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Annual Report for the Division of Crops Research 1995

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PREFACE

This report of the Division of Arable Crops of the Department of Agricultural Research, Ministry of Agriculture, Botswana, highlights crop research activities for the year 1994/95. The chapters are arranged on commodity programme basis, to bring related activities together for ease of reading.

The Division continues its effort in adaptive research to identify technologies for increased and sustainable production in dryland agriculture. Four sorghum and one mung bean varieties were released for use by the farmers, and the relevant programs continue to foster the popularization of these varieties in collaboration with extension personnel.

The commodity research programs have in the past emphasized crop improvement, and have made good progress. It seems this emphasis should now shift to agronomy, soil fertility and water management, and pest control, all of which seem to be in overwhelm the farmers in several parts of the country.

1.0 CEREAL IMPROVEMENT PROGRAM

1.1 Variety Evaluation

1.1.1 Introduction

The main objective of the cereals programme is to increase productivity of sorghum (***Sorghum bicolor),*** maize ***(Zea mays***) and pearl millet (***Pennisetum glaucum***) through genetic manipulation and selection. Research on these crops emphasises the development of cultivars that have high yield potential and tolerance to biotic (pests, diseases, weeds) and abiotic (rainfall) stresses which are the major production constraints in Botswana.

1.1.2 Materials and Methods

Sorghum, pearl millet and maize cultivars were evaluated in 1994/95 season, at Sebele, Goodhope, Mahalapye, Mpandamatenga, and Matsaudi, research stations. A Randomised Complete Block Design with 4 replications was used. A standard plot size 4 rows, 5.0 m length with an interrow spacing of 0.75m was used. A compound fertilizer 3:2:3 was applied at the rate of 300 kg per hectare prior to planting. Plots were over seeded and later thinned to a recommended spacing of 30 cm for sorghum (40,000 plants/ha) and 50 cm for maize and pearl millet (26,000 plants/ha). When the seedlings were about 30-60 cm high they were top dressed with Limestone Ammonium Nitrate at the rate of 150 kg per hectare. Data recorded included days to 50% flowering, plant height, grain yield and susceptibility to diseases and pests. Data were analysed using ANOVA and additive main effects and multiplicative interactions (AMMI) model.

1.1.3 Results and Discussion

1.1.3.1 Maize Hybrid Trial

Evaluation of maize hybrids were conducted during the rainy season (December to April) 1993/94 and 1994/95 at three locations: Sebele, Goodhope and Mpandamatenga. The trial in 1993/94 season failed at Mpandamatenga due to moisture stress. The hybrids were obtained from different commercial companies in South Africa and Zimbabwe.

The differences among hybrids for days to 50% silking, plant height, and grain yield were significant at $P<0.05$ and for days to 50% anthesis at $P<0.10$ across sites. The genotype x environment (GE) interaction was significant at $P<0.05$ for grain yield, plant height, days to 50% silking, and days to 50% anthesis. (Table 1). The environment accounted for more than 85% of the treatment variation for all the variables except for anthesis silking interval (ASI) where the contribution was 26%.

Table 1. Analysis of variance for five traits measured on two seasons three locations (five environments) with pertinent to mean squares.

Sources of variation	Df	Days to silking	Days to Pollen	ASI	Plant Height	Grain Yield
		Mean squares				
Reps	3	13.82 ns	13.15	3.5	641.82*	4082445**
Genotypes (G)	15	39.56**	32.98*	4.6	3186.28**	2313954**
Environments (E)	4	7602.26**	6367.88**	22.01**	136340**	136812975**
G x E	60	16.48**	13.41**	3.01**	453.69**	725576
Error	236	7.53	7.05	2.26	247.29	650926.30
Total	318					

*, ** indicate significance at P<0.05 and P<0.01. respectively.

Mean yields across five environments ranged from 4620 kg ha^{-1} to 210 kg ha^{-1} (Table 2). This wide variation for grain yields reflected significant environmental and genotypic effects (Table 1). High yields in 1993/94 at Sebele and Goodhope reflected adequate moisture and good rainfall distribution in contrast to 1994/95 in the same locations (Table 3). Mean yields across environments shows that Goodhope was a more productive environment than Sebele for both seasons (Table 2). The local cultivar Kgalagadi Early Pearl (KEP) was out-yielded by most of the hybrids. However, it still ranked better than 3-4 hybrids in each of the five environments, and seemed the most stable across the environments.

Table 2.: Grains yield (kg/ha) and rankings in brackets in environments.

	Locations					
	Sebele		Goodhope		Pandamatenga	Means Across Sites
	93/94	94/95	93/94	94/95	94/95	
KEP	2660 (13)	440 (12)	3400 (12)	390 (15)	2640 (13)	1910 (14)
A 293W	3460 (4)	570 (9)	4350 (3)	730 (8)	2790 (8)	2380 (7)
CRN 3839	3320 (7)	750 (3)	3930 (8)	840 (7)	3530 (3)	2470 (3)
PAN 6364	2790 (12)	480 (11)	3350 (13)	720 (9)	2770 (9)	2020 (13)
PAN 6363	3350 (6)	590 (8)	3980 (6)	720 (10)	3170 (5)	2360 (8)
PNR 473	3440 (5)	660 (5)	4100 (5)	1000 (3)	2920 (7)	2420 (6)
PNR 663	2500 (15)	240 (16)	3930 (9)	210 (16)	2220 (15)	1820 (15)
PHB 3253	3080 (9)	290 (14)	3620 (11)	1070 (1)	2450 (14)	2160 (11)
PHB 3427	4030 (2)	810 (1)	4200 (4)	1050 (2)	2750 (10)	2570 (1)
PHB 3435	2820 (11)	760 (2)	3950 (7)	880 (6)	4090 (1)	2500 (2)
R 201	3010 (10)	570 (10)	4470 (2)	720 (11)	2980 (6)	2350 (9)
PHEB-7	1660 (16)	260 (15)	1620 (16)	440 (14)	2190 (16)	1230 (16)
PHTJ-6	2580 (14)	750 (4)	3220 (14)	1000 (4)	2660 (12)	2040 (12)
A 1849	3810 (3)	620 (6)	2770 (15)	930 (5)	2720 (11)	2170 (10)
CRN 4141	4080 (1)	430 (13)	3630 (10)	470 (13)	3820 (2)	2490 (4)
CRN 4523	3200 (8)	600 (7)	4620 (1)	600 (12)	3210 (4)	2450 (5)
C.V.(%)	27.6	33.9	30.7	36.6	30	30
SED	400	93	572	134	426	220
Site Mean	3110	550	3730	740	3280	2280

Table 3: Monthly rainfall distribution during in (mm) 1993/94 and 1994/95 seasons across the three locations.

	Locations					
	Sebele		Pandamatenga		Goodhope	
	1993/94	1994/95	1993/94	1994/95	1993/94	1994/95
October	80	30	0	44	80	12
November	46	6	158	20	56	16
December	52	86	140	57	92	63
January	127	40	153	69	67	68
February	92	46	40	113	125	23
March	38	176	0	45	35	96
April	1	26	0	18	0	40
Season Total	436	410	492	366	455	317

Maturity ranges are indicated in (Tables 4.) Most of the hybrids flowered early at Goodhope during 1993/94 and late during 1994/95. This wide variation correlates well with moisture conditions during the two seasons (Table 3). During the drier years flowering was delayed. When flowering was delayed, grain yield was reduced as shown in (Table 2 and 4).

Table 4: Means of two traits of maize grew in two seasons at Pandamatenga, Sebele, Goodhope

	Mpandamatenga 1994/95		G.hope 1993/94	G.hope 1994/95		Sebele 1993/94		Sebele 1994/95		
Hybrid	Days to 50% silking	Days to 50% Pollen	Days to 50 % Silking	Days to 50 % pollen	Days to 50 % Silking	Days to 50% pollen	Days to 50% silking	Days to 50% pollen	Days to 50 % silking	days to 50% pollen
KEP	60	59	57	54	87	83	64	61	76	71
A293W	60	60	58	55	87	83	61	58	71	69
CRN 3839	62	61	58	56	84	80	65	62	71	68
PAN 6364	62	61	59	57	88	86	62	59	76	72
PAN 6363	61	59	57	55	86	83	62	59	71	69
PNR 473	61	60	59	55	87	84	64	62	77	72
PNR 663	61	60	58	55	78	82	66	63	72	70
PHB 3253	65	64	64	59	82	79	69	65	73	70
PHB 3427	60	61	61	58	85	80	64	62	76	71
PHB 3435	66	64	61	58	83	79	64	64	72	70
R 201	61	62	58	55	87	82	61	58	70	61
PHEB-7	67	65	65	61	87	84	67	64	75	72
PHTJ-6	61	64	63	61	87	82	67	65	75	71
A1849	63	61	64	58	86	83	67	63	77	71
CRN 4141	64	59	60	56	88	85	62	59	73	69
CRN 4523	63	61	59	56	87	83	66	65	70	68
C.V.(%)	3.6	5.3	3.4	3.2	4.7	3.4	4.1	5.0	3.6	2.7
SITE MEAN	61	61	59	56	85	82	64	62	73	70
SED	1.4	1.5	1.0	1.0	1.3	1.1	1.3	1.6	1.4	1.0

1.1.3.2 Maize population

Two random mating maize populations were started in 1992/1993 season. The populations were composed of exotic lines crossed with Kalahari Early Pearl. The two populations are at cycle 3. Plants of un- desirable traits are discarded and only the best 5 % are selected and carried on to the next cycle. The populations will be carried on until equlibrium is reached.

