7	+4	+1	-1	-65
ETa (mm)	2	21	81	3	-3*	38	0	21	14	177
ETa (mm/day)	0.1	2.3	4.3	0.4	0.0	2.2	0.0	1.5	1.6	
	^ "			^ "	^ "	^ "	^ "	^ "	^ "	

W a t e r s t r e s s

* = inaccuracy of measurement

<u>details</u> :

Crop/variety:	Maize/KEP
Planting:	7/11/86
Spacing:	0.8 m x 0.6 m
Final plant pop:	8 000 pl/ha
Cobs/plant:	0.01
Yield:	91 kg/ha
Plot size:	320 sqm
Harvest:	10/3/87

The daily evapotranspiration rates reflect, that soon after planting water stress occured. The only period, when water supply was sufficient, was end of November till mid December. After this, the plants were permanently under water stress, including the sensitive crop development stages of tasseling and grain filling. This, and the very poor plant population, explain the extremely low yield obtained from this plot.

PEST CONTROL

To investigate the critical number of pests with regard to economic threshold is far beyond the project's capacity. But a simple trial including the major crops could give us an idea, whether a chemical treatment will be paid off by the yield difference obtained, as compared to the yield of a nontreated plot.

16 rows each of maize, sorghum, millet, and cowpeas were planted in long strips, devided in 4 replicates. Pest control was conducted on 8 rows of each crop alternately on each block. For yield estimation only the 4 center rows of each treatment were considered to avoid side effects.

The treatments conducted are shown in table 13.

Table 13. TREATMENTS OF PEST CONTROL TRIAL AT MAZANGA

Treatment	Maize	Sorghum	Millet	Cowpeas
0 8 rows	Non treated	Non treated	Non treated	Non treated
I 8 rows	Carbofuran (10 kg/ha) Chlordane (3.0 1/ha) Chlordane (3.0 1/ha)	Carbofuran (10 kg/ha)	Carbaryl (0.5 kg/ha)	Monocrotph (1.0 1/ha) Monocrotph (1.3 1/ha)

After thinning, maize and sorghum were treated with carbofuran against stalkborers. Later in season maize was treated twice with chlordane against termites. Millet was sprayed once with carbaryl against corncrickets and grasshoppers. Cowpeas were sprayed after thinning against beanfly and later against flower eating beetles using Monocrotophos.

The results are presented in table 14.

Table 14: YIELD (MEAN VALUES IN KG/HA OF DIFFERENT CROPS, NONTREATED (0) AND TREATED (1) WITH INSECTICIDES

Crop/variety	0 kg/ha	I kg/ha	Yield diff. kg/ha	Yield diff. Pula/ha	Insect costs Pula/ha	Benefit Pula/ha
Maize/KEP	711	808	+97 o	+29	-171	-142
Sorghum/Segaol.	1317	1154	-163 o	-54	- 65	-119
Millet/Ser.6A	317	562	+245 o	+64	- 10	+ 54
Cowpea/ER7	256	311	+55 o	+19	- 49	- 30

o = no significant difference (t 0.95)

The returns were calculated on the following basis:

Maize:	0.30 Pula/kg	Carbofuran:	130	Pula/20 kg
Sorghum:	0.33 Pula/kg	Chlordane:	8.84	Pula/500 ml
Millet:	0.26 Pula/kg	Carbaryl:	5.08	Pula/250 gr
Cowpeas:	0.35 Pula/kg	Monocrotoph.:	108	Pula/5 lt

Paired t-tests were used for each crop to compare the mean yields of the different treatments and no significant differences could be found on t 0.95 level. However, the yield difference is expressed in Pula per ha, calculated with 1986 BAMB prices for Maun, given above. For comparison the total chemical costs for treatment I (see table 13) are presented.

Conclusive it can be said, that under the condition of the 86/87 cropping season, with these low yield levels, the chemical pest control has not paid off at all with maize, sorghum, and cowpeas. Only with the millet there seems to be a small benefit of 54 Pula per ha. But we should not forget, that the yield difference is not significant.

FODDER CROPS

It is a well known problem, that in arid areas the draught animals are just in poorest condition, when their strength would be needed most for ploughing at the beginning of the rainy season.

The herd, including draught oxen, graze on the natural pasture ground, and at the end of the cropping season they may be driven in the fields to feed on the crop residues. Growing fodder crops and supplementary feeding is not practiced. It is almost impossible to convince farmers to grow fodder crops, while they struggle for producing food for their own consumption.

Since 1983/84 the project has been demonstrating supplementary feeding to it's own draught oxen with great success. A way of producing additional fodder had to be choosen, which would not compete with field activities during cropping season. The first step was to show farmers to collect crop residues of legumes, maize, and sorghum from the fields after harvest, and store them at a termite-save place. Then, about 6 weeks before ploughing season, the draught oxen were fed daily with those crop residues, and when the ploughing season started, they were in proper condition.

The other approach was the introduction of a fodder tree, which needs no attendence, once it has established. In 1983 a plot of 900 sqm was planted with Leucaena leucaephala (spacing 2 m x 3 m) on an island, because of it's sensitivity against water logging. The seedlings were grown in paper bags and then transplanted in the field.

The plant wholes had to be treated with chlordane against termites, and the small plants were irrigated once a week, until they had established. Already the next season the trees could be pruned and the leafs and small twigs were dried and stored, delivering high nutritious supplementary fodder.

In 1986/87 cropping season the trees were pruned in the middle and at the end of the rainy season, producing the following yield (table 15).

Table 15: YIELD OF LEUCAENA (t/ha), AIR DRIED LEAVES AND SMALL TWIGS, XHWAA 1986/87

Harvest	Date	Yield (t/ha)
1st	22/1/87	1.67
2nd	1/5/87	0.50
Total		2.17

The leaves and twigs contain approximately 30% protein, but the daily rate should not exceed about 20% of the total died because of their mimosine content.

Evaluating the yield (table 17) it should be considered, that the total rainfall in 1986/87 cropping season was only 264 mm at Xhwaa, restricting growing rates.

WEED CONTROL

Once row planting will have been adopted, one could think about chemical weed control, as another step to reduce labour requirements. However, under the present conditions, low floods, erratic rainfall, unreliable yields, every additional input cannot but be justified, because it's return is more than questionable. But with view at the possible improvement of water supply (Southern Okavango Integrated Water Development Plan) there will be a possibility of establishing yields on a higher level, which may justify higher farming inputs.

The weed population of the molapo soils mainly depend on the elevation (flooding pattern, soil formation) and the intensity of cultivation. The most frequent weeds to be found on molapo soils are listed in table 18. The collection does not pretend to be complete, neither does the sequence reflect the order of occurance.

Table 16. COMMON WEEDS ON MOLAPO SOILS

Common name	Scientific name
Cocklebur	Xanthium strumatium
Heartleaf sida	Sida cordifolia
Pigweed	Amaranthus ?
Spiny sesbania	Sesbania bispinosa
Yellow nutsedge	Cyperus esculoentus
Stargrass	Cynodon dactylon
Reeds	Phragmites australis

A weed control trial, consisting of 6 treatments was carried out at the new research plot at Tshonxomo, details are given below:

Design : randomized block, 6 treatments, 4 replicates
whole plot size: 460.8 sqm
block size: 115.2 sqm
single plot size: 4 rows, 6 m long = 3.2 m x 6 m = 19.2 sqm

Varients :
1 = no weed control (check plot)
2 = mechanical (hoe)
3 = Sorghomil 4 l/ha
4 = Faneron + Gesaprim (0.75 + 1) l/ha
5 = Buctril + MCPA
6 = Basagran 3 l/ha

The plot was cropped with sorghum (Segaolane), which was thinned to a desired spacing of 0.8 m x 0.4 m, corresponding with a plant population of approx. 31 000 plants per ha.

The weed control was supposed to be conducted in a 2-4 leaf stage of the weeds. But after planting the crop on the 10/12/86, weather conditions were unfavourable and the weeds emerged faster than the sorghum. The weed control was conducted about 2 weeks after planting, when the stage of sorghum still varied from emergence to 5-leaf stage, while the weeds were already in a 6-8 leaf stage. Before weed control, the starting point of weed population was estimated, using a counting frame, size 0.1 sqm. From each single plot the weed population of 1 sqm (10 random counts) was determined.

Ten days after weed control the weed population was estimated again, following the same procedure. Those weed counts were repeated at 10 days intervals until no significant difference between the weed stand of the different treatments could be observed.

For spraying the herbicides a 18 l knapsack sprayer was used, supplied with a regular flat fan nozzle. Holding the nozzle on top of the plant rows, and moving approximately 1 step per second, an application rate of 325 l/ha was achieved, with a sufficient overlap between the rows. For each treatment the required amount of solution was measured according to the plot size. While spraying, the weather was hot, cloudless and windy, but no drift of the spray could be observed. The plants showed no water stress.

Results

The stand of weeds, counted before and after weed control, are presented in table 17.

Table 17. COUNTS OF TOTAL WEED POPULATION (pl./sqm) BEFORE CONTROL AND SEQUENTLY AFTER CONTROL FOR DIFFERENT TREATMENTS

Variant	days after weed control 0	13	23	34	47
No weed contr.	128 o	110	75	64	52
Mechanic	141 o	5 +++	5 +++	14 +++	20 +
Sorghomil	111 o	15 +++	14 +++	25 ++	26 o
Faner. + Gesapr.	101 o	15 +++	15 +++	15 +++	23 +
Buctr.+ MCPA	128 o	15 +++	18 +++	26 ++	30 o
Basagran	155 o	9 +++	15 +++	20 +++	17 +

No weed control = check plot

0 = no sign. diff.
+ = sign. diff. 5%
++ = sign. diff. 1%
+++ = sign. diff. 0.1%

The counts taken before weed control show a relatively homogeneous weed stand (no sign. diff.) with an average of 127 plants per m^2. Looking at the check plot without any weed control, we find a natural reduction of weed stand with time, due to over population and water stress.

As compared to the check plot, the plots with weed control show a very high significant reduction of weed stand, which lasted more than 4 weeks after application for all treatments. However, 7 weeks after treatment there was no significant difference between the check plot and sorghomil and buctril + MCPA left, while the other treatments still showed a significant difference on a 5% level.

Looking at this long term effect of the various treatments, we have to consider the prevailing climatic conditions. This season rainfall was extremely low and poorly distributed. Plant growth was considerably restricted, and the crop never formed a real canopy.

The crop yield is presented in table 18.

Table 18: GRAIN YIELD OF SORGHUM (kg/ha), WEED CONTROL TRIAL AT TSHONXOMO, NONFLOODED MOLAPO

Treatment	Stand of crops (plants/m 2)	Grain yield (kg/ha)
1. No weed control	1.2	523
2. Mechanical (hoe)	3.4	443 o
3. Sorghomil	2.3	918 o
4. Faneron + Gesaprim	2.5	639 o
5. Buctril + MCPA	2.9	391 o
6. Basagran	2.0	417 o

LSD 5% = 486 kg/ha
C.V = 41%
Trial mean = 555 kg/ha

o = no sign. diff.

The crop yield of the different treatments shows a great variance because of the heterogen crop stand. The check plot without any weed control produced even more than some of the weeded plots. Under different weather conditions with fast growing plants, the short and the long term effect of the various chemicals might have been quite different. Beside this, the weed population might have recovered faster after treatment, but also the crop canopy might have closed sooner, suppressing the weed growth. Therefore no final conclusions can be drawn from this trial so far, it needs to be repeated for more seasons.