1.1.3.3 Sorghum Cultivar Evaluation

Twenty four sorghum cultivars were evaluated in 1994/95 seasons at five experimental stations. The trial was composed of genotypes from the Department of Agricultural Research in Botswana, and the Sorghum and Millet Improvement Program (SMIP) in Zimbabwe. Two standard cultivars Segaolane and PNR 8544 were included as checks.

Mean yields across the 6 locations ranged from 3330 Kg ha^{-1} to 130 kg ha^{-1} (Table.5). The differences in yield reflect evironmental variation. The differences among cultivars for plant height, days to 50% flowering, and grain yields were significant at ($P<0.05$) across the six locations, indicating a possibility of selecting among the genotypes. Genotype by environment interaction was significant ($P<0.05$) for plant height and days to 50 % flowering and for grain yield ($P<0.10$).

Table 5: Means of grain yield in six locations in Botswana 1994/95 season

	Locations						
Genotypes	Sebele	Mahalapye	Panda.	Matsaudi	G/hope	Pelotshe.	Means Across locations
	Grain yield (kg/ha)						
SDSH 139.	1580	2710	2400	570	1700	230	1560
SDSH 38	1330	2390	3050	740	1980	680	1690
SDSH 404	490	1990	2810	260	880	160	1150
SDSH 327	530	2180	3110	560	1140	200	1440
SDSH 328	780	2340	3330	290	1270	140	1370
SDSH 148	1200	1710	2620	590	1310	240	1260
SDSH 378	970	2490	2790	230	1340	340	1260
SDSL 87049T	160	1840	2670	140	760	300	1220
LARSVAT 46-85	480	1210	2380	230	550	290	890
SDSL 87049D	380	1810	2740	470	1330	320	1190
SDSL 89420	680	1470	2430	450	1310	200	1100
KUYUMA	650	1280	2810	550	1760	430	1240
ZSV 3	610	1680	2110	130	1310	300	990
SDSH 430	310	1230	2170	490	800	200	900
SDSH 409	420	1880	3330	380	1230	670	1150
SDSH 236	370	2010	2960	320	940	300	1200
BSH 1	760	2060	2970	400	1430	290	1330
MAHUBE	350	1290	1470	250	940	260	770
SDSL 87019	650	1400	2110	410	900	130	1020
PHOFU	690	980	2570	200	1330	100	1040
MMABAITSE	700	1840	1810	300	720	560	990
TOWN	250	1100	1930	390	1430	470	930
SEGAOLANE	650	1810	1830	370	1020	170	1010
PRN 8544	500	1340	2270	190	1160	430	1020
C.V(%)	43	74	30	128	76	71	301
SED	140	700	384	252	499	107	53
SITE MEAN	650	1880	2530	390	1170	310	1880

Mpandamatenga had the highest mean yield of all the cultivars while Pelotshetlha had the lowest. Mpandamatenga had the highest mean due to favorable rainfall distribution as indicated in (Table 2). Hybrid SDSH 328 and SDSH 430 had the highest yield at Mpandamatega. Hybrid SDSH 139 was the highest yielder at Sebele and Mahalapye, while hybrid SDSH 38 was the highest at Matsaudi, Goodhope and Pelotshetlha. SDSH 38 had the highest mean average across locations. Check cultivars ranked 17 and 18 th across locations showing that there are better genotypes to which can replace them.

Table.6 shows maturity differences across locations and among genotypes. At Mahalapye most genotypes flowered late while at Pelotshetha it was the opposite. Mahube was the earliest in reaching days to 50% flowering in all the locations, while other genotypes were not consistent across locations. The difference is attributed to rainfall distribution and different dates of planting across locations. The differences will help in selecting genotypes that will be able to fit in those particular environments.

Table 6: Means of sorghum cultivars for days to 50% flowering grown in six location

GENOTYPE	SEBELE	MPANDA.	MAHALAPYE	GOODHOPE	PELOTSHE.
MATSAUDI					
SDSH 139	71	69	93	75	62	99
SDSH 38	84	71	93	68	62	98
SDSH 404	87	82	115	85	63	86
SDSH 327	77	69	105	82	63	99
SDSH 328	78	69	104	80	62	86
SDSH 148	73	70	84	71	63	83
SDSH 378	79	74	104	77	62	88
SDSL 87048T	60	78	109	85	63	86
LARSVT 46-85	81	74	109	81	62	99
SDSL 87049D	76	74	105	82	63	75
SDSL 89420	76	73	107	76	62	86
KUYUMA	76	69	99	65	62	99
ZSV 3	87	83	112	86	63	86
SDSH 430	73	67	71	62	62	80
SDSH 409	81	69	103	68	62	73
SDSH 236	84	77	110	83	63	75
BSH 1	78	70	102	74	63	89
MAHUBE	67	65	57	60	62	76
SDSH 87019	79	72	96	71	63	86
PHOFU	78	70	97	66	63	86
MMABAITSE	83	70	86	76	63	91
TOWN	85	70	99	81	63	91
SEGAOLANE	71	68	100	63	63	80
PRN 8544	73	70	100	69	62	86
C.V.(%)	15.5	3.3	13.4	10.2	1.7	10
SED	6.0	1.0	6.6	3.8	0.5	3.2
SITE MEAN	77	72	98	74	62	90

1.1.3.4 Sorghum Commercial Hybrid Trial

Sixteen hybrids from different seed companies were evaluated at Mpandamatenga, Sebele, Goodhope, and Matsaudi. The objective was to evaluate the hybrids for adaptation under Botswana conditions.

The results are shown in Tables 7,8, and 9. The highest grain mean yield was obtained at Mpandamatenga and the lowest at Matsaudi. The differences may be attributed to good rainfall distribution at Mpandamatenga. P 8171 had the highest yield at Sebele and Goodhope. Hybrid SDSH 236 and CRN 766W had the highest yield at Mpandamatenga and Matsaudi respectively. At Sebele, Matsaudi, the local check segaolane ranked higher than most of the hybrids, while at ranked last at Mpandamatenga and Goodhope. This indicates that under poor rainfall conditions Segaolane performed better than hybrids and under favourable conditions it performed the opposite.

Table 7: Means of sorghum commercial hybrids grown in Sebele, 1994/95

Hybrid	Days to 50% flowering (days)	Plant height (cm)	Grain yield Kg/ha
P 8262	70	90	980
P 8320	85	100	1330
P 8319	78	100	960
P 8601	59	70	1100
P 8171	74	90	1780
Segaolane	71	80	1070
NK 283	70	80	720
SDSH 48	80	100	1103
SDSH 236	81	90	300
SDSH 409	82	90	480
SDSH 430	70	80	470
Macia	78	80	890
XS BO1	92	100	490
CRN 766W	66	70	1090
DC 75	90	110	930
CRN 7610	62	70	1210
C.V.(%)	8	8.4	49.2
SED	3.1	3.7	229.8
Site mean	76	90	930

Table 8: Means of sorghum commercial hybrids grown in Pandamatenga, 1994/95

Hybrid	Days to 50% flowering (days)	Plant height (cm)	Grain yield Kg/ha
P 8262	60	120	2270
P 8320	69	140	3530
P 8319	60	110	2970
P 8601	54	90	1910
P 8171	67	120	1740
Segaolane	62	140	2130
NK 283	50	100	2390
SDSH 48	68	140	2930
SDSH 236	69	160	3490
SDSH 409	47	110	2400
SDSH 430	56	120	2630
Macia	64	100	2650
XS BO1	68	150	3150
CRN 766W	69	120	1950
DC 75	71	80	2100
CRN 7610	46		1910
C.V.(%)	15.8	15.4	15.7
SED	4.8	61.1	197.1
Site mean	61	118	2510

Table 9: Means of sorghum commercial hybrids grown in Matsaudi, 1994/95

Hybrid	Days to 50% flowering (days)	Plant height (cm)	Grain yield Kg/ha
P 8262	71	70	350
P 8320	-	50	350
P 8319	77	70	380
P 8601	71	70	470
P 8171	72	80	290
Segaolane	71	90	450
NK 283	88	70	500
SDSH 48	78	70	270
SDSH 236	87	50	430
SDSH 409	69	90	270
SDSH 430	76	60	380
Macia	85	80	290
XS BO1	82	80	450
CRN 766W	72	80	720
DC 75	76	50	240
CRN 7610	98	80	410
C.V.(%)	14.6	30.9	58.5
SED	5.7	11.3	112.3
Site mean	78	70	380

Table 10: Means of sorghum commercial hybrids grown in Goodhope 1994/95

Hybrid	Days to flowering	Plant height (cm)	Grain yield Kg/ha
P 8262	67	110	1650
P 8320	72	120	1710
P 8319	71	120	2120
P 8601	60	100	930
P 8171	64	110	2380
Segaolane	66	120	1220
NK 283	62	100	1420
SDSH 48	71	130	1790
SDSH 236	79	150	1110
SDSH 409	67	120	1480
SDSH 430	64	100	1570
Macia	68	90	1390
XS BO1	73	140	1470
CRN 766W	66	100	1640
DC 75	89	120	1170
CRN 7610	60	80	1710
C.V.(%)	4.03	7	43.8
SE	1.4	15.3	339.2
Site mean	69	100	1550

1.1.3.5 Sorghum line Development

Nineteen crosses were made in the off-season nursery at Mzarabani, Zimbabwe. The crosses were composed of the most drought tolerant germplasm from Botswana and selections from the regional trials (Table 10). Promising F_1 crosses were evaluated at Sebele for further development. Selected progenies will be advanced through generations until they reach uniformity.