EXTENSION

In order to contact more farmers, the project emphasised the group approach in 1986/87 season. As the year before, groups of farmers were trained on principles of improved cultivation methods. But those had been selected according to their ability with regard to own draught power and labour supply. The idea was to form groups of 15-20 farmers, and have a block demonstration of improved methods vs. traditional methods per group. After having attended the theoretical course on improved cultivation methods in advance, the group would be called together at planting time to prepare and plant part of a plot according to the instructions of the extension worker, while the other part of the plot is treated with traditional methods.

Taking advantage of the group spirit, the farmers are trained on the job to handle the recommended methods, and they are expected to practice those methods on their own fields. For each required field operation, i.e. thinning, interrow cultivation etc. farmers are called to the block demonstration to be trained first, before they go and practice on their own fields. In the mean time they are visited by the extension officer, say once a week, to check, whether problems occured.

Before harvest all interested farmers are called for a field day to visit the block demonstration and some fields of the group members. The results of improved cultivation methods vs. traditional methods can be demonstrated and experiences be exchanged. Such a field day is a opportunity to raise more interest of other farmers, either to increase the size of existing groups or to form new groups. The size of a group should not exceed the above mentioned number of 15-20, because this is the number of farmers an extension worker can visit within one week. Conducting a block demonstration, there is a problem of timing involved, because the joint operations on the block demonstration have to be well ahead to ensure, that farmers don't miss favourable conditions on their fields. Members of one group will conduct their own field operations approximately at the same time, and therefore they should be visited all within one week.

The next step is to delegate some of the burden of work from the extension worker to the farmers to act as a "key-farmer" in small groups, helping their neighbours to practice the recommended methods.

BLOCK DEMONSTRATIONS

Xhwaa molapo system

The total size of the block demonstration plot was 2880 sqm, being devided in a "traditional" and a "improved" portion of similar size. In order to avoid envy and jealousy amongst farmers, a neutral place was chosen for the block demonstration at one of the project's trial plots.

On 13/12/86 a group of 14 farmers (12 men + 2 women) gathered at the field to carry out the block demonstration.

The "improved" part had been ploughed before and was now harrowed in order to kill the emerged weeds and to prepare the seed bed. Afterwards the farmers planted 20 rows of maize, 20 rows of sorghum, and 10 rows of cowpeas, using the implement alternately under supervision of the project staff. Farmers were trained to plant parallel in straight rows, which is essential for the later use of the cultivator, and to remove the seed hopper, exchange seeds and seed plates etc.. The "traditional" portion was completely handled by the farmers. They were given a bag each of maize, sorghum, and cowpeas, which they mixed and broadcasted. Afterwards one farmer assisted with his ox-team and ploughed the seeds under.

The group members were then released to practice on their own fields what they had learned. Harrows and planters were lent out by the project, because not all of them owed implementats. On the 5/1/87 the group was called again to meet at the block demonstration. This time hardly any crop had emerged on the broadcast part, while the row planted crops showed a satisfactory stand. This fact was much appreciated by all group members. Farmers were trained now to use the cultivator between the rows, and afterwards the importance of thinning was stressed. This time the meeting was attended by 11 farmers. The farmers, who had row planted on their own, were looked after by the project staff regularly and assisted in lending a cultivator.

Before harvest all interested farmers were called for a final field day, to visit the project's on-station trials, the block demonstration, and some fields of the group members.

Table 20. XHWAA BLOCK DEMONSTRATION, RESULTS AND DETAILS, NONFLOODED MOLAPO

Details		Broadcasted	Row planted
Plot size (sqm)		1440	1440
Ploughed		13/12	9/12
harrowed		---	13/12
Planted		13/12	13/12
Crop:	Maize	Mixed cropping	20 rows sole cropp.
	Sorghum	(4:1:1)	20 rows
	Cowpeas		10 rows
Total seed rate (kg/ha)		13.2	20.8
Emergence:	Maize	2.0	3.3
(pl./sqm)	Sorghum	0.5	20.0
	Cowpeas	1.0	15.3
Weeding		One hoe	One mechanical (cultiv. + hoe)
thinning		---	by hand
Crop stand:	Maize	Nil	1.6
(pl./m)	Sorghum	Nil	3.6
	Cowpeas	<0.1	3.4
Grain yield:	Maize	Nil	752 +
(kg/ha)	Sorghum	Nil	241
	Cowpeas	3.0 Total = 3.0	83 Total = 1076

+ = located in depression

Results and details of the Xhwaa block demonstration are given in table

20. Contrary to former information the farmers used less seeds for broadcasting than for row planting. But they might broadcast more under preflooded conditions.

Since soil moisture conditions were marginal when planting, emergence was very poor on the broadcasted part, but satisfactory on the row planted portion. Soon later all crops dried up on the broadcasted part, because the ploughed top layer was loose and not compacted. The remaining row planted crops suffered from long dry periods. Maize was sprayed once with chlordane to control termites. According to crop water requirements, cowpeas were planted on the highest point and maize in the depression of the saucer shaped molapo, which is reflected by the yields. Although yields generally remained low, there was no doubt amongst the participating farmers, that row planting had proved successful.

At Mazanga the emergence of the crops was much better than at Xhwaa, because just after finishing planting a nice shower fell, assuring good germination also on the broadcasted part. Later both parts suffered a lot from water stress, but since the broadcasted portion was over populated, the final yield was very little as compared to the reasonable yield off the row planted and thinned crops. This fact was well recognized by the group members, when they were called for a field day before harvest.

Table 21. MAZANGA BLOCK DEMONSTRATION, RESULTS AND DETAILS, NONFLOODED MOLAPO

Details		Broadcasted	Row planted
Plot size (m2)		700	700
Ploughed		5/12	12/11
Harrowed		---	5/12
Planted		5/12	5/12
Crop:	Maize	Mixed cropp.	18 rows sole cropp.
	Sorghum	(2:3:2)	18 rows
	Cowpeas		8 rows
Total seed rate (kg/ha)		16.3	20.1
Emergence:	Maize	2.3	3.8
(pl./sqm)	Sorghum	8.0	10.3
	Cowpeas	1.5	7.4
Weeding		1 hoe by hand	1 mechanical (cultiv. + hoe)
thinning		---	by hand
Crop stand:	Maize	1.1	1.1
(pl./m2)	Sorghum	8.8	3.5
	Cowpeas	1.5	2.7
Grain yield:	Maize	12.0	12.0
(kg/ha)	Sorghum	111.0	714.0
	Cowpeas	20.0 total = 143	131.0 total = 857
Harvesting		4/2 - 17/3	4/2 - 16/3

CONCLUSIONS AND RECOMMENDATIONS
(Nonflooded conditions)

TILLAGE

The time-consuming ploughing should be done well ahead before planting season, in order to be able to concentrate efforts on planting, when conditions are favourable. Ploughing should start with the first rains in October, as soon as the soil moisture allows the operation.

Generally only the sandy top layer should be cultivated, to avoid the ploughing up of the clayey subsoil, which would result in a deterioration of soil physical properties. But depending on conditions, the ploughing depth has to be deep enough to assure a proper weed control.

Before planting the harrow should be used not only to prepare the seed bed, but also to destroy the weeds, which have emerged in the meantime. In some cases, when there is a long time between ploughing and planting, two harrow operations might be necessary, because the weeds should not grow too big, otherwise the harrow cannot destroy them. This is not just an additional effort, but it will pay back by a reduced weeding requirement in a later stage.

The spike harrow has proved to be an useful instrument to control the very common Star grass (Cynodon dactylon) by pulling out and gathering the rhizomes. Beside this, the harrow has a levelling and slightly compacting effect to support a proper planting and thus homogen seed germination.

PLANTING :

Since trials of previous years have shown, that early plantings can be very successful, one should always try to achieve one early planting on a portion of his field. But generally the strategy under dry molapo conditions is orientated to yield stabilization and risk minimization rather than aiming at maximum yields. Spreading the planting dates is one measure to reduce the risk of crop failures by utilizing rains at different crop stages.

Planting should start with the first suitable rains in November, but should immediately be interrupted when conditions become unfavourable, and be continued with the next promising rainy period. Experience of the last years has shown, that plantings after January are hardly successful, so planting should be finished by this time.

CROPPING PATTERN :

Maize and sorghum are the favourite crops, prefered by the local people as stable food. Cowpeas and groundnuts, and to a little extend millet, play a minor roll, but are planted on small areas. However, under dry and unfavourable conditions maize almost ever fails to produce, while sorghum, millet, and cowpeas at least produce a small yield. This has to be considered, when planning the cropping pattern. With sorghum and cowpeas there are also various varieties available with differences in drought resistance and growing period.

In a saucer shaped molapo the water availability varies with the elevation and micro topography. During dry years those patches, which benefit from run-off water and mostly have the better soil, are clearly indicated by better plant growth. This locations should be reserved for planting maize and sorghum varieties like Segaolane, Marupantsi or the local Tshabatsie. More drought resistant varieties like 8-D and 65-D should be planted next up the molapo, followed by millet and cowpeas. If available, cowpea varieties like ER7 (short cycle) and Blackeye or Tswana (medium cycle) should be planted for better utilization of the rains.

Most attention should be paid to avoid any unnecessary competition between plants, so weeding should be done properly and in time, and the crops should be thinned early to the desired spacing, depending on the conditions.

As a general guideline for dry molapo conditions, the plant population should not exceed the following numbers:

Crop	Plant population (plants per ha)	Spacing (cm)
Maize	20 800	0.8 x 0.6
Sorghum	31 250	0.8 x 0.4
Millet	31 250	0.8 x 0.4
Cowpeas	50 000	0.8 x 0.25
Groundnuts	50 000	0.8 x 0.25

Although it is difficult to practice crop rotation, when planting crops at different locations according to their water requirement, it should be practiced whenever possible. Intercropping legumes into cereals and just varying the spacing according to crops and molapo level, could be a solution to overcome this problem of crop rotation. But this method has not been tested sufficiently to be recommended yet. Anyway, intercropping must not interfer with row planting and interrow cultivation.

Trials with intercropping were started this season and will be continued, because in the long run we have to aim at such a system for reasons like risk minimization and low inputs.

FERTILIZATION

Under dry molapo conditions, when water becomes the major stress factor, no yield response on fertilization can be expected. In some cases even a negative effect has been observed. But as stated in paragraph 3.1.3, the withdrawn nutrients will have to be replaced in the long run to avoid decomposition of soil fertility.

The proposal of using kraal manure, as one can find in many reports, is not feasible. First of all, the majority of cattle posts are far away from fields, so there would be a problem of transport. Secondly, the amount of manure, which accumulates in a kraal is very limited and the quality must be very poor. To apply a reasonable amount of nutrients with kraal manure, one has to think about quantities of 10 tons per ha.

Under wet molapo conditions and proper crop management, a well-balanced application of mineral fertilizer will result in a positive yield response and may be economically justyfied. But under the present conditions fertilization cannot be recommended.

WEEDING :

Ploughing early with sufficient depth and then harrowing before planting, are the first measures of proper weed control. About 4 weeks after planting, when crops have established, the cultivator should be used to weed between the rows. Handweeding combined with the thinning of the crops will only be necessary on the rows.

A cultivator equipped with flat sweeps proved to work better than a cultivator with tines. Those cultivate too deep, are heavy to pull, and leave uncultivated strips in between.

A second weeding should follow about 6 weeks later, before the plant canopy closes.

The use of herbicides cannot be recommended in the present situation because of economical reasons, although they proved to be effective in field trials.

PLANT PROTECTION :

Normally the problems of pests are more severe under dry molapo conditions, when the plants are stressed most of the time. Under such conditions yield expectations are low, and the risk of failures is high. So the return of any additional input is very questionable, this stands also for chemical pest control.

In a low-cost orientated cropping system agronomic methods should rather be used to reduce the risk of pests and diseases.

Measures to reduce the risk of pests and diseases are:

- ploughing with sufficient depth,
- the only use of healthy and dressed seeds,
- early planting,
- avoid monoculture for many years and practice crop rotation,
- the pest sensitive cowpeas should not be sole cropped in large scale, they should rather be intercropped in cereals,
- proper weed control, because many weeds are also hosts for pests and diseases,
- ant hills around the fields should be destroyed regularly.

FODDER CROPS :

As long as farmers struggle to produce their own food, they won't accept the production of fodder crops. In the present stage the production of fodder must not interfere with other activities during cropping season. As a first step, crop residues should be collected after harvest and stored at a termite-save place. Secondly, fodder trees like Leucaena should be planted to produce high nutritious supplementary fodder (approx. 30% protein).

Being in it's 3rd year, a Leucaena plot of 900 sqm produced about 200 kg of dried leaves under very unfavourable conditions. This would be enough to provide supplementary fodder to 4 oxen at a daily rate of 2 kg per animal for about 4 weeks, to be fed before ploughing.

EXTENSION

Generally the group approach proved well this season, starting with theoretical courses before ploughing season to prepare and encourage farmers, and train them later practically on the job in form of block demonstrations. Although conditions were very unfavourable and discouraging this season, the adoption rate of improved cultivation methods as well as the attendance of meetings and field days was satisfactory.

The conductions of block demonstrations have to be well ahead off the peak of main operations like planting and weeding, to assure proper attendance and to avoid a delay of farmer's own activities. Also the field days should be carried out earlier next season, before farmers get busy with bird scaring and cattle management.

15.3 Water Management in the Boro Shorobe Flood Plains

INTRODUCTION

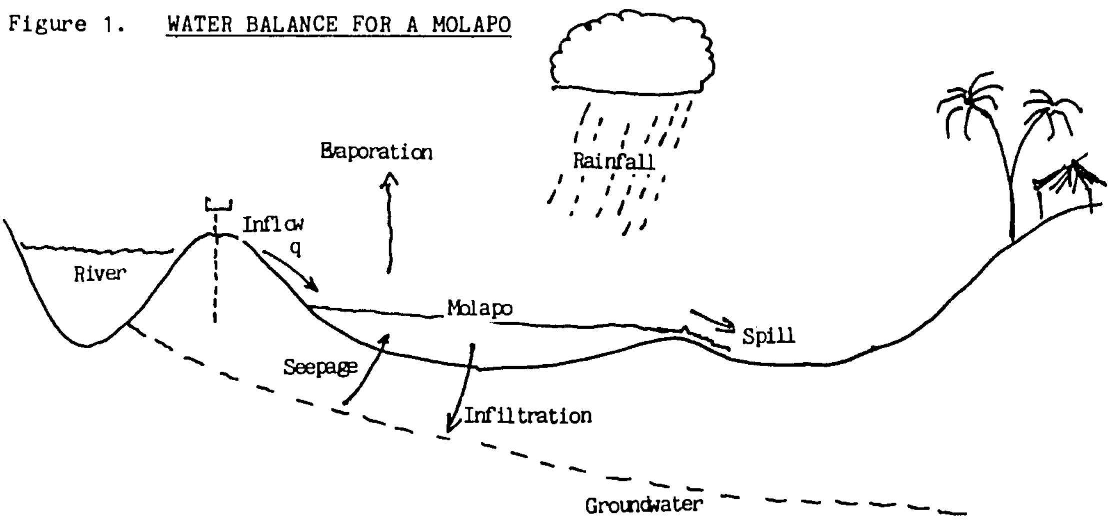
Only since the completion of the 1/10000 scale topographic maps for the Molapo project area (in 1986), has it been possible to produce a true picture of the water balance, conductive demands on supply channels/routes and a working water management plan for the entire area. This has come at a time when implementation of greater water security for the Southern Delta is being considered and helps remove many of the uncertainties which have hindered appropriate planning.

For detailed reports refer to the MDP technical reports - Water Management.

15.3.1 FLOOD SIMULATION

A Mathematical model was developed to determine the volumes of water needed, the duration of innundation and the depth of water infiltration that could be accomodated between the commencement of flooding and necessity for arable agriculture to begin. this was derived from a water balance in a Molapo, as schematicly depicted in figure 1.

Figure 1. WATER BALANCE FOR A MOLAPO

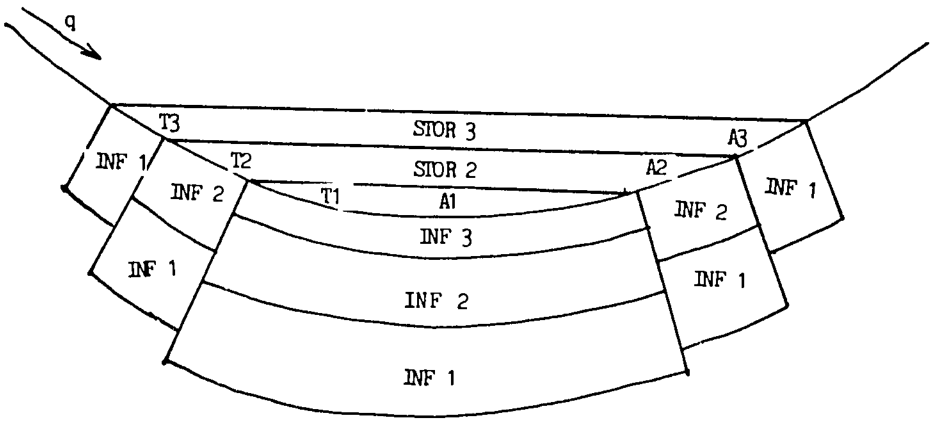


As flooding occurs during the dry winter months it is possible to exclude rainfall. For simplicity it is acceptable to also exclude seepage, to or from groundwater as this has not been observed in recent years. Likewise spill from one Molapo to another can also be disregarded by treating each section as an integral basin.

The mathematical model operates by considering the cummulative effect of quantities of water entering the molapo. Each new quantity adds to previous water, floods newland and increases the surface area of the flood. As the infiltration rate changes with time so differing factors have to be applied to accomodate its rapid decline.

The model can be visually represented as in figure 2.

Figure 2. THE WATER BALANCE IN A MELAPO BASIN AS USED FOR FLOOD SIMULATION



The components of the water balance are as follows.

1) Field Storage (Stor)

Incremental volumes of water entering the molapo. The storage is decreased by evaporation and infiltration. The surface area and depth of the storage is determined from contour map interpretation.

2) Infiltration

Infiltration rates have been determined for three day intervals after flooding. Initially these are rapid, (INF 1) finally reaching a steady state after one month, (INF 10).

When the flood expands then the newly flooded area starts "INF1" whilst the previously flooded portion assumes the slower rate of "INF2" etc.

The value selected for infiltration is soil specific but practice shows that the following :tios of infiltration are applicable to the ten 3 day periods following inundation.

Infiltration	1	0.48	6	0.05
Steps	2	0.18	7	0.04
	3	0.08	8	0.03
	4	0.05	9	0.02
	5	0.05	10	0.01

3 Evaporation (E ACT)

Evaporation is proportional to the surface area of free water and the time period considered. This is approximated to be half the total surface area flooded during 3 days, giving:

$$EACT = \frac{A}{2} \times \frac{EO}{100} \times T \quad (TCM)$$

Where EO is open water evaporation in mm/day - divided by 100 to give an answer in thousands of cubic meters, (TCM).

The Water Balance

With a 'static' flood, the supply is just adequate to match the consumption, but with an 'expanding' flood allowance has to be made for consumption and then the innundation of new land.

An iterative calculation was set up covering the above points and run on a micro computer for each molapo profile as accessed by the oncoming flood.

15.3.2 BORO BACK FLOW

Back flow has been assumed to consitute about 20% of the water discharged by the Boro River. By computing the volume of water required to have achieved the 1984 flood, as recorded from areal photography, and ground checking, it is concluded that between 5.8 to 7.7 m3/s were required - being 26 - 35 % of the Boro. A figure of 31% is therefore taken as the backflow in 1984 over a period of 2.5 months.

15.3.3 POTENTIALLY FLOODABLE AREA FROM BORO BACK FLOW

Taking a value of 30% as Boro backflow with 15% being the water actually entering the Molapo system them the probability of achieving Melapo flooding under different Boro flow regimes is presented in table 1.

Table 1. RESULTS OF ANALYSIS OF GAUGE DATA OF THE LAST 17 YEARS NEAR THE BORO T-JUNCTION, AND OUTCOMES OF SIMULATION RUNS .

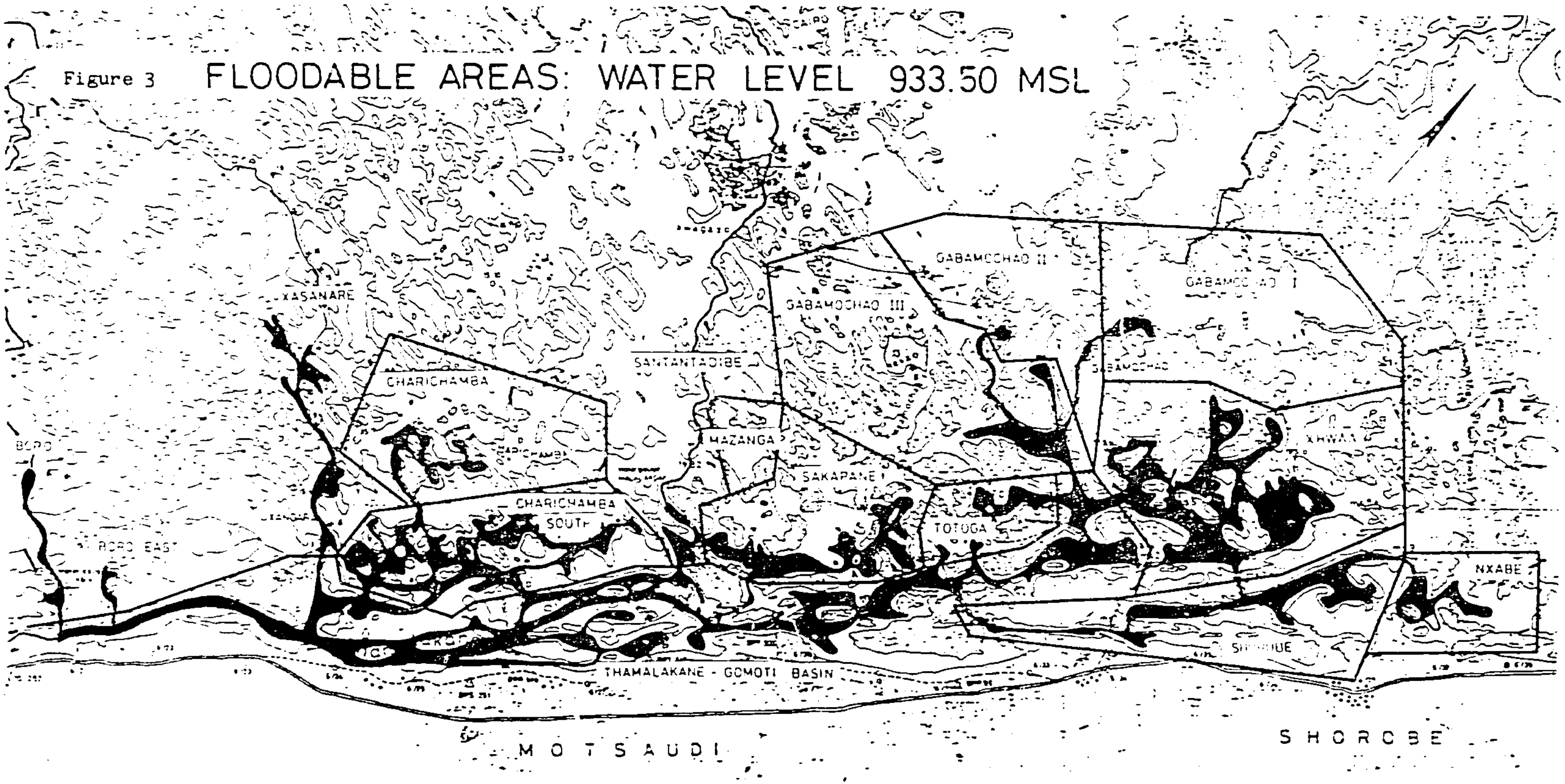
Chance %	Q-Boro M3/s	WL MSL	Q-back 15%	Area ha Simul.	ha below contour	Flooded %
10	< 6	<932.44	.90	0*	27	0
30	<12	<932.95	1.80	0*	193	0
50	>21	>933.69	3.20	1093	1665	66
30	>24	>934.70	3.60	1229	2680**	46
19	>26	>934.70	3.90	1331	2680**	50

** = Area below 934 MSL only, excluding Gabamochao 2 & 3 and Boro-East (together 830 ha).

It can be seen that increasing the back flow from the Boro does not produce a simple linear increase in flooded area. It is true that the area is floodable (see table 2, figure 3 and 4) but the rate of convayance of water up the Thamalakane and between the islands of the Melapo, poses a limitation given the narrow time frame for flooding to take place.