Table 11: Pedigrees of sorghum line development.

Plot No.	Pedigree
1	Segaolane x Bots 79
2	Segaolane x Town
3	Segaolane x SDSL 89420
4	Segaolane x TAM 428
5	Segaolane x LARS.46-48
6	Segaolane x SDSL 87019
7	Segaolane x MACIA
8	Segaolane x RADAR
9	Segaolane x SDS 2583
10	MACIA x SDS2583
11	Macia x Marupantse
12	Macia x Bots 79
13	Macia x Kanye Standard
14	Kanye x Segaolane
15	ICSB 12 x Segaolane
16	Segaolane x Larsv.19
17	Macia x Tam 428
18	Town x Bots 79
19	Town x Marupantse

Table 1.1: Means of three traits of Pearlmillet varieties grown at Sebele

Variety	Days of 50% flower	Plant height (cm)	Grain yield (kg/ha)
SDMV-88004	72	140	1740
SDMV-89003	75	105	1627
SDMV-89007	58	150	1533
SDMV-89005	73	150	1557
ICMV-88908	58	136	1497
SDMV-90016	66	134	1800
SDMV-91018	65	133	1780
SDMV-89001	70	155	1207
SDMV-89004	62	139	1767
ICMV-87901	60	118	1297
91BS-6-1	59	128	1280
92BS-6-1	50	128	1580
92BS-6-02	65	126	1503
Serere 6A	55	132	1489
Farmers Local	85	191	1523
C.V.%	6.58	6.15	30.0
Mean	65	138	1550
S.E.	2.14	4.24	232

Table 1.2 : Means of three traits of pearlmillet varieties grown at Matsaudi

Variety	Days of 50% flower (days)	Plant height (cm)	Grain yield (kg/ha)
SDMV-88004	79	124	1144
SDMV-89003	74	120	1033
SDMV-89007	82	114	887
SDMV-89005	82	125	904
ICMV-88908	68	111	893
SDMV-90016	73	101	1304
SDMV-91018	70	120	1371
SDMV-89001	82	119	1127
SDMV-89004	80	121	927
ICMV-87901	71	111	864
91BS-6-1	67	109	683
92BS-6-1	64	125	880
92BS-6-02	70	109	776
Serere-6A	67	128	640
Farmers local	80	146	1340
C.V.%	12.24	12.79	46.17
Mean	73	119	985
S.E.	4.51	7.59	227

1.2 Pearl Millet variety trials

1.2.1 Introduction

Pearl millet is a warm weather crop which grows fairly well in soils with poor soil fertility vis-a-vis other cereals. It is also tolerant to drought. Pearl millet is a popular crop in the Central, Francistown and Ngamiland regions.

Objective

To identify and select Pearl Millet varieties with high yield potential and stability.

Justification

The study is expected to identify superior genotypes of pearl millet with potential to replace old varieties which have poor agronomic traits.

1.2.2 Experimental approach

Trials were conducted at Sebele, Matsaudi, and Etsha-8 during 1994/95 cropping season. Planting was done between late December 1994 and early January 1995 at different test sites. A randomised complete block design with four replications was used. A plot of four rows, 5 metres length, 0.75 m apart was used and 0.50 m within row spacing. Weeds were controlled by hand weeding. A compound fertilizer containing nitrogen, phosphorus and potassium in a ratio of 2:3:2 (22) was applied at planting at the rate of 300 kg/ha. Data were recorded on 50% flower, plant height, plant stand and grain yield. There were fifteen varieties including two checks namely Serere-6A and farmers local variety.

1.2.3 Results and discussion

Data were only recorded from Sebele and Matsaudi because Etsha experimental crop failed. The yields at Sebele ranged from 1207 kg/ha to 1800kg/ha. The highest yielder was SDMV-90016 (Table 1.1). This variety performed well in 1993/94 season as well and will go to on-farm trials after 1995/96 season. At Matsaudi in the North West the grain yields ranged from 640kg/ha to 1371kg/ha (Table 1.2). The highest yielder was SDMV-91018 (1371 kg/ha) and the lowest, Serere-6A (640 kg/ha). However, there was no significant difference among genotypes at both sites. The results indicated that some pearlmillet introductions can adapt to the local environment because they performed consistently well in yield over the past two seasons. Among these are SDMV-89004 and ICMV-88908 whose performance to being verified on-farm.

1.3 Evaluation of seed dressing fungicides for the control of sorghum downy mildew at Pandamatenga 1994/95 - Botswana

1.3.1 Introduction

Downy mildew of sorghum caused by *Peronoselerospora sorghi* (Weston and Uppal, C.G. Shaw) is a potentially destructive disease in the area of Pandamatenga, where rainfall provide high humidity and conducive temperatures for disease development. The local lesions develop quickly and cause premature drying of the leaves.

Fredrickson et al ,1992 in a field survey in Pandamatenga identified 5 % incidence of systemic downy mildew and 50 % incidence local lesions downy mildew.

The disease causes two types symptoms ;systemic form which is induced when the pathogn colonises the meristematic foliar tissues this is at the seedling stage and the local lesion infection results from the conidial infection of leaves after emergence. Several fungicides have been found to completely control sorghum downy mildew local lesions and systemic infection compared with the checks,(Anahosur 1978, Anahosur and Patil 1980, Anaso et al 1989, Balasurbramanian 1976, Matocha et al 1975, Safeeulla 1976, Singh and Williams 1977-78).

Objectives

The purpose of the study was to evaluate the effects of Apron plus 50 DS and Apron C 700 SD in reducing sorghum downy mildew incidence and severity on five sorghum varieties.

1.3.2 Materials and Methods

The trials were conducted at the Pandamatenga Agricultural Research Station during the 1994\95 season. Apron plus 50 DS is an optimised combination of tow systemic fungicides (metalaxyl and carboxin and a systemic insecticide furathiocarb). The seed lots were treated dry at the rate of 10 g per kilogram of seed before sowing. Apron C 700 SD is a combination of two fungicides namely metalaxyl (systemic) and captab (non systemic), applied in slurry form at the rate of 2 g of chemical in 5 ml of water per 1 kg seed. The seeds were shaken in the slurry to give full coverage before planting. Planting was done on the 5th January and on 28th January 1995. Four sorghum varieties namely Phofu, Segaolane, Mmabaitse, Mahube and one sorghum hybrid BSH-1 whose level of susceptibility to sorghum downy mildew is not known were evaluated. The untreated seed were used as the control. These seed - lots were sown in a split plot design with the varieties as main plots and the fungicides treatment as subplots.

The main plot size was 10 m x 6 m (main plot) and split plot 5 m x 6 m with spacing of 1 m between rows and 0.3 m within rows. The plots were 6 rows of which the first and the last rows were planted with the sorghum downy mildew susceptible sorghum variety (Marupantse) to serve as infector and source of inoculum. Sorghum downy mildew incidence and severity were recorded as number of infected plants in each plot. Observations of systemic infection of main shoots , tillers and local lesions on leaves were recorded at 6 weeks after planting. The data were analyzed separately for each fungicide using SAS.

1.3.3 Results and Discussion

The results for the trial on Apron C 700 SD are presented in Tables 1a,1b,2a,2b 3a and 3b ,and for Apron plus are presented in Tables 4a,4b,5a,5b,6a and 6b. The untreated plots had the highest incidence of both systemic and local lesion infection.

The variety was significant at (P<0.01) for Apron C(Table 1a and 1b) in the first time of planting,but treatment was not significant. The interaction was not significant, therefore variety and fungicide can be evaluated separately. In the second time of planting (Table 2a and 2b) the interaction was significant so the differences in the percentage disease incidence and yield increase on the treated plots could be due to the application of the fungicide.

Table 1: Effect of Apron C 700 SD on local lesions and systemic infection of sorghum downy mildew (5 th January at Pandamatenga 1995

	Local Lesion Infection			Systemic Infection		
Variety	Treated	Untreated	Mean	Treated	Untreated	Mean
Phofu	35.00	30.19	32.60	0.00	0.00	0.00
Segaolane	63.40	95.27	79.33	0.00	0.00	0.00
Mmabaitse	82.32	91.03	86.68	0.00	2.34	1.17
Mahube	78.70	90.07	84.39	0.66	0.00	0.33
BSH-1	77.07	75.79	76.43	0.00	0.00	0.00
Mean	67.30	76.47	71.89			0.30
CV (%)			27.81			381.27
LSD (0.05)			26.73			0.77

In the second time of planting the treatment was significant at (P<0.05) for Apron C 700 SD and (P<.0.01) for Apron plus on local lesion infection and there was no significant difference between treatment on plants showing systemic infection.

For the second time of planting (Tables 2) complete inhibition was obtained from Apron C 700 DS on Segaolane while the other varieties showed some low levels of systemic infection.

Apron plus 50 SD completely inhibited the disease expression on Phofu (Table 4) and on Phofu, Segaolane aand Mmabaitse (Table 5) in comparison with their controls.

Table 2: Effect of Apron C 700 DS on local lesions and systemic infection of sorghum downy mildew trial planted on the 28th January 1995 at Pandamatenga.

	Local Lesions Infection			Systemic Infection		
variety	Treated	Untreated	Mean	Treated	Untreated	Mean
Phofu	38.69	61.40	50.04	1.35	8.26	2.88
Segaolane	53.26	68.78	61.02	0.00	5.41	1.72
Mmabaitse	50.46	76.39	63.43	1.39	0.00	0.74
Mahube	48.41	69.63	59.02	4.84	5.77	2.65
BSH-1	62.78	85.74	74.76	1.52	4.59	3.57
Mean	50.72	72.37	61.55			2.31
CV (%)			17.08			165.34
LSD (0.05)			7.53			3.95

Table 3: Grain Yield (Kg\ha) for the Apron C 700 SD Trials of sorghum downy mildew planted at Pandamatenga.

	5th January Planting			28th January Planting		
Vriety	Treated	Untreated	Mean	Treated	Untreated	Mean
Phofu	5955	6227	6091	2487	2314	2400
Segaolane	5193	4728	4960	3025	2942	2984
Mmabaitse	4814	4615	4714	2872	2706	2789
Mahube	3364	3830	3597	2939	2181	2560
BSH-1	6400	6280	6340	2646	2427	2537
Mean	5145	5136	5141	2794	2514	2654
CV (%)			17.75			15.94
LSD (0.05)			1244.4			992.31

There was no consistence in yield differences for the treated plot in the Apron C (Table 3) first date of planting trial while the second date of planting results indicated higher yields on all the plots treated with the fungicide in comparison with the controls.

The first time of planting for Apron plus 50 DS (Table 4), the treatment was not significant but variety was significant at $P < 0.01$ so the differences in percentage disease incidence between the varieties may not be as a result of fungicide application but due to variety performance.

Table 4: Effect of Apron plus 50 SD on local lesion and systemic infection of sorghum downy mildew trial planted on 5th January, 1995 at Pandamatenga.

	Local Lesion Infection			Systemic Infection		
Variety	**Treated**	**Untreated**	**Mean**	**Treated**	**Untreated**	**Mean**
Phofu	22.38	43.51	32.94	0.00	4.45	2.23
Segaolane	33.54	49.65	41.60	0.60	2.07	1.33
Mmabaitse	18.41	36.32	27.37	0.59	5.08	2.84
Mahube	29.94	51.94	40.94	0.59	5.08	2.84
BSH-1	48.48	47.10	47.79	1.19	7.52	4.35
Mean	30.55	45.70	38.13	0.48	3.92	2.20
CV (%)			41.83			151.46
LSD (0.05)			27.57			5.12

In the second time of planting Apron plus 50 DS (Table 5) treatment was significant at $P<0.05$ on both local lesion and systemic infections. There was no significance difference on varieties on both local, systemic and yield (Table 6)

Table 5: Effect of Apron plus 50 DS on local lesion and systemic infection of downy mildew of sorghum planted 28th January 1995 at Pandamatenga.

	Local Lesion Infection			Systemic Infection		
Variety	**Treated**	**Untreated**	**Mean**	Treated	Untreated	Mean
Phofu	40.83	62.18	51.51	0.00	0.00	0.00
Segaolane	66.71	96.11	82.09	0.00	0.00	0.00
Mmabaitse	81.96	82.23	82.09	0.00	0.00	0.00
Mahube	59.23	61.92	60.68	0.49	0.48	0.49
BSH-1	74.23	89.32	81.77	0.00	0.00	0.00
Mean	64.64	78.35	71.49	0.10	0.10	0.10
CV (%)			18.75			6.14
LSD (0.05)			37.93			0.67

Table 6: Grain yield (Kg/ha) in Apron Plus 50 DS sorghum downy mildew trial planted 5th January 1995 at Pandamatenga.

	5th January Planting			28th January Planting		
Variety	**Treated**	**Untreated**	**Mean**	**Treated**	**Untreated**	**Mean**
Phofu	3564	3372	3468	2859	2945	2903
Segaolane	4685	4097	4391	3391	3364	3378
Mmabaitse	3870	3065	3468	3065	3318	3192
Mahube	3936	3648	3792	2886	2706	2796
BSH-1	4242	4259	3468	2706	2779	2743
Mean	4059	3688	3874	2981	3023	3002
CV (%)			17.04			19.43
LSD (0.05)			1288.3			0.63

For the Apron plus 50 DS trial higher yields were obtained for the treated in the first time of planting (Table) and in the second time of planting there was no consistence.

The variety performance in each date of planting was not dependent on the fungicide because of the variability in the yield. The interaction was not significant except in all the trials, except on second date of planting for the Apron C at $P<0.01$ for the local lesion infection and yield .The application of the fungicide showed low local lesion percentage incidence and treated plots had higher yields than the controls.

Both treatments significantly reduced sorghum downy mildew when compared with their controls. The sorghum varieties reacted differently to the expression of both the local lesion, systemic infections of the disease and yield Tables 1 to 6).

From Tables 1 - 6 it can be observed that the fungicides controled soil borne infection (systemic) better than the secondary infection (local lesion).

1.3.4 Conclusion

Apron C 700 DS did not completely inhibit systemic infection of the downy mildew on Phofu, Segaolane, Mmabaitse, BSH-1. The two fungicides (Apron plus 50 DS at 10 g per kilogram of seed and Apron C 700 SD seed treatment at 2 g ai/kg) did not provide complete control against sorghum downy mildew on both the local lesion and systemic infection stages. The trials are expected to continue for another 2 seasons.

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2.0 OIL SEEDS IMPROVEMENT RESEARCH

2.1 Groundnut (*Arachis hypogaea* L.) Improvement Research

2.1.1 Introduction

Oilseed crops are a source of edible oil and protein for human diet and livestock feeds. In Botswana there is a need to increase grain yields and oil content of oilseed production by undertaking relevant research to ensure a stable supply and an increased potential for processing and better returns for the producers. Work is continuing in the national programme on the evaluation of groundnut germplasm for adaptation and high yield potential under Botswana conditions. Obtaining early material (110-115 days) could benefit groundnut growers in Botswana provided the varieties are widely accepted. The objective of the research are to select varieties which can perform better than the locally grown varieties even under drought stress.

2.1.2 Materials and methods

The germplasm was obtained through collaboration with the SADC/ICRISAT Regional Groundnut Improvement Project and other institutions such as ISRA in Senegal. Several multi-locational trials were conducted at Sebele, Goodhope, Mahalapye and Mpandamatenga under rainfed conditions. A randomised complete block design with four replications or a square/rectangular lattice with three replicates. A plot was compressed of 3 or 4 rows of 6m length, with a spacing of 0.75 m between and 0.10 m within the row. Single superphosphate (200 kg/ha) and LAN (100 kg/ha) were applied after emergence and gypsum at flowering at rate of 500 kg/ha. Data collected included emergence and final stand count, days to 50 percent flowering, haulm weight, pod weight, shelling percentage, and 100 seed weight. Pests and diseases were monitored throughout the season. The varieties Sellie and 55-437 were used as checks unless otherwise stated. Data was analysed using ANOVA in Mstat C. Mean separation was performed with last significant difference LSD in the same programme.

2.1.3 Results and Discussion

2.1.3.1 Short duration variety evaluation trial 1 (EX - ICRISAT)

Significant differences among lines were observed for pod yield, shelling percentage and 100 seed weight (Table 1). ICGV 92194 yielded higher but not significantly different from ICGV 92216, ICGV 92234 and ICGV 92222. The shelling percentage (56.9) was below average, indicating low seed yield. The pre-release composite varieties GC 8-13/35 and S45/46 performed well, with pod yields of 1150 kg/ha and 1052 kg/ha respectively.

Table 1: Yield, yield components and other variables measured on groundnut lines selected for the Short Duration Variety Trial 1 (ex-ICRISAT) at Sebele.