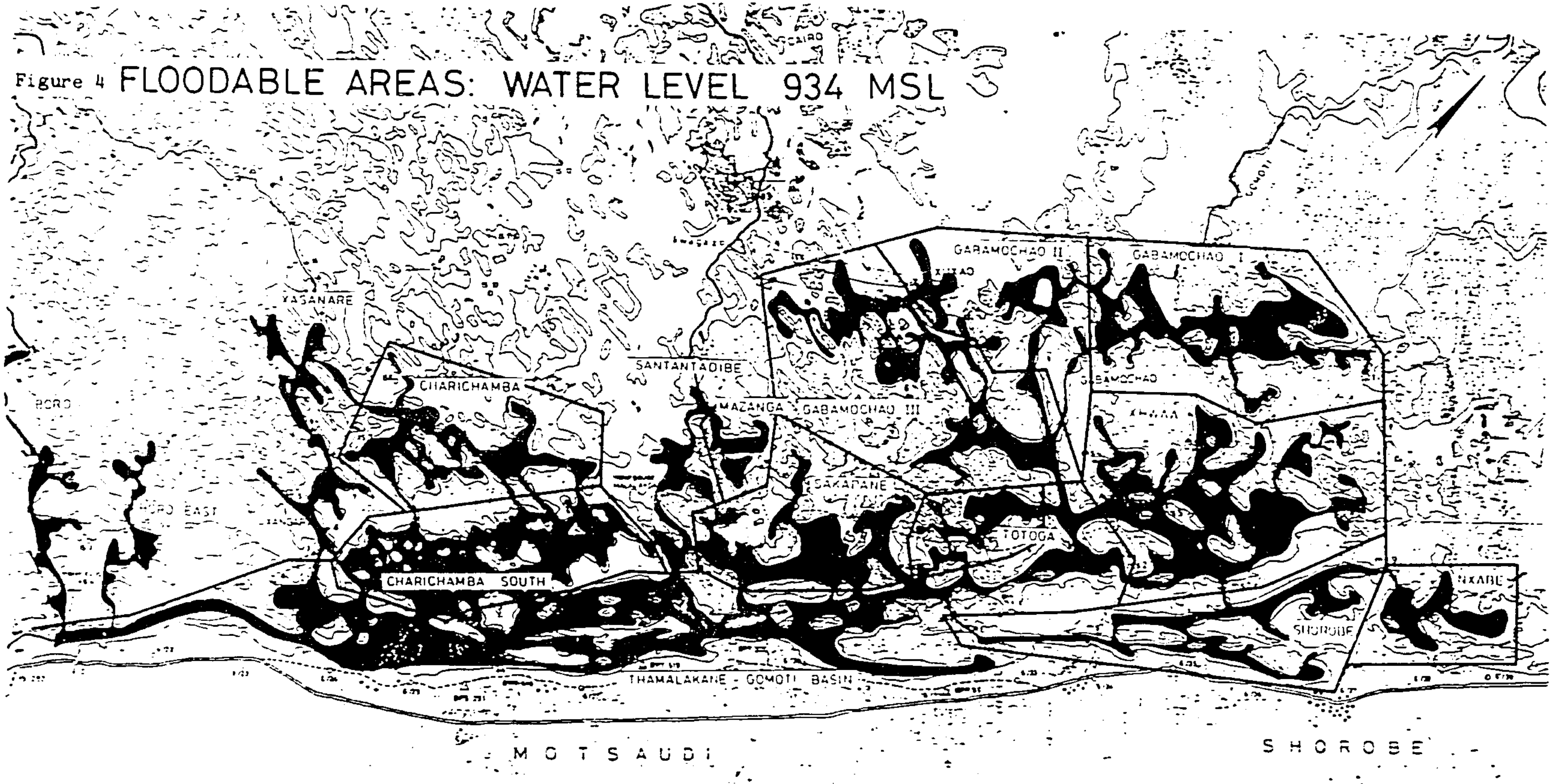
It is deduced that under the present circumstances that backflow can be expected to only flood half the potentially available land.

Figure 3 FLOODABLE AREAS: WATER LEVEL 933.50 MSL



Scale 1 : 100 000

Figure 4 FLOODABLE AREAS: WATER LEVEL 934 MSL



Scale 1 : 100 000

Table 2. FLOODABLE AREAS (in ha): AT GIVEN STATIC WATER LEVELS

	934.50	934	933.75	933.50	933.25	933	932.75	932.50	932.25	932	931.75	931.50	931.25	931
Xhwaa		532	473	410	311	202	89	42	15	3	3	0		
		159		94		13		1						
Shorobe		420	367	305	253	199	152	98	63	38	21	9	2	0
		32		22		6		2						
Nxabe		160	117	75	37	14	3							
Mazanga		70		30		5								
		1373		936										
Gab. I		477		194		49		9		3				
Sakapane		408		173		16		2						
Totoga		150		93		28		5		0				
Charichamba		312		129		48		16		1				
		1347		589										
Gab. II		220												
Gab. III		500												
Boro East		110												
Santantadibe		130												
Boro		170												
Xasanare		210												
		1340												
Thamalakane	1839	1453		885										
Chari South	688	558		301		44		3						
		2011		1186										
TOTAL		6069												

This area could be increased by diverting additional water directly into the area through the Xasanare but a more favourable option will be to allow a greater proportion of Boro back flow during the critical initial discharge period Mid-June. This can be neatly achieved through operating a gated structure at the Matlapaneng road crossing, rapidly raising the water level in the Upper Thamalakane, providing enhanced back flow before flood cessation is required so that the land can fall dry in time for planting.

The presence of a 'Master bund' on the Thamalakane upstream of the Boro junction is essential to exclude high or prolonged flood water swamping the Melapo area.

The operating system would require early enhanced flooding followed by flood exclusion.

15.3.4 THE TIMING OF FLOOD AND RECESSION

Flood heights in excess of 934 MSL will cover more area at the expense of delaying flood recession on the lower parts of the Melapo.

In the heavy soil Xhwaa/Shorobe Melapo a period of about 4-5 months is required to adequatly recharge soil moisture. If flooding starts in June then the 'heaviest' land should fall dry by mid November. A delay in flooding will cut into the growing season if full flood depth of 934 MSL is desired. A reduction of flooding time will necessitate a unrealistically high flooding rate to achieve 934 MSL.

The optimum timing for flooding will be between June and September. Total flood exclusion from mid September to end of May.

15.3.5 WATER CONSUMPTION PER FLOODED HECTARE

Even without taking into consideration the 'dead storage' of the Thamalakane basin, (which must be filled before flooding the Melapo), the water consumption per hectare is large.

Table 3 gives the computed values for a back flow of 3 m^3/s, showing that there is a steep rise with the duration of innundation.

On grounds of water use efficiency innundation of longer than 4-5 months should be avoided.

Table 3. FLOODED AREA (ha), TOTAL INFLOW VOLUME (in TCM*) AND AVERAGE WATER CONSUMPTION PER HA FLOODED FOR 1-9 MONTHS

Months	Inflow TCM*	Area ha	TCM/ha
1	7776	483	16
2	15552	793	20
3	23328	1025	23
4	31104	1197	26
5	38804	1325	29
6	46656	1421	33
7	54432	1492	36
8	62208	1545	40
9	69984	1585	44

* TCM = thousands of cubic metres of water.

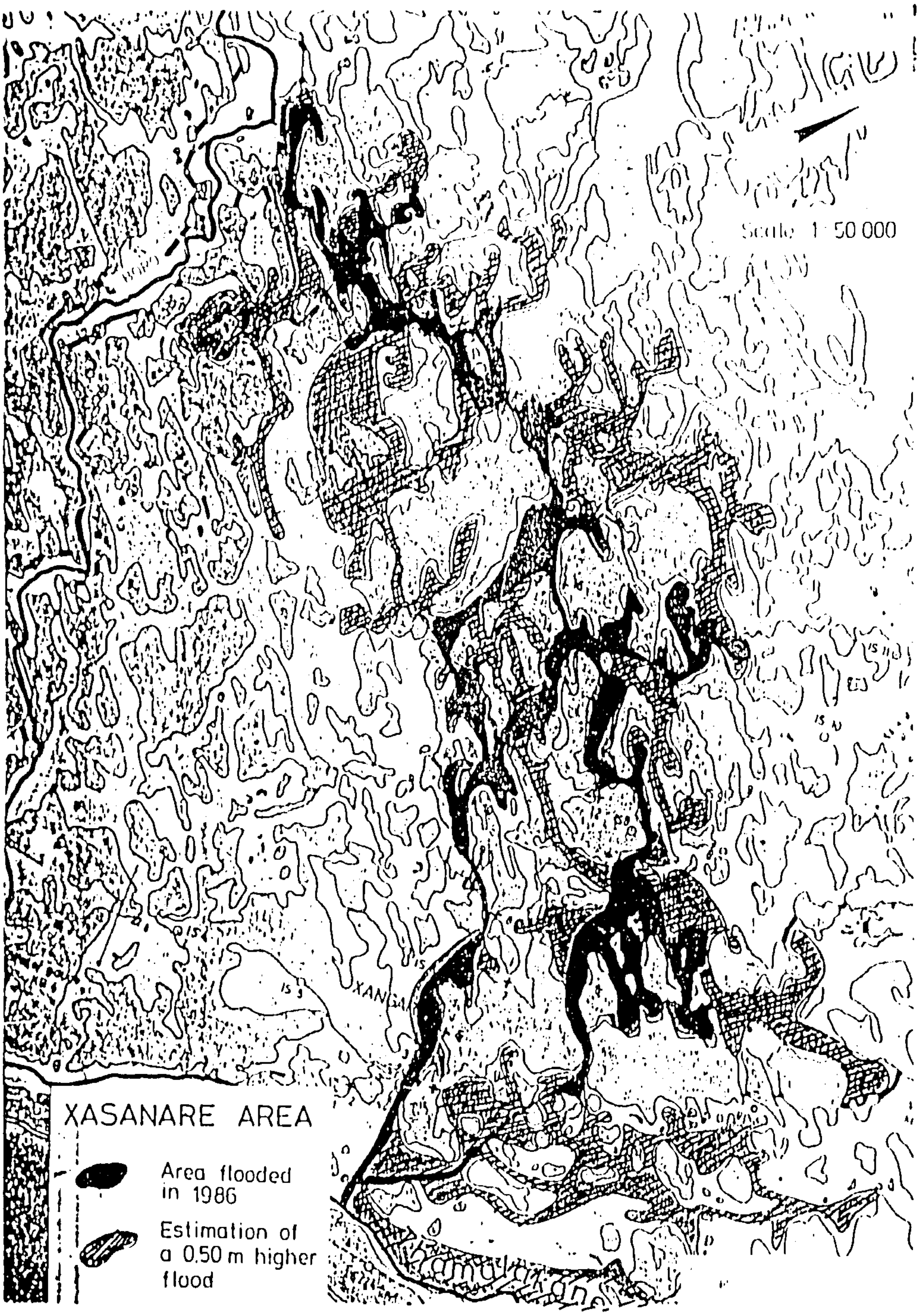
15.3.6 THE SPECIAL CASE OF THE XASANARE

The Xasanare is an ill defined channel branching off the Boro on its northern bank about 10 kms upstream of the Thamalakane. Since bunding during the lower Boro improvement, in 1970, is has not served as a major conduct. However its potential was demonstrated in 1986.