Accession number	Emer stand(000) plant /ha	Days to 50% flowering	Final stand (000) plants/ha	Haulm weight (kg/ha)	Pod yield (kg/ha)	Shell %	100 seed weight (g)
ICGV 92194	60	26	73	2535	1571 9a	56.9bcdef	34.1cdefgh
ICGV 92195	61	27	74	2282	113bcdef	61.2abcd	28.4ij
ICGV 92197	61	26	71	2751	1027bcdefg	54.5cdefg	33.1defghij
ICGV 92198	62	25	58	2018	428l	57.7bcdef	29.6hij
ICGV 92199	66	26	64	2323	837efghijk	61.7abcd	38.6cde
ICGV 92200	61	25	67	2517	823efghijk	57.2bcde	31.6ghij
ICGV 92201	62	26	69	2537	611ijkl	56.4cdef	31.5ghij
ICGV 92203	65	25	72	3301	1145bcde	62.7abcd	34.0cdefghi
ICGV 92204	64	26	70	1701	823efghijk	62.3abcd	46.9a
ICGV 92206	62	26	70	947	566kl	64.2abc	27.6j
ICGV 92207	69	25	68	2514	998bcdefgh	61.6abcd	39.1cd
ICGV 92208	63	25	68	2155	556kl	51.2efg	34.0cdefghi
ICGV 92209	65	26	71	2865	948cdefghij	54.1cdefg	31.8fghij
ICGV 92210	58	25	62	3786	650hijkl	47.5fgh	32.3hij
ICGV 92211	64	26	75	3384	940cdefghij	54.0cdefg	37.2cdefg
ICGV 92212	65	25	69	1942	826efghijk	61.0abcd	32.4fghij
ICGV 92214	62	27	72	2228	1076bcdef	61.4abcd	34.1cdefgh
ICGV 92216	66	25	73	2306	1213abcd	57.0abcd	32.5efghij
ICGV 92217	66	26	75	2053	1068bcdefg	55.5cdef	32.6efghij
ICGV 92219	65	26	72	3005	918cdefghijk	51.9efg	31.1hij
ICGV 92220	65	26	68	2330	906cdefghijk	60.5abcd	32.5efghij
ICGV 92221	59	26	64	2270	948cdefghij	59.1bcdef	30.5hij
ICGV 92222	64	28	73	2438	1314ab	62.3abcd	45.9ab
ICGV 92224	58	26	65	1998	752fghijkl	52.5cdefg	33.4defghij
ICGV 92227	62	26	65	2680	881defghjk	44.3gh	35.0cdefgh
ICGV 92228	56	25	62	1983	605jkl	52.8cdefg	29.7hij
ICGV 92229	63	29	68	2996	1133bcde	58.8bcdef	33.2defghij
ICGV 92230	65	27	74	2552	712ghijkl	57.4bcdef	33.7defghij
ICGV 92231	61	26	72	2436	1073bcdefg	55.9cdef	37.5cdef
ICGV 92232	63	26	69	2247	751fghijkl	39.0h	30.4hij
ICGV 92233	61	25	68	3360	1142bcde	61.7abcd	30.4hij
ICGV 92234	65	26	66	3486	1263abc	53.1defg	29.9hij
ICGV 92235	60	25	65	2982	972bcdefghi	69.1a	33.7defghij
ICGV 92237	55	25	57	2453	816efghijk	60.0bcdef	31.9fghij
GC8-13/35	64	25	71	2677	1150bcde	65.7ab	32.5efghij
S 45/46	64	25	72	2470	1052bcdefg	64.5ab	40.0bc
Mean	63	26	69	2514	933	57.4	33.6
CV(0.05)	8	4	9	31	24	11.4	12.3
SE	5.1	1.1	6.4	788	223	6.54	4.13
Eff.over RCBD		126	122	126	162	105.3	
LSD(0.05)					363	9.6	6.1

Design: 6x6 lattice square. Means followed by the same letter indicates no significant difference at 0.05 probability level

2.1.3.2 Short Duration Variety Evaluation Trial 2

There were significant differences among varieties in all the measured attributes (Table 2). ICGV 92263 had the highest pod yield of 1509kg/ha, which was, not significantly different from ICGV 92240, ICGV 92241, ICGV 92251, S45/46, Sellie and ICGS 31 (Table 2). The line ICGV 92241 flowered earlier than the rest of the high yielders, but not significantly different from Sellie and ICGV 92240.

Table 2: Yield, yield components and other variables measured on groundnut lines selected for Short Duration Trial 2 (ex-ICRISAT) at Sebele

Accession number	Emer stand (000) plants /ha	Final stand (000) plants /ha	Days to 50% flow-ering	Pod yield (kg/ha)	Haulm weight (kg/ha)	Shelling %	100 seed weight (grams)
ICGV 92238	56g	69cd	27abcde	1090cd	2715i	76a	30bcd
ICGV 92239	62efg	75bcd	25ef	1072cd	2231ghi	58bcde	28cd
ICGV 92240	68bcdef	78bc	26def	1248abc	2972fghi	58bcde	31bcd
ICGV 92241	71abcde	78bc	24f	1200abc	2316ghi	59bcde	30bcd
ICGV 92242	62efg	69cd	25ef	923cde	2210hi	58bcde	29bcd
ICGV 92245	75abc	79bc	26cde	1046cd	2656abcde	62bc	34bcd
ICGV 92247	63efg	75bcd	26bcde	648ef	3044cdef	40f	28cd
ICGV 92249	79a	84ab	26bcde	819def	3520abcd	48ef	31bcd
ICGV 92250	65defg	67cd	28ab	547f	3016bcdef	43f	32bcd
ICGV 92251	64efg	71cd	27abcde	1223abc	3161cdef	56cde	32bcd
ICGV 92252	64efg	68cd	27abcde	980cde	2582abcde	61bcd	39b
ICGV 92253	63efg	72bcd	25ef	704ef	2038abc	59bcde	30bcd
ICGV 92255	61efg	69cd	25ef	1088cd	2456a	66abc	30bcd
ICGV 92257	67cdef	72bcd	28abcd	931cde	2653abc	57bcde	32bcd
ICGV 92258	68bcdef	75bcd	26def	1133bcd	2608ab	60bcd	38bc
ICGV 92259	66cdef	79bc	28abc	1057cd	2857bcde	57cde	39b
ICGV 92260	74abcd	75bcd	25ef	1142bcd	2632efg	63bc	35bcd
ICGV 92261	74abcd	79bc	25ef	842def	1981bcde	62bc	30bcd
ICGV 92263	64efg	72bcd	27abcde	1509a	2818abcde	55cde	35bcd
ICGV 92267	70abcde	76bcd	27abcde	1092cd	2084bcde	56cde	27d
ICGV 92270	59fg	64d	29a	1088cd	2103abcde	50ab	33bcd
S 45/46	67bcdef	74bcd	28a	1241abc	2902abcde	68bcde	54a
Sellie	77ab	95a	25ef	1460ab	3523efgh	59bc	34bcd
ICGS 31	68bcdef	76bc	29a	1231abc	2981abcde	62bc	30bcd
GC 8-13/35	67cdef	73bcd	26de	1126bcd	2658defg	64bc	30bcd
Mean	67	75	26	1058	2669	58	33
CV(%)	8.7	10.2	5	19.4	20.3	11.4	20
SE	5.8	7.6	2.3	205.6	541	6.7	6.6
Efficiency over RCBD	146	-	68	158	144	125	-
LSD(0.05)	9.6	1.2	2.2	337.6	888.8	11.0	10.8

Design: 5x5 lattice square. Means with the same letters indicate no significant difference at 0.05 probability level

2.1.3.3 Selections for earliness and dormancy (ex-ICRISAT)

The lines were significantly different for all the variables measured except days to 50% flowering (Table 3). Most of the lines performed well above the mean and ICGX-SM 88084/5/17 and ICGX-SM 88083/5/29 significantly out yielded variety 55-437(check) by 31 and 33% respectively. Shelling percentages of the lines were high, averaging 68%, indicating good seed fill, an important characteristic which is difficult to maintain under dryland production.

Table 3: Yield , yield components and other variables measured on groundnut lines in the selection for earliness and dormancy (ex-ICRISAT) at Sebele.

Acc. Number	Emer stand '000 plants /ha	Days to 50% flowe-ring	Final stand '000 plants /ha	Haulm wt kg/ha	Pod wt kg/ha	Shell %	100 seed wt (g)
ICGX-SM 88081/5/69	86abcde	28	116bcde	3346abc	1276defgh	71abc	33j
ICGX-SM 88081/5/24	75cdefg	29	96ijk	3253bcde	1205efgh	72a	38efghij
ICGX-SM 88082/5/1	87abcde	27	130a	3434abc	1474abcde	72a	34ij
ICGX-SM 88083/5/2	91a	28	120bc	3469abc	1403*	71abc	36fghij
ICGX-SM 88081/5/73	86abcde	25	111defg	3168cde	1225defgh	71abc	34j
ICGX-SM 88081/5/67	77bcdefg	27	93jkl	2223f	1113gh	72ab	42bcde
ICGX-SM 88081/5/19	84abcdefg	24	109ghi	3219cde	1444bcdefg	72a	36fghij
ICGX-SM 88081/5/63	70fg	28	90klm	3479abc	1077gh	62fghi	53a
ICGX-SM 88081/5/20	88abcd	26	99hij	2432ef	920h	57i	40cdef
ICGX-SM 88081/8.50	70g	27	67n	3249bcde	1280cdefgh	71abc	37fghij
ICGX-SM 88083/5/7	90ab	26	120bc	3712abc	1179fgh	65abcefg	35fghij
ICGX-SM 88084/5/24	79abcdefg	26	107efgh	3089ef	986h	58hi	45bc
ICGX-SM 88083/5/20	91ab	26	116bcd	4082bcde	1606abc	68abcdefg	34hij
ICGX-SM 88083/5/5	82abcdefg	26	99ghi	3796abc	1019gh	66bcdefg	37efghij
ICGX-SM 88083/5/3	83abcdefg	26	80m	4130cde	990gh	65defg	34fghij
ICGX-SM 88084/5/23	89abc	26	111cdef	3381abc	1223cdefgh	62ghi	42bcde
ICGX-SM 88083/5/45	93a	25	125ab	3146cde	1193gh	67abcdefg	40defghi
ICGX-SM 88084/5/17	87abcde	30	109defg	4062ab	1648a	69abcde	46b
ICGX-SM 88083/5/29	83abcdefg	28	106fgh	3440abc	1680ab	68abcdefg	39defgh
ICGX-SM 88084/5/21	76bcdefg	26	104ghi	3373abc	1518abcdef	68abcdef	42bcde
ICGX-SM 88081/5/2	72efg	26	84lm	3211cde	1213cdefgh	64efgh	39cdefg
ICGX-SM 88093/5/3	81bcdefg	25	102ghi	3335abcd	1507abcd	71abcd	35hij
55-437	76defg	27	90jklm	2511def	1258bcdefgh	65cdefg	47b
ICGX-SM 88088/5/12	84abcdef	27	104fgh	2505ef	1326bcdefg	71abc	44bcd
ICGX-SM 88088/5/26	85h	28	112defg	3574abc	1397bcdefg	69abcde	34ghij
Mean	83	27	104	3305	1286	67.5	39.2
CV(%)	8.5	7.5	16.4	15.2	14.8	5.7	7.2
SE	7.0	2.0	17.0	503.0	190.6	3.8	2.8
Efficiency over RCBD	101.5	103.4	104.1	-	135.6	-	133
LSD (0.05)	11.6		9.0	826.3	364.4	6.3	5.4

Design: 5x5 Square lattice. Means with the same letters indicate no significant difference at 0.05 probability level.

2.1.3.4 Regional Spanish groundnut variety trial (ex-ICRISAT)

At Sebele there were significant differences among varieties in all measured variables, with several varieties giving above average yields (Table 4).None of the lines gave yields significantly better than the checks.

Table 4: Yield and yield components of lines evaluated at Sebele from the Regional Spanish Groundnut Variety Trial.

Acc. number	Emer stand (000)/ha	Days to 50% flower	Final stand (000)/ ha	Haulm weight (kg/ha)	Pod Yield (kg/ha)	Shell%	100 seed weight (grams)
ICGV 87119	78e	29ab	96d	3196cde	1536abc	67abc	43abcd
ICGV 87069	85b	26bcde	94f	3916b	1276cd	66abc	42abcd
ICGV 87063	83c	28abcd	77l	3683bc	1338bcd	68ab	33ef
ICGV 87981	75h	25de	93f	3301cde	1630a	68abc	34ef
ICGV-SM 91001	66j	27abcde	72m	3480bcde	1470abcd	62abcd	46abc
ICGV 86950	86a	24e	104b	3282cde	1498abc	68abc	38de
ICGV-SM 87069	69l	27abcde	83j	3358bcde	1653a	59cde	42bcde
ICG 11215	80d	25de	85e	3647bcd	1416abcd	56de	41cd
ICG 9212	69l	29ab	80k	3012e	1382abcd	63abcd	45abc
ICGV 87003	76g	29abc	91h	3063de	1618a	60bcde	44abc
ICGV-SM 90015	77f	29abc	92g	3540bcde	1218d	59cde	48a
ICGV-SM 91002	69d	30a	88l	4587a	1269cd	53e	47ab
FLOWER-11	65k	26bcde	78l	3026e	1539abc	65abc	40cd
SELLIE	80d	26cde	122a	3349bcde	1583ab	66abc	33ef
55-437	86a	27abcde	100c	3461bcde	1556ab	70a	31f
MEAN	76	27	91	3460	1465	63.5	40.6
CV(%)	8.4	9.0	17.4	11.9	13.1	9.7	10.1
SE	6.4	2.4	15.8	41.3	192.7	6.1	4.1
LSD(0.05)	287	3.5	714	589	275	8.8	5.8

Design: 5x5 lattice square. Means with the same letters indicate no significant difference at 0.05 probability level

Results obtained at mahalapye, showed significant difference only for emergence stand, days to 50% flowering and 100 seed weight (Table 5).Variety 55-437 and Flower 11 were superior in both yield and shelling percentage compared to the rest of the lines.

Table 5: Yield and yield components lines evaluated at Mahalapye from the Regional Spanish groundnut Variety trial.

Acc. number	Emer stand '000 plants/ha	Days to 50% flo-wer	Final stand '000 plants/ ha	Haulm wt kg/ha	Pod Yield kg/ha	Shell %	100 seed wt (g)
ICGV 87119	23h	33abc	16	1406	748	65	54ab
ICGV 87069	28b	29d	19	1378	844	67	60a
ICGV 87063	27d	30cd	17	1146	812	64	37e
ICGV 87981	25f	30cd	15	1356	727	70	46cd
ICGV-SM 91001	29m	34ab	14	1324	773	61	58ab
ICGV 86950	29a	29abcd	22	1442	772	68	46cd
ICGV-SM 87069	20l	32abcd	16	1306	806	65	58ab
ICG 11215	28c	30bcd	20	1325	786	66	52bc
ICG 9212	18h	32abcd	15	1283	551	68	60ab
ICGV 87003	22k	30bcd	12	1177	795	70	57ab
ICGV-SM 90015	26e	34a	19	1296	565	61	59ab
ICGV-SM 91002	23i	35a	16	1767	650	67	59ab
FLOWER 11	22j	31bcd	18	1606	922	71	58ab
SELLIE	27d	29d	20	1291	794	66	42de
55-437	25g	29d	20	1492	1008	71	43e
MEAN	24	31	17.2	1373	770	66	52.6
CV (%)	17.9	7.7	25.1	25.8	23.7	8.9	10.5
SE	6.4	2.4	5.0	413	193	6.1	4.1
LSD(0.05)	19.6	3.4	-	-	-	-	7.9

Means with the same letters indicate no significant difference at 0.05 probability level

Across location analysis only showed significant differences in pod yield between locations and among varieties, but the interaction was not significant (Table 6).

Table 6: Pod yield of the lines evaluated at two sites

Acc. number	Sebele	Mahalapye	Mean
	← ----	Yield KG/HA ----	→
ICGV 87119	1536	748	1141.8
ICGV 87069	1276	844	1060.3
ICGV 87063	1338	812	1075.5
ICGV 87981	1630	727	1178.5
ICGV-SM 91001	1470	773	1121.3
ICGV 86950	1498	772	1134.7
ICGV-SM 87069	1653	806	1229.1
ICG 11215	1416	786	1100.9
ICG 9212	1382	551	966.6
ICGV 87003	1618	795	1206.3
ICGV-SM 90015	1218	565	891.7
ICGV-SM 91002	1269	650	958.7
FLOWER-11	1539	922	1230.8
SELLIE	1583	794	1188.4
55-437	1556	1008	1282.1
MEAN	1465	770.2	1117.8
CV (%)	13.1	23.7	16.8
SE	191.9	182.5	187.8

2.1.3.5 Preliminary Early maturity trial, Botswana - Senegal

The lines in this trial are selections from the Botswana-Senegal collaborative breeding effort. Significant varietal differences were observed in emergence and final stand, haulm weight, pod yield, shelling percentage and 100 seed weight (Table 7). Several lines yielded above the mean and the lines 053BS, 014BS and 0044BS significantly outyielded Sellie while 55-437 was outyielded by 014BS. The highest yielding line 014 BS, had a 26% yield advantage over Sellie. The average shelling percentage was 66.7%, while that of the best line was 67.3%. There is potential for selection within this group of lines based on yield and shelling percentage.

Table 7: Yield, yield components and other measured variables of the early maturing lines evaluated at Sebele

Variety	Emer stand Plant/ ha '000	Days to 50% flower	Final stand Plant/ha '000	Haulm Weight Kg/ha	Pod weight Kg/ha	Shell %	100 seed weight (g)
010 BS	84ab	26	110ab	3140bcdef	1452cdef	68.9a	32ef
053 BS	87ab	27	115a	3150bcdef	1689ab	68.0a	35bcde
093 BS	90a	27	109ab	3921a	1338def	67.5a	30fg
008 BS	86ab	27	113a	3668abcd	1509bcde	68.3a	34abcde
014 BS	86ab	26	108ab	4136a	1790a	67.3ab	32ef
064 BS	84ab	26	103ab	2847ef	1425def	69.8a	32ef
Sellie	80abc	27	96bcd	3549abc	1414bcdef	67.3a	35bcde
55-437	81abc	26	101abc	3433abcdef	1505bcdef	69.5a	33def
0022 BS	81abc	26	106ab	3824ab	1583bcde	68.0a	27gh
0024 BS	72bcd	26	78ef	2823f	1374def	67.7a	32cdef
0035 BS	66d	26	85def	3190bcdef	1403cdef	69.6a	38ab
0044 BS	69cd	30	87cde	4143a	1141h	57.4d	36abcd
0046 BS	82abc	26	100abc	3742abcde	1665abcd	69.3a	31ef
0049 BS	69cd	27	85def	3930a	1619abc	67.6a	37ab
0058 BS	65de	26	84def	3118cdef	1450def	65.6abc	33cdef
0060 BS	66d	26	83def	3724abcd	1498cdef	68.1a	39a
0061 BS	65d	28	80ef	2869f	1427def	59.5bcd	33cdef
0068 BS	50e	26	65g	2962cdef	1309fgh	66.8ab	37abc
0095 BS	61de	26	72fg	3057def	1214gh	66.6ab	32ef
0100 BS	86ab	27	108ab	3230abcdef	1313efg	60.9cd	26h
Mean	76	27	94	3423	1456	66.7	33
CV (%)	11.4	4.6	9.1	124	8	5.5	7.4
SE	8.6	1.2	8.6	424	116	3.7	2.3
Eff.over RCBD	102	103	-	140	166	138	136
LSD(0.05)	14.5		14.5	712	195.7	6.18	4.17

Design: 4x5 rectangular lattice. Means with the same letters indicate no significant difference at 0.05 probability level

2.1.3.6 Evaluation for Adaptation and yield (ex-SARGEIT Plus)

At Sebele, significant varietal differences were only observed for emergence and final stand, haulm weight and shelling percentage (Table 8). The variety ICGS 31 had the highest pod weight (1853 kg/ha), but this was not significantly different from other lines and its shelling percentage was below average.Two lines, S45 and S46 had significantly higher shelling percentages, 71% and 72% respectively. These varieties are all in the pre-release stage.

Table 8: Yield, yield components of groundnut varieties evaluated at Sebele (Ex- Sargeit plus).

Variety	Emergence ('000) Plants/ha	Final Stand Plant/ha ('000)	50% flower	Haulm weight kg/ha	Pod weight kg/ha	Shell%	100 seed weight
Flower 11	76de	82fg	28	3547abc	1713	61fg	40.0ab
Sellie	95ab	120a	28	3362abc	1578	68bcd	34.8def
55-437	65e	74g	27	3299abc	1294	68abcd	31.4f
Agaat	98a	119abc	28	3800ab	1582	62efg	35.4de
Harts	81cd	96ef	25	3084bcd	1237	60g	42.6a
Jasper	85bcd	104bcde	25	4039a	1615	62efg	39.6abc
Robbie	91abc	115abcd	26	3773ab	1610	64efg	37.6bcd
Kwarts	94ab	120ab	26	3524abc	1661	69abc	37.0bcde
GC 8-13	86bcd	103cde	25	2816cd	1381	65def	31.1f
GC 8-35	85bcd	105abcde	25	2212d	1492	68abcd	36.1cde
S 45	87abcd	102de	28	3708abc	1601	71ab	40.6ab
S 46	86abcd	105abcde	29	3702abc	1434	72a	41.4a
ICGS 31	89abc	118abcd	26	2958bcd	1853	65cde	33.5ef
Mean	86	105	26.8	3371	1543	65.8	37
CV (%)	8.4	9.0	8.2	16.3	13.7	3.7	5.9
SE	7.2	9.5	2.2	5.5	211	2.4	2.19
LSD(0.05)	12.2	16.0	-	924.0	-	4.09	3.70

Means with the same letters indicate no significant difference at 0.05 probability level

At Goodhope, significant differences among varieties were observed in emergence and final stand, haulm weight and 100 seed weight (Table 9). ICGS 31, Flower 11, GC-8-13, Jasper and Agaat had yields significantly higher than the rest, but their shelling percentages were below the mean (Table 9). S46 had the highest shelling percentage. At Goodhope pod yield was low due to drought and termite damage. ICGS 31 shows a potential to withstand drought, hence it has been selected for further evaluation.

Table 9: Yield, yield components of groundnut varieties evaluated at Goodhope (Ex- Sargeit plus).

Variety	Emerg. stand Plants /ha '000	Final stand plant/ha '000	Days to 50% flower	Haulm weight Kg/ha	Pod weight Kg/ha	Shell %	100 seed wt.
Flower 11	68cd	68d	30	2109abc	326	65	34.6bc
Sellie	87ab	94ab	33	1696bcde	304	64	32.6c
55-437	52d	53e	33	1701bcde	304	67	31.2c
Agaat	94a	101a	31	2128abc	390	58	30.2c
Harts	71bcd	80cd	32	1230e	193	70	39.3a
Jasper	82abc	82bc	31	2175abc	378	68	40.7a
Robbie	92a	84bc	31	1970abcd	281	65	30.2c
Kwarts	82abc	87bc	34	1462cde	230	70	33.3c
GC 8-13	83abc	83bc	32	2012abcd	422	65	30.4c
GC 8-35	85ab	84bc	32	1365de	363	67	31.7c
S 45	89a	90abc	35	2215ab	309	63	39.8a
S 46	85ab	83bc	37	1336de	109	83	38.6ab
ICGS 31	91a	88abc	30	2442a	578	65	33.2c
Mean	82	83	32	1834	322	67	34.3
CV	11.6	7.9	7.4	24	49.5	10.6	7.7
SE	9.5	9.5	2.4	439	159.2	15.8	2.65
LSD(0.05)	16.0	13.3	-	740.4	-	-	4.5

Means with the same letters indicate no significant difference at 0.05 probability level

At Mahalapye, significant differences were observed among varieties for 100 seed weight and days to 50 percent flowering (Table 10). Jasper had the highest 100 seed weight (52.6g) and also among the high yielders with 1126kg/ha pod weight. The line ICGS 31 had the highest pod yield, however the yield was not significantly different among the other varieties

Table 10: Yield and yield components of groundnut varieties for the Adaptation and Yield Trial at Mahalapye (Ex- Sa rgeit plus).

Variety	Emergence stand plants/ha '000	Final stand plants/ha'000	50% Flower	Haulm weight Kg/ha	Pod weight Kg/ha	shell %	100 seed wt.
Flower 11	41	31	30c	2242	1067	60	49.6ab
Sellie	48	33	32abc	2400	859	65	40.2c
55-437	50	41	32abc	1950	1315	68	42.9bc
Agaat	47	45	33abc	1854	763	62	41.3c
Harts	40	36	32bc	1501	849	61	49.1ab
Jasper	38	32	30c	2232	1126	60	52.6a
Robbie	46	34	35ab	1644	775	59	42.9bc
Kwarts	53	34	30c	1704	1062	67	45.2bc
GC 8-13	44	35	31c	1401	1128	60	41.5c
GC 8-35	40	48	31c	1100	1217	62	42.6bc
S 45	52	41	35a	2321	1086	65	44.8bc
S 46	50	42	35a	1776	1186	64	44.5bc
ICGS 31	48	38	30c	1284	1404	68	40.0c
Mean	46	38	32	1801	1064	63	44.4
CV	31.7	26.7	6.1	39.4	37.2	7.3	9.6
SE	14.6	10.1	2.0	70.9	396.2	4.6	4.25
LSD(0.05)	-	-	3.3	-	-	-	7.17

Means with the same letters indicate no significant difference at 0.05 probability level

At Pandamatenga, significant varietal differences were observed only for pod weight (Table 11). Generally the yields were poor due to drought and termite damage.

Table 11: Yield, yield components of groundnut varieties evaluated at Pandamatenga (Ex- Sargeit plus).

Variety	Emergence plants/ha '000	Final stand plants/ha'0 00	50% Flower	Haulm Weight Kg/ha	Pod yield Kg/ha	Shell%
Flower 11	90	34	33	832	311a	32
Sellie	91	40	33	588	62bc	60
55-437	84	47	34	1314	64bc	58
Agaat	99	38	34	953	94b	49
Harts	94	40	34	1249	32c	56
Jasper	87	41	34	788	39c	72
Robbie	95	37	33	1207	99b	53
kwarts	91	36	32	625	54bc	64
GC 8-13	99	33	33	543	64bc	71
GC 8-35	94	31	35	370	37c	56
S 45	84	31	33	501	76bc	55
S 46	98	32	37	452	32c	69
ICGS 31	93	43	35	945	79bc	64
Mean	92	37	33	79.7	80.3	58
CV(%)	11.1	23.0	2.9	60.7	39.4	34.7
SE	10.2	8.5	1.0	484	31.7	20.3
LSD (0.05)	-	-	-	-	53.4	-

Means with the same letters indicate no significant difference at 0.05 probability level

Analysis of variance across sites showed significant differences (P<0.001) among varieties and sites for emergence and final stand, days to flowering and haulm weight (Table 12). The genotype x environment interaction was only significant (P<0.001) for final stand. The varieties ICGS 31, Flower11, S45, Jasper and GC 8-35 yielded above average. The shelling percentages were good despite the low yields and limited moisture, especially at Goodhope. Generally, the varieties flowered much earlier at Sebele than at other sites.

Table 12: Yield and yield components of groundnut varieties for Variety Evaluation for adaptation (ex-SARGEIT), results across locations.