When farmers breached the Xanasare bund at the diversion from the Boro, it showed that the Xanasare may inundate about 1000 ha even during years in which the Boro flow is so little that no molapo land can be flooded by backflow.

In principle the Xanasare area differs from the Thamalakane area as it has a general gradient of roughly 30 cm/km and by having a surface drainage to lower fields. These melapo convey water rather than having dead storage which is typical for the backflow area around the Thamalakane basin. (Fig. 5).

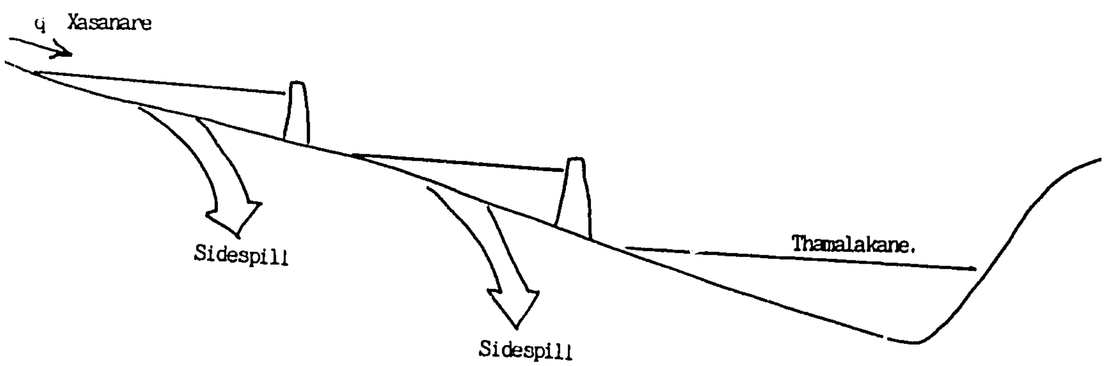
Figure 5. FLOODING AND POTENTIAL FLOODING IN THE XASASANARE AREA



A point of concern here is that the area around the Xanasare was not so often cultivated in the past, which may be explained by the possibility that it was too wet as suggested by the satellite imagery. The soils are generally lighter than in Xhwaa and Shorobe. It seems that farmers are developing interest towards this area that gradually dried up after the Xasanare was closed by a dam in 1970, (the dam was breached twice in recent years). The land tenure system might put restrictions to move in but this is not (yet) known.

An option for development of the Xasanare area may be to put up bunds with flow regulating structures in bottlenecks of the channel. This would back-up the water, creating side spill and thus increase the floodable hectarage. Instead of a water flow along the gradient one would introduce a series of cascading backwaters as depicted in figure 6. This option has not been worked out in detail.

Figure 6. <u>SKETCH OF CASCADING BACKWATERS ALONG THE XASANARE DISCHARGING INTO THE THAMALAKANE BASIN</u>



15.4 **Soil/water studies for irrigation potential**

15.4.1 DRYING CURVE

The soil around 12 neutron probe access tubes in the Rice Project extension area was saturated and left to dry. The soil moisture content at a depth of 20-40 cm was monitored with the neutron probe. As 6 of the tubes were supposedly in slightly lighter soil, the results are plotted in concidered in two groups. For comparison the saturated moisture content was also determined in the laboratory, and yielded 32 vol% with a standard deviation of 1.7 vol% over 6 samples. Field capacity at about 25 vol% and was reached after 14-24 hours. A distinction between the two groups appears not justified, but was maintained after different time lapses.

15.4.2 RING-INFILTROMETER TESTS

Infiltration rates were first assessed with a (double) ring infiltrometer in Xhwaa, Mazanga and at the Rice Project extension area. The results were not satisfying as the lowest infiltration rate measured after 5 hrs was 85 mm/hr at Xhwaa, which did not seem realistic as compared with 4mm/day repeatedly measured during flood recession.

Cracks in the dry soil during the infiltrometer test could largely explain this observation. However, the occurence of rainfall run-off ponds during the cropping season (also dry soil due to less than average precipitation) contradicts the foregoing.

As expected, averaged infiltration rates had large standard deviations, yielding coefficients of variation as high as 78%.

15.4.3 SPRINKLER TEST

More efficient infiltration figures were obtained from a sprinkler test in the Rice Project extension area. Two sprinkler heads were set up to serve concentric circles and rain gauges were used to measure the application rate, which decreased with the radius of the circle. The test was run on bare soil for 30 hours, and allows the following conclusions:

1. The application, as measured with the raingauges compared well with the increase in soil moisture content.

2. There was no clear moment when puddling started and the test was to terminate. A few puddles formed right at the beginning of the experiment, only gradually increasing in number. It seemed most puddles had formed at the periphery of the circle. Although the application rate there was lower, the big droplets had a visible impact on the soil texture.

3. As one of the sprinkler saddles was leaking, a pond formed at the centre of the sprinkled area, which gave the opportunity to compare in fact three application rates: ponding, 7.5 mm/hr and 4.9 mm/hr. It appeared that the application rate 7.5 mm/hr and ponding had similar results, but clearly differed from the infiltration under the 4.9 mm/hr application rate. This suggests that the rate of 7.5 mm/hr may be about the maximum that can be applied. On the other hand one reason that the infiltration

under ponding condition was hampered because of trampling and smearing of the soil during fixing and adjustment of the sprinkler heads.

4. The sprinkler test took place on ploughed land with a rough surface that facilitated a lot of water storage on the surface without run-off. Especially along the periphery of the circle which was served by the big droplets, this surface storage seemed to be of great importance to prevent water from running off over longer distances. This stresses the importance of cultivation methods for water conservation, i.e. contour ploughing.

15.4.4 PONDED BASIN TEST

Four small basins of about 2 m@|2|@ each were prepared in the field, covered with polytheen sheeting and filled up with water to a level that was pre-set by a needle pushed into the soil. At time T=0 the polysheet was pulled away and the amount of water that drawn was from a drum to maintain the water level in the basin at the tip of the needle was measured at regular time intervals.

Based on these data the cumulative infiltration and the instantaneous infiltration can be expressed as a power function. As the coefficient is dependant on the initial moisture content of the soil the tests were repeated in the same basin at short intervals, trying to find the basic infiltration rate. This rate converges after prolonged innundation. This basic infiltration rate is usually also the upper design limit of a sprinkler capacity.

From the results it appears that the instantatneous infiltration rate after 8 hours of innundation is estimated to average 7.2 mm/hr, with a standard deviation of 0.9 mm/hr (out of 5 determinations). The median values for the power functions yield:

I cum = 1.889 t** 0.623

I ins = 1.177 t** -0.337

with I in mm and t in min.

Especially for surface irrigation it is of importance to take into account the faster initial infiltration. Examination of the average realized infiltration per hour versus observation period yields a value of about 15 mm/hr during 6 hours.

From this it can be concluded that a layer of water of 90 mm would infiltrate within 6 hours time. Such a short innundation period is harmless for a standing maize crop.

15.4.5 SURFACE IRRIGATION EXPERIMENTS

Between 24-6-85 and 21-10-85 wheat was grown on a 0.44 ha plot. It was irrigated roughly at an interval of 2 weeks with an application depth of 85 mm, by means of short level furrows that were served with water from a hose discharging 2.4 l/s. Later a week's interval was used, applying 42 mm. This practice worked out at an application of 6 mm/day. The crop did not show symptoms of drought stress or water logging, although it was probably over-irrigated, after too long intervals. Apparently the infiltration rate of the soil was adequate to cope with this irrigation practice, which was carried out with a minimum of design and supervision.

A more elaborate surface irrigation experiment was conducted between June and October 1986, with the aim to establish design parameters for border strip irrigation. Four replicate strips were prepared of 35 m long and 7.5 m wide, to be planted to wheat. A head ditch was served with water from a 80 mm quick coupling pipe and 5 Hp pump unit. Water was extracted from the Boro river. The slope of the strips was about 0.7%, and the lay out was such to have minimal side slope. The water was meant to overtop the head ditch and to flow down the slope like a film. The water advance was measured by timing the moment it reached each of the six stations that were set at regular intervals. These stations were also used for soil moisture sampling. With every irrigation application and recession period were timed.

The principle of border strip irrigation is that the water infiltrates under expanding film of water that runs down the slope of the field. After the water supply is shut off the water on the field will still be running-off. As a result the upstream part of the field will dry fairly soon, but at the lower end the water will be backed up by an earth mound. This serves to compensate the fact that the infiltration started earlier at the upstream part.

To obtain an even distribution of the water, given a certain slope, surface roughness and infiltration rate of the soil, one has to balance the discharge of the head ditch and the length of the run.

The results of the experiment are summerized below;

1. The average moisture content of the soil, as measured over the six stations to a depth of 1.20 m is plotted versus time in figure 3. As 25 vol% is regarded as field capacity it can be seen that the field was kept quite wet. The field was irrigated once per week.

2. The total water application was 616 mm over about 98 days, averaging 6.3 mm/day. The actual evapotranspiration was calculated from the change in soil moisture content between the irrigations, yielding 359 mm over 74 days, or 4.9 mm/day on average. Hence the water use efficiency is estimated at 77%, which is as good as one may get with surface irrigation systems and shows that on small plots irrigators can obtain good results by manually distributing the water.

3. Over-irrigation showed from the moisture content figures of the bottom layer that was sampled (0.9-1.2 m depth). It exceeded the value of Field Capacity of 25 vol% on 54 occassions out of the measured 75. The percolation losses could not be qunatified in detail but can be estimated by supply - increase in soil moisture - evaporation between moisture measurements, yielding 616 - 408 - 156 = 52 mm, or some 12 percent.

4. The increase in soil moisture content after irrigation was compared with the recession period to examine the infiltration rate. Occurences with percolation (soil beyond Field Capacity) were discarded. The results are plotted on a double logarithmic scale in order to derive the parameters of an infiltration power function. However, the scatter of observations does not show a trend.

   Finally the data are compared with the infiltration function that was derived from the basin ponding test. Ten observations fall above that line and eleven fall below. The function seems to describe the infiltration fairly correct, but does not (can not) account for the high variation in infiltration. It could be emphasized that this infiltration function only holds for a moist to wet soil for a period of up to 8 hours.

5. An advance function could not be established because of the poor performance of the water "film". Earthen mounds (cross checks) were erected in order to distribute the water properly. An increased discharge would have helped, but the pump capacity was too small and besides, much longer border strips would have been necessary to maintain an acceptable moisture uniformity over the field.

6. A contour map with contour intervals of 10 cm was prepared for the experimental plot in order tolay out the border strips such as to meet the slope requirements.

   It appeared that the land surface was too rough and that land planning seems imperative for the introduction of surface irrigation, even in the relatively flat parts of the melapo.

15.4.6 DRIP IRRIGATION

A 0.44 ha plot was layed out with 16 mm dripper lines with pressure compensating drippers of 2.2 l/s rated discharge at spacing on the line. The unit was operated by a 5 Hp portable pump and 280 m long quick coupling pipeline of 80 mm diametre. Water was drawn from the Boro, until 21-4, when the Boro fell dry. Two maize varieties were planted on 22-1-1986; the traditional KEP and the hybrid PNR 473, both at a density of 50,000 plants per ha. Neutron probe access tubes were put in diagonally across the field to a depth of 1.2 m, with six replicates along the dripper lines and 6 replicates between the dripper lines. The measured depth intervals were 20 cm.

The results of the trial are described below;

1. The average moisture content along the dripper lines and that between the dripper lines was plotted versus time . From the graph it appeared that (except for the initial period) the soil moisture content between the dripper lines was lower than along the dripper lines. This to such extent that light drought stress was frequently observed in plants located between the dripper lines. Especially so during the heat of the day.

2. The wetting "onions" of the dripper lines met between the dripper lines at a depth of 40 - 80 cm. This was too deep to establish an even germination on a field lines were shifted by one metre, one week after planting (the plant row spacing was 1 m, whereas the dripper lines were spaced at 2 m). This was late, but did temporarily promote a better moisture distribution over the field for germination.

3. Plant population counts one week after planting allowed following conclusions;

   a. The hybrid PNR 473 germinated both along and in between the dripper lines significantly better than the traditional variety KEP.

   b. The traditional variety KEP did not germinate better along the dripper lines.

4. The dripper discharge uniformity was examined, and proved excellent.

5. The total application was about 410 mm over 88 days, or 4.7 mm/day. Including the rainfall of 57 mm the total water consumption was 5.3 mm/day.

6. The occurence of percolation losses was examined by screening the soil moisture figures for a depth of 0.9 - 1.2 m. On 24 out of 60 measurements along the dripper lines the value of Field Capacity of 25 vol% was exceeded, indicating probable percolation. The soil moisture in between the dripper lines never exceeded 25 vol%, out of 60 measurements. The percolation losses could not be quantified as irrigation took daily, whereas moisture measurements were done at a weekly interval.

7. The overall conclusion is that the dripper lines gave no operational difficulties, but were too widely spaced for the soil type (Gleyic Luvisol). The field does not have to be pre-irrigated, provided that the dripper lines are moved (perhaps more than once) during germination.

15.4.7 DISCUSSION

The irrigation investigations that have been described here must be considered as reconnaisance work. It is not complete nor conclusive in any respect, but serves to establish an approach for further trials.

Issues hardly or not addressed in this report are land availability in terms of land areas with acceptable soils and topography nearby water; in terms of land tenure; and in terms of acceptability. Soil salinity and sodicity have merely been mentioned, but have not been treated in any detail here. Also this report is restricted to technical design aspects, excluding agronomy and economics. This seems a serious shortcoming, but it is believed that the economics of irrigation trials only deserve attention when the irrigation system matches the environment. Ultimately the economics will determine which irrigation method (if any) is the most feasible, but a realistic decision must be based on the comparative performance of sound designs.

An important aspect here is the scale we are looking at. A traditional smallholder who goes for irrigation on a 2 ha plot has different requirements to his irrigation system than a small commercial farm of say 50 ha. This pertains to technical aspects such as maintenance, drainage requirements, the use or absence of farm machinery, the land area with uniform soil; but also to managerial issues like irrigation rotation schedules, cropping calendar and pattern and seed production.

The following summarizes an opinion of the possible feasibility of the various irrigation systems for the Boro-Shorobe area:

1. <u>Surface irrigation</u>

This can almost be excluded except, perhaps, for some small plots with a favourable location to be irrigated with level furrows or small basins. This for the following reasons.

a. The bowl shape of the melapo requires a long complicated canal lay out and hampers drainage by gravity.

b. The steepness and irregularity of the slopes causing erosion hazards and requiring expensive land planning or complicated field day outs with small basin or furrow dimensions.

c. Perhaps the soil heterogenity creates management problems like locally leaching of nutrients due to percolation.

Nevertheless, on small level plots basin irrigation may prove a cheap and easy way for small holders to irrigate without great financial risk. Low water use efficiencies (of 20%) are common in surface irrigation. Low pressure conveyance systems may substitute the canals and greatly increase the flexibility of the system (movable and independent of the reservoir level). However, maintenance of pump unit and fuel costs may become a burden.

2. **Sprinkler irrigation**

This requires much more investment than surface irrigation without adding to the value of the land. It can cope with uneven topography. The conventional system with movable sets of quick coupling pipes proved sturdy and durable, but is cumbersome to operate in a tall crop. The design can match differences in soil over the farm, but raises the required managerial skills. A worrying aspect of overhead irrigation is the loss of soil structure at the surface due to droplet impact. A range of working pressure and sets of different nozzles on the sprinkler heads contribute to the flexibility of the system. Water use efficiencies (about 80%) are much higher than in surface irrigation, although it may be reduced by evaporation by 30%.

Centre pivots

These are only interesting for commercial farms with high management level. The main diadvantage is that they require a uniform soil over the whole circle that is served. Also, the application rates towards the end of the boom are probably too high for the "molapo soils", depending on the length of the boom. This is especially so for low pressure systems, as the jetting radius of the nozzles is smaller, hence the irrigation depth should be applied in shorter time when the boom passes over. However, modern systems have nozzles fitted on brackets on either side of the boom, in order to reduce this problem.

Drip irrigation

This system is the most expensive to purchase, but has the reputation to be the most economical to run, due to low pressure, low percolation losses and low evaporation losses. The system is adaptable to different soils and topography and is the easiest to maintain as compared with other systems. Irrigation depth can be precisely tuned. The system is layed out after planting and coiled up before harvesting. These operations may cause damage by twisting the lines, but this is quick, cheap and easy to fix.

This system may prove suitable for smallholders and for larger farms though sedimentation and clogging of the system is a permanent hazard, especially when fertilizers are injected in the water. This hazard can be remedied by flushing and rinsing with (phosphoric) acid.

Lastly it is stressed that the individual irrigation trials should fit in a long term investigation schedule they should be composed of matching components. That is, a drip irrigation trial should cover a sufficiently large area to match the pump unit in terms of head and discharge requirements, and to match the conveyance system in terms of head losses.

Only then can the hydraulic performance of the system be compared with crop performance, yield and pumping costs. This will bring the figures out of the sphere of theoretical projections into actually observed values, and the economics will be more realistic. Still uncertainties will remain on economics when irrigation system is introduced into practice and beyond the research station.

Subsequent investigations into irrigation could well be accomodated in the projected Fertilizer and Irrigation Management Plot in the Rice Project extension area. The prime aim of this station remains to study salinity and/or sodicity hazards and soil structural developments in molapo soils and methods to remedy them. Irrigation trials can very well fit in that programme.

Section 16 . PANDAMATENGA

SUMMARY

A start has been made with the development of the Pandamatenga Research Station. Even from the first season the importance of nitrogen fertilizers was observed on newly cleared land. Low levels of maize leaf nitrogen confirmed this requirement but indicated that the nutrition of phosphorous and potassium were adequate.

Micronutrient analysis showed generally low levels for manganese, zinc and copper, but satisfactioy values for iron. Observations were made on the performance of castor, cotton, cowpeas, maize, mungbean, sorghum, soyabean and sunflower.

In the very dry 1986/87 season cotton and sorghum showed most promise.

16.1 INTRODUCTION

In August 1985 Land allocations were authorized and the development of the Pandamatenga Commercial Farms was launched. The Department of Agricultural Research was allocated Farm Q023 on the South Western edge of the central clay plain, a farm of about 400 ha of vertisol and 100 ha of sandvelt soils.

In the absence of available funding a modest start to research was made with the financial and collaborative assitance of the Agricultural Division of the Botswana Development Corporation (BDC).

An area of 6 ha was enclosed by a 1.8 m high electrified fence. An access road was cut through the forest by bulldozer which was then used to destump half the enclosure. All tree stumps were carried off the plot and burnt outside the experimental land prior to primary tillage. The land was ready late in January 1986 and was planted to a factorial fertilizer trial under maize and observation plots of sorghum, cowpea and castor bean.

The raw state of land preparation, late planting and absence of any on site supervision precluded obtaining meaningful yield data, but very useful observations were made.

For the following season (1986/87) the experimental plot was enlarged to 10 ha so that it could accomodate a collborative programme between this Department and the Botswana Development Corporation (BDC). Cooperation with BDC has been invaluable for these initial stages, before the funds for a full research farm are made available. Special credit should go to BDC's Agricultural Division who implemented most of the crop and tillage observation plots.

16.2 Location and soil types on the Research Farm

The location of farm Q023 is shown in figure 1. It has two major soil types within its boundary which differ completely in texture, slope and natural vegetation table 1. The boundary between the soils is very marked and coincides with the abrupt change in topography in the southern quarter of the farm (Figure 2), the Pellic Vertisol to the north (approx 400 ha) and the Ferralic Arenosol to the south (approx 100 ha).

Figure 1 Pandamatenga Central plain

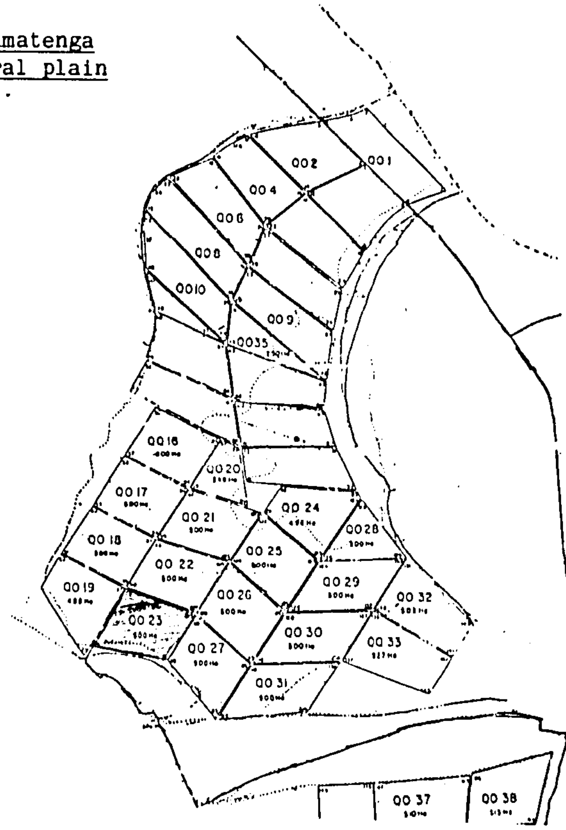


Figure 2 Research station, Q023

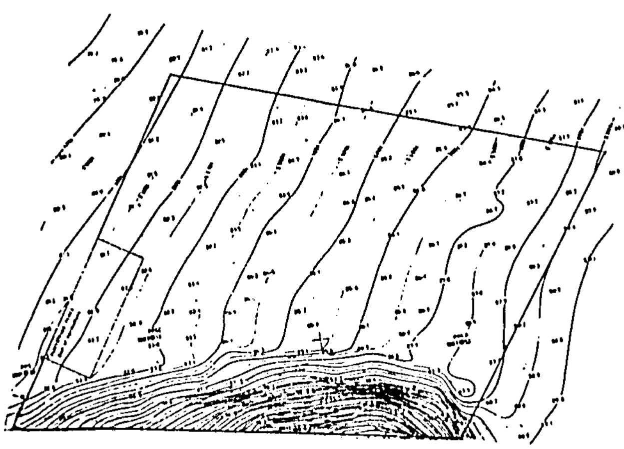


Table 1. THE SOILS OF THE RESEARCH FARM

The Pellic Vertisol

Soil profile description (18° 35' 45"S, 25° 29' 21"E)

Topography: Flat with weak gilgae 20-30 cm deep 1-2 m apart surface strongly cracked to depth of 1 m, slope 0.2%.