Variety	Emerg. stand Plants per ha '000	Final Stand Plants per ha '000	Days to 50% Flower	Haulm Wt. (kg/ha)	Pod wt (kg/ha)	shell %
Flower 11	69ef	54b	30b	2182ab	854	54.7
Sellie	80ab	72a	32ab	2011ab	701	64.2
55-437	64f	54b	31ab	2066ab	744	65.6
Agaat	84a	76a	31ab	2184ab	707	57.8
Harts	72de	63ab	31ab	1766ab	578	61.7
Jasper	73cde	65ab	30b	2309a	790	65.7
Robbie	81ab	68ab	31ab	2149ab	691	60.3
kwarts	80ab	69a	30b	1828ab	752	67.5
GC 8-13	78bc	63ab	30b	1693ab	750	65.2
GC 8-35	76bcd	67ab	31ab	1262b	777	63.5
S 45	78bc	66ab	33ab	2186ab	768	63.7
S 46	80ab	66ab	34a	1816ab	690	72.1
ICGS 31	80ab	72a	30b	1907ab	979	65.7
Mean	77	66	31	1950.9	752.4	63.7
Sebele	86	105	27	3371	1543	65.8
Goodhope	82	83	32	1834	321	67.1
Mahalapye	46	38	32	1801	1064	63.3
Panda.	92	37	34	797.4	80.3	58.4
CV (%)	14.5	13.8	6.3	28.4	31.7	18.4
SE	10.8	9.1	1.9	555.0	239.0	11.7
LSD(0.05)	5.7	15.4	3.2	942.8	-	-

Means with the same letters indicate no significant difference at 0.05 probability level

2.1.3.7 Drought tolerance variety evaluation trial

There were significant differences among varieties for all measured attributes except days to 50% flowering and pod weight (Table 13). Variety 90109 had the largest haulm weight, which was not significantly different from that of ICGV 90114. Even though there was no significant difference between the varieties in pod weight, these two varieties were among the best pod yielders. Variety 55-437 out yielded all the varieties. Half of the varieties tested had shelling percentages greater than the mean. The highest shelling percentage was shown by variety 90108, which did not differ significantly from that of 55-437. Variety ICGV 90114 had the largest seeds, having a 100 seed weight of 41.6g. This did not differ significantly from that of ICGV 90114 and ICGV 90118.

Table 13: Yield and yield components of groundnut varieties evaluated for drought tolerance at Sebele (ex-ICRISAT)

Variety	Emer. stand '000	50% Flower	Final stand '000	Haulm wt. kg/ha	Pod weight Kg/ha	Shell%	100 seed wt
ICGV 90105	101bcd	25	82bcd	3192bcd	1103	48.9bcd	35.9bcde
ICGV 90107	110ab	28	95a	2785d	1041	51.0fgh	35.2bcde
ICGV 90108	117a	31	87abc	3593bcd	1245	67.0a	33.6cdef
ICGV 90109	105bcd	27	88ab	4800a	1347	57.5cde	41.6a
ICGV 90113	72g	27	66f	3406bcd	1037	50.1fgh	28.5f
ICGV 90112	76g	26	69ef	2710d	820	55.0def	30.7ef
ICGV 90114	104bcd	27	87abc	3858abc	1548	58.1bcd	39.9ab
ICGV 90118	76g	27	69ef	4192ab	1313	46.7gh	36.6abc
ICGV 90121	100cde	26	91ab	2887cd	1210	62.4abc	31.8cdef
ICGV 90125	97de	24	82bcd	2983cd	1090	51.7efg	32.7cdef
ICGV 90120	91ef	26	74def	2809d	968	60.9bcd	31.2def
ICGV 90132	97de	27	81bcd	3423bcd	1119	60.8bcd	36.0bcd
ICGV 90135	87f	27	78cde	3539bcd	1225	45.4h	29.5f
55-437	109abc	27	84bc	2675d	1447	63.7ab	29.7f
Mean	96	27	81	3347	1179	56.4	33.8
CV	6.3	8.0	7.0	18.3	20.0	6.3	9.2
SE	6.05	2.16	5.67	612.5	235.8	3.53	3.11
Lsd (0.05)	10.1	-	9.5	1028	-	5.95	5.24

Means with the same letters indicate no significant difference at 0.05 probability level

2.1.3.8 Variety evaluation for adaptation (ex-ICRISAT)

Significant differences were observed among varieties for days to 50% flowering, final stand, haulm weight and pod yield (Table 14). Several lines including Sellie performed above the mean. The highest yielding line in terms of haulm weight and pod weight was ICGV 87379 but the weights were not significantly different from those of Sellie. This variety also had a shelling percentage among the highest (64.6%).

Table 14: Yield, yield components and other variables of groundnut varieties evaluated at Sebele (ex- ICRISAT)

Variety	Emer stand plants/ha '000	50% Flower	final stand plants/ha '000	Haulm weight Kg/ha	Pod yield Kg/ha	Shell %	100 Seed weight
ICGV 87976	97cde	26bcd	80	3354ab	1634ab	61.5	32.2
ICGV 87983	110ab	25cd	87	2998b	1348abc	58.0	34.7
ICGV 87386	101bcde	25bcd	89	3528ab	1546ab	61.8	28.5
ICGV 87979	103abcd	25bcd	81	3445ab	1369abc	62.6	30.0
ICGV 87390	112a	26bcd	84	3412ab	1625ab	57.4	30.5
ICGV 87953	94de	33a	82	3015b	1380abc	62.7	28.9
ICGV 87394	73g	24d	72	1741c	852d	55.5	29.9
ICGV 87980	102bcde	25bcd	83	3328ab	1635ab	63.6	31.6
ICGV 87982	97cde	25cd	85	3006b	1117cd	59.3	27.9
ICGV 87380	106abc	25bcd	86	3309ab	1481ab	65.3	29.4
ICGV 87388	100cde	26bcd	83	3659ab	1625ab	61.0	30.8
ICGV 87975	84f	27b	68	3342ab	1300bc	68.4	30.5
ICGV 87379	94e	26bc	80	3972a	1658a	64.6	32.0
Sellie	100cde	25bcd	86	3244ab	1571ab	55.8	30.4
Mean	98	26	82	3240	1439	61.3	30.5
CV (%)	10.4	4	10	14	14.5	9.3	13
SE	10.2	1.04	8.2	563.6	208.7	5.7	4.0
LSD (0.05)	17.0	2.0	-	758.8	351.7	-	-

Means with the same letters indicate no significant difference at 0.05 probability level

2.1.3.9 Breeding materials from Senegal, SR2 F3 lines.

The lines marked with an asteric in Table 15 are those that were selected based on their superiority in pod yield and shelling percentage. The progeny of these lines, F4, will be planted next season and further selections will be made.

Table 15: Pod weight per plant for F3 lines (SR2) from Senegal.

Line No.	Pod Wt/plant (g)	Line No	Pod wt/plant (g)	Line No.	Pod wt/plant (g)	Line No.	Pod wt/plant (g)
21	22.0	51*	56.3	84	13.3	54	12.4
50	15.7	51*	28.6	39*	28.3	54	16.4
24	11.2	51*	27.7	33*	16.9	54	23.0
57	22.7	49*	25.1	48	18.1	54	13.3
34*	12.2	49*	24.1	62	11.2	54	20.8
34*	30.9	69*	32.4	41	15.7	54	17.5
34*	28.5	70*	20.9	26	15.5	74	13.5
59	17.2	70	13.6	76	18.2	74	16.8
58	21.0	43*	17.9	77	4.2	74	14.1
19	23.4	43*	25.4	40*	15.9	47*	52.3
15	14.5	7*	25.1	40*	20.8	47*	51.4
15	15.0	7	14.2	40*	19.7	47*	34.2
15	14.1	7	16.6	30*	11.9	47*	32.0
71*	21.3	4	18.7	30*	20.6	46	19.9
71*	32.9	4	17.5	30*	20.3	46	27.6
65	15.3	14	13.1	78*	14.6	46	26.7
45*	20.3	8	13.7	78*	37.4	46	23.0
45*	33.3	3	10.7	78*	26.4	46	23.1
45*	11.5	35*	39.9	54	31.4		

2.1.3.10 Conclusion

It is noteworthy to point out that this season's groundnut trials were low yielding in locations where there was a drought spell. There is a need to screen the germplasm further for drought tolerance, especially that some of them are in the pre-release phase. This will enable us to know how sensitive these varieties are in times of drought.

2.2 Sunflower (*Helianthus annuus* L) improvement.

2.2.1 Introduction

Previous sunflower evaluation trials in Botswana have shown the crop's adaptability and a high yield potential. This study was to evaluate the performance of four hybrids supplied by South African seed companies, in comparison with our locally grown cultivar Russian 4.

2.2.2 Materials and Methods

Sunflower Variety Trial.

Four hybrids, SNK 37, SNK 43, SNK 33 and SNK 34 were compared to the open pollinated variety Russian 4, which was used as a check. A randomised complete block design with 4 replicates was used. Each plot comprised of four 10m rows with a spacing of 0.75m between rows and 0.50m within the rows