Vegetation: Grassland with scattered trees, frequent low mopane shrubs.

Parent Material: Lacustrine deposits

Drainage: Poor

Profile Horizons:

Depth (cm)	Description
Ah1 0-4	Very dark brown (10YR3/0.5) clay, strong fine to medium granular structure; loose to slightly hard calcareous nodules; many fine roots; abrupt wavy boundary to:
Ah2 4-15	Colour and texture as above; moderate medium to very course subangular blocky structure; very hard consistancy (when dry); many to fine to medium pores; few small hard calcareous nodules; many fine roots; clear wavy boundary to:
B1 15-40	Dark yellowish brown (10YR4/0.5) clay; with moderate prismatic in moderate coarse to very course angular to sub angular blocks; extremely firm to extremely hard with small slikensides; few fine to medium pones; very small hard calcareous nodules with very few very fine Fe/Mn nodules; roots common fine, clear wary boundary to:
B2 40-10 0+	Colour, texture consistancy pores and roots as above but with a very course prismatic structure in moderate coarse to very coarse angular blocks; calcareous and Fe/Mn nodules increasing with depth; roots becoming few and very fine.

The Ferralic Arenosol

Soil profile description (18° 36' 36"S, 25° 29' 02"E)

Topography: Gently sloping, 2.0%, with slight irregularities
Vegetation: Muture Woodland
Parent Material: Aolian sand
Drainage: Somewhat excessive

Profile Horizons:

Depth (cm)	Description
AH 0-25	Dark brown (7.5YR 4/5 to 4/5 when wet) sand, weak medium to coarse subangular blocks; loose to soft consistancy with common fine to coarse pores; many fine and medium roots; gradual smooth boundary to:
B1 25-60	Colour becoming darker and redder (6YR 3.5 5/4, moist) very weak medium subangular blocky structure; soft consistancy; common fine pores; common fine and medium roots; gradual smooth boundary to:
B2 60-110	Yellowish red (5YR3/6 moist) structureless sand; soft consistance; common fine pores; common very fine roots; gradual smooth boundary to:
B3 110-160+	Red (3.5 YR 3/5) structureless sand as above.

Soil Analysis

	Pellic Vertisol					Ferralic Arenosol			
Particle size analysis: Depth cm	0-4	4-15	20-35	60-80	100-140	0-20	30-50	80-100	135-155
Sand									
2000-500	5	9	8	7	5	15	16	15	16
500-250	12	15	14	12	8	47	42	41	42
250-100	5	3	3	3	2	22	24	24	23
100-54	3	2	2	2	2	9	11	11	10
Silt									
54-2	9	11	11	14	10	2	2	3	3
Clay 2	65	60	62	62	72	5	6	7	5
pH in water	6.7	6.2	6.4	7.0	8.1	6.5	5.3	5.4	5.1
in $CaCl_2$	6.1	5.3	5.3	6.0	7.3	5.8	4.3	4.2	4.3
% Organic Carbon	0.7	0.4	0.4	0.4	0.5	0.2	0	0	
P (Brays No. 1) ppm	4	1	1	1	1	13	1	1	1
Exchangeable Cations meq/100g									
Ca	32.5	30.0	31.1	32.7	61.1	2.2	0.1	0	0
Mg	8.3	8.1	8.0	8.3	9.8	0.6	0.4	0.4	0
K	0.5	0.2	0.0	0.1	0.1	0.1	0	0	0
Na	0.2	0.4	0.7	1.5	2.7	0.3	0.4	0.4	0.4
Total CEC	43.8	42.1	43.9	44.8	50.3	6.0	2.6	2.3	2.2
% Base Saturation	95	92	91	96	>100	57	36	35	40
CEC Meq/100 Clay	64	67	18	70	67	80	33	34	44

Additional profile information (SMSS, 1987)

Profile 009 - Pedon 86P0507, 18° 27' 47"S 25° 34' 01"E

Pellic vertisol

	Depth	0-17	17-30	38-61	61-85	84-105	105-150 cm
Water holding							
1/10 bar		57.3	56.7	56.1	53.4	56.6	62.0
1/3 bar		54.5	54.0	53.0	50.3	53.6	56.4
15 bar		37.7	37.7	38.6	38.5	39.1	38.8
Dithionite extract							
Fe%		1	1	1	1	1	1
Mn%		.1	.1	.1	.1	.1	.1
Al%		.2	.3	.2	.3	.3	.3
From water saturated past extract.							
Ca meq/l		1.6	1.5	1.2	0.6	0.6	0.5
Mg meq/l		0.5	0.5	0.4	0.2	0.4	0.2
Na meq/l		0.3	1.5	2.3	2.4	3.3	2.9
K meq/l		0.1	0.1	0.1	tr	tr	tr
HCO3 meq/l		2.3	2.9	2.8	2.4	2.7	2.6
Cl meq/l		0.2	0.2	0.8	0.3	0.4	0.3
SO4 meq/l		0.2	0.2	0.2	0.2	0.9	0.3
NO3 meq/l		tr	tr	tr	tr	tr	tr

16.3 **Research Programme 1986/87**

This seasons activities are outlined below. Permanent staff took charge of the site in January 1987 while eased subsiquent crop management problem and allowed the accurate harvesting of yields.

Trials and Observation Plots Established

1) Repeat factorial N.P.K. trial with fresh fertilizer and residual plots - test crop maize.

2) Comparison of primary land preparation to manage the grass sward

   a) Plough down
   b) Burn
   c) Cut and remove

Each treatment with and without 80N, 60P. Test crop maize.

3) Sorghum and Millet variety comparison trial, reported in section 2.1.

4) Mungbean variety trial

5) Observations on the following crops.

Sorghum	4 varieties
Maize	2 varieties
Sunflower	3 varieties
Soybeans	2 varieties
Castor	1 variety
Cotton	1 variety

6) Land preparation:

1) flat mouldboard ploughed
2) ridges
3) tied ridges

Rainfall was below average and less than 370 mm were recorded at our site. (See Appendix I). Nontheless the diversity of crops grown and the reasonable yields obtained was most encouraging.

16.4 **Results and discussion**

16.4.1 IMPORTANT OBSERVATIONS FROM THE 1985/86 SEASON

a) There was an acute nutrient deficiency in crops (maize, sorghum and castor) grown on newly cleared land in the absence of fertilizer.

b) Of the major nutrients N, P and K. Wherever N (nitrogen) was applied the plants grew very vigorously, (table 2 and illustration).

c) Nitrogen levels of 122 kgN/ha produced better growth than using the rate 56 kgN/ha. A level of 19 kgN/ha was completely ineffective.

d) On farmers fields where piles of tree stumps and brush wood were burnt the crops grew taller, matured earlier and produced bigger heads than on land unaffected by fire.

Table 2. EFFECT OF MAJOR NUTRIENTS ON MAIZE HEIGHT (21/2/86)

a) Main effects

		Plant height (cm)	LSD 5%
Nitrogen kg/ha	0	60.6	
	56	119.1	
	112	118.6	13.9
Phosphorous kg/ha	0	97.2	
	42	102.4	
	126	96.8	NS
Potassium kg/ha	0	95.0	
	100	103.2	6.7

Illustration 1. CASTOR PLANT, DWARFED WITH YELLOW LEAVES THROUGH ACUTE NITROGEN DEFICIENCY

Illustration 2. CASTOR PLANT GROWING IN A NITROGENT FERTILIZED PLOT
(same date as illustration above)

b) Interactions

MAIZE PLANT HEIGHTS (cm)

Nitrogen kg/ha	Phosphorous kg/ha 0	42	126
0	62.3	59.6	59.9
56	132.5	112.6	122.8
112	114.4	129.8	110.8

LSD 5% = 13.3

Only nitrogen and phosphorous showed any significant interaction but without any logical relationship to normal plant growth. There were no significant N. P.K. interactions.

16.4.2 1986/87 SEASON

The Rainfall

Rainfall over the research plot was well below average for Pandamatenga. The season started quite well with 300.4 mm up to the end of January. However subsequent rainfall was very light and the seasonal total only reached 365.4 mm.

This had an important impact on both research and observation trials, only permitting short season crops or crops planted on land fallow from last year to go through to yield.

The Fertilizer Trial

The N.P.K. factorial trial using N = 0, 56 and 112 kg/ha; P = 0, 42 and 126 kg/ha; K = 0, 100 kg/ha; with three replicates, was planted to maize (PNR 473) on the 26th November 1986. The trial was laid out adjacent to the 1985/86 season plots which were also planted to PNR 473. This gave both fresh and residual fertilizer treatments.

The residual fertilizer plots were split to give the true residual and banded compound fertilizer applied at planting at the rate 300 kg 3.2.1/ha.

The poor post silking rainfall very badly effected the maize which went into premature senesience with mishapen, part filled, cobs. The grain yield was collected for the zero and highest fertilizer plots so as to give an indication of production, table 3. Additional yield data was not collected as it was felt that the crop was predominantly drought affected.

Table 3. YIELD OF GRAIN FROM ZERO AND THE HIGHEST N AND P TREATMENTS

Treatment	Grain yield kg/ha	
	1986/87 treatment	1985/86 treatment
Zero fertilizer	573	859
126 kg P/ha	488	784
112 kg N/ha	643	688

Up to silking the crop grew very well without undue moisture stress. At silking leaf samples were collected from each plot for nutrient analysis. Each sample being a composite of five whole leaves from immediately below the cob, collected at random from within the plot from those plants with silks recently emerged. The leaf samples were air dried, ground and analysed for major nutrients N,P,K,Ca and Mg. Those samples from Zero and 112+ 126+ 100 kg N,P,K/ha treatments were further analysed for Fe,Mn,Zn and Cu. The analysis for boron and sulphur were attempted but failed through laboratory problems.

The mean leaf nutrient values are as follows.

Nitrogen	1.65%	SE 0.162	N = 205
Phosphorous	0.20%	SE 0.018	N = 206
Potassium	2.37%	SE 0.098	N = 206
Calcium	0.37%	SE 0.029	N = 136
Magnesium	0.19%	SE 0.020	N = 156
Iron	85.4 ppm	SE 21.8	N = 18
Manganese	12.9 ppm	SE 3.5	N = 18
Zinc	14.5 ppm	SE 2.7	N = 18
Copper	4.6 ppm	SE 1.3	N = 18

In comparison to other reported values for maize leaf nutrient status it is clear that the Pandamatenga maize was predominantly deficient in nitrogen. Table 4.

Table 4. VALUES OF MAIZE LEAF NUTRIENT STATUS AT SILKING

	Normal Values			Critical/Low Values		Pandamatenga
	1	2	3	4	2	Value
N%	3. 2	2.90	3.06	3.00	1.20	1.65
P%	0.18	0.20	0.32	0.25	0.11	0.20
K%	2. 4	2. 0	2.12	1.90	1.50	2.37
Ca%	0.70	-	-	0.40	.30	0.37
Mg%	0.40	0.17	-	0.25	.13	0.19
Fe ppm	82	102	-	25	-	85.4
Mn ppm	38	120	-	15	-	12.9
Zn ppm	26	30	-	15	15	14.5
Cu ppm	6	9.3	-	5	-	4.6

1, Lockman 1972; 2, Chapman 1966; 3, Sumner 1977; 4, Melsted et al 1969;

The intensity of the nutrient imbalance is assessed using the Diagnostic and Recommdation Intergrated System (DRIS) as detailed by Sumner (1977). The computed indices for the Pandamatenga samples are:

N = -33
P = + 7

K = +40

This again placing a strong emphasis on the relative deficiency of nitrogen.

This trial incorporates eighteen possible nutrient combinations under three different circumstances producing 54 fertilizer environments.

The leaf nutrient contents were <u>NOT</u> significantly different between the three trials (fresh, residual or residual and supplimented fertilizer) so the whole data file is analysed together.

Further more as there was no significant effect by either the phosphorous or potassium treatments on leaf nutrient concentrations, attention can justifiably by focused on nitrogen (Table 5).

TABLE 5. NUTRIENT EFFECTS OF TREATMENT ON MAIZE LEAF NUTRIENT CONTENT (% DM).

MAIN EFFECTS	Treatment	Zero	56	112 kg/ha	LSD 1%
	Nitrogen	1.47	1.67	1.82	0.19
	Treatment	Zero	42	126 kg/ha	
	Phosphorous	.21	.20	.20	NS
	Treatment	Zero	100	kg/ha	
	Potassium	2.34	2.41		NS

Even at 1.82% N the leaf nitrogen value is sub optimal and further nitrogen fertilization would be needed if high production levels (say in excess of 5 tons/ha) were sought.

Anaysis of the soil for phosphorous (Bray No. 2) clearly showed the effect of phosphorous fertilizers, table 6.

Table 6 SOIL PHOSPHOROUS LEVELS AFTER FERTILIZER APPLICATION

Treatment	Brays P (ppm)
Zero P	7.4
42 kg/ha	16.8
122 kg/ha	32.3
Lsd 5%	3.7

There was no measurable impact of 100 kg/ha K on the exchangable potassium.

DTPA extraction for micronutrient availability in neutral and calcareous soil is given in table 7.

Table 7. MICRONUTRIENTS EXTRACTED BY DTPA AND CRITICAL LIMITS

	ppm	SE	(n)	Critical limits*
Fe	22.2	4.4	18	2.5
Mn	15.5	2.5	17	1.2
Zn	0.33	0.09	17	0.6-0.8
Cu	2.0	0.18	17	0.2

* Critical limits given in ppm. (Lindsay and Norvell 1978)

The results indicate a strong possibility that zinc deficiency may well be experienced under good growing conditions. This is in accord with the rather low leaf zinc levels reported in table 4. The high copper values above are at odds with the low leaf levels found.

Sorghum and Millet Variety Testing

The trial was planted very late on the 21st January 1987. Germination was good but subsiquent growth rather limited being almost totally dependent upon residual moisture. Details are reported in table 1, section 2.1, of this report. The trial grain yield mean was only 217 kg/ha with the best sorghum variety producing 408 kg/ha. The millet entries produced better than almost all sorghum varieties.

Mungbean Variety

The three most promising exotic mungbean varieties were planted in duplicate 200 m^2 plots alongside the 'local' variety.

The local variety was more vegetative, longer season and lower yielding than the exotic varieties, see table 8.

Table 8. YIELD OF MUNGBEAN VARIETIES

	Yield kg/ha
Local	99
VC 2764 A	290
VC 2750 A	263
VC 1482 E	303

The yields are only about 30-40% of expected potential but further selection is required to find a strictly determinate variety with low pod shattering, suitable for combine harvesting. The present varieties require about three pickings.

Observation plots on production (Implemented by BDC Staff)

Large plots of maize, sorghum, sunflower, soybean, castor and cotton were planted using three basic land preparation techniques:-

a) Mouldboard ploughed - planted on ridges
b) Mbp, ridged - planted on ridges
c) Mbp, tied ridges - planted on ridges

The site was very heavily fertilized to improve the phosphorous and potassium status. Nitrogen, phosphorous and potassium fertilizers were incorporated before planting at the rates of 49.5 N, 99 P, 500 K, kg/ha with an additional 52 kg N/ha applied as a top dressing where appropriate. A second addition of nitrogen would have been applied under more favourable conditions.

The results are presented in table 9.

Table 9. <u>CROP, VARIETY, POPULATION AND YIELD PERFORMANCE OF CROPS GROWN UNDER THREE LAND PREPARATION METHODS</u>

Crop	Variety	Plant pop. /ha	Yield kg/ha Flat	Ridges	Tied ridges	Dates Planting	Harvest
Sorghum							
	65D		-	2088	889	6-8/11	16/3
	DC 99		1354	1006	1507	6-8/11	21/4
	NK 300		-	1976	1529	6-8/11	21/4
	Segaolane		1318	1461	2094	6-8/11	21/4
Maize							
	KEP	38 000	208	173	322	6-9/11	27/4
	CG 4141		191	455	557	6-9/11	27/4
Sunflower							
	209/210/222*	38 000	713	453	559	8/11	9/4
Cotton							
	Akala 90		1269	861	1003	9/11	15/4 6/5
Soybean							
	Sable		376	351	338	8/11	8/4
	Sable +N**		193	157	337	8/11	8/4
	Impala		434	209	513	8/11	8/4
	Impala +N		314	219	276	8/11	8/4
Castor							
	H [illegible]	8888	520	581	651	7-9/11	9/4

* All varieties harvested together by error

** Because the soybean showed severe N deficiency half of each plot was sidedressed.

General observations

There were no germination problems with any crop but subsiquent rodent damage was very severe, especially for maize and sunflower. The severity of the damage may have been due to the relatively small area planted in amongst undeveloped land. Similar problems were experienced by other Pandamatenga farmers. Seedling establishment was improved when additional seed was left on as a 'bait' on the soil surface, down the field margins.

Cotton and sunflower were both heavily infested with <u>Heliothis</u>. A routine insecticide programme was needed to control the pest. The cotton flowered prolificly and and though there were a considerable number of flared squares, the boll set was impressive.

Tillering on the sorghum was very prolific even though populations were quite high (estimated to be above 75,000/ha).

During the dry winter months, after the cropping season, elephants walked through the fence.

Section 17. SEED MULTIPLICATION UNIT

PRODUCTION AND DISTRIBUTION OF SEED FOR THE 1987/88 SEASON

Seed processing began on June 1st and continued through until the end of November. Initially, seed was purchased from contract growers but as the season progressed seed was purchased from non-seed growers whose fields had previously been inspected and, finally, grain was bought on the basis of germination only (including 581 MT from BAMB). In order to meet the requirements for KEP maize seed it was necessary to purchase 306 MT from outside the country. Apart from that, and small amounts of seed for research purposes, all seed was purchased within Botswana. The majority of the seed was stored outside under tarpaulins until distribution began in July. Funds have been allocated, and work will soon commence on the new processing plant and storage building. This will alleviate the storage problem which has been a major difficulty for the last few seasons, when seed has had to be stored outside under tarpaulins,rendering it liable to rain damage. Another development is the irrigation of Basic Seed crops for the first time.

The seed distribution is summerised in table 1, and a full breakdown showing both composition and distributing authority for a total of 6147.85 MT is presented in table 2.

Table 1: SEED DISTRIBUTION - SUMMARY (MT)

	DAFS		BAMB	BCU	OSSCA	TOTAL
	DROUGHT RELIEF AND ARAP	FOR SALE				
SORGHUM	5018.35	-	36.67	2.00	0.80	5057.82
MILLET	1.60	-	-	-	0.25	1.85
MAIZE	641.77	*40.56	156.35	102.20	6.50	947.38
COWPEAS	6.00	-	11.32	-	-	17.32
SUNFLOWER	-	-	2.88	-	-	2.88
GROUNDNUTS	-	-	-	-	0.20	0.20

* - Mainly hybrids sold at subsidised prices.

Table 2: SMU SEED DISTRIBUTION (87/88 PLANTING SEASON), (MT).

	DAFS	BAMB	BCU	OSSCA	RESEARCH & other free seed	CONTRACT GROWERS	BASIC SEED PRODUCTION	TOTAL
SORGHUM								
Segaolane	4128.88	23.96	2.00		2.97	43.46	0.02	4201.29
Marupantsi	816.53	12.15		0.80	0.01	11.10	0.04	840.63
8D	72.94	0.30			0.07	9.60	0.04	82.95
65D					0.48	3.30	0.04	3.57
Town					0.04		0.06	0.10
Kanye Std.					0.02		0.01	0.03
PNR 8311		0.26			0.05			0.31
TOTAL	5018.35	36.67	2.00	0.80	3.64	67.46	0.21	5129.13
MILLET								
Serere 6A	1.60			0.25	0.74	1.05	0.02	3.66
Tswana 6A					0.01			0.01
TOTAL	1.60			0.25	0.75	1.05	0.02	3.67
MAIZE								
K.F.P.	650.57	125.10	99.20	6.50	3.05	16.10	0.04	900.56
Potch. Pearl					0.01		0.04	0.05
CG 4141	21.76	18.44			0.56			40.76
PNR 473	10.00	12.81	3.00		0.49			26.30
R 201					0.01			0.01
Misc. hybrids					0.07			0.07
TOTAL	682.33	156.35	102.20	6.50	4.19	16.10	0.08	967.75
COWPEAS								
ER 7	2.00	3.13			0.36	2.05	0.07	7.61
Blackeye	4.00	8.19			1.23	3.80	0.13	17.35
Tswana					0.17	0.70		0.87
TOTAL	6.00	11.32			1.76	6.55	0.20	25.83
SUNFLOWER								
R 104					0.03	0.13	0.06	0.22
SO 209		2.88			0.35			3.23
TOTAL		2.88			0.38	0.13	0.06	3.45
GROUNDNUTS								
Sellie				0.2	0.52	15.67	0.13	16.52
MISCELLANEOUS								
Dolichos					1.45			1.45
Sunnhemp					0.05			0.05
TOTAL					1.50			1.50
							TOTAL	6147.95

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APPENDIX

Rainfall (mm) 1986/87

	Goodhope	Sebele*	Mahalapye	F'town	Maun	Matsaudi	Xhwaa	Etsha	Pandamatenga
July	-	-	1	-	-	-	-	-	-
August	-	12	-	-	-	-	-	-	-
September	37	8	-	12	-	17	-	44	-
October	34	53	64	66	35	44	47	100	98
November	71	96	62	67	51	74	47	55	29
December	55	77	62	61	65	78	47	22	92
January	60	50	36	68	47	22	35	7	81
February	79	41	15	31	57	43	61	40	37
March	51	43	12	7	22	25	25	60	23
April	24	11	14	-	-	-	-	-	-
May	-	-	-	-	-	-	-	-	-
June	-	-	-	-	-	-	-	-	-
TOTAL	391	411	266	312	279	303	264	327	365

* at lab field

APPENDIX

Rainfall (mm) 1986/87

	Goodhope	Sebele*	Mahalapye	F'town	Maun	Matsaudi	Xhwaa	Etsha	Pandamatenga
July	-	-	1	-	-	-	-	-	-
August	-	12	-	-	-	-	-	-	-
September	37	8	-	12	-	17	-	44	-
October	34	53	64	66	35	44	47	100	98
November	71	96	62	67	51	74	47	55	29
December	55	77	62	61	65	78	47	22	92
January	60	50	36	68	47	22	35	7	81
February	79	41	15	31	57	43	61	40	37
March	51	43	12	7	22	25	25	60	23
April	24	11	14	-	-	-	-	-	-
May	-	-	-	-	-	-	-	-	-
June	-	-	-	-	-	-	-	-	-
TOTAL	391	411	266	312	279	303	264	327	365

* at lab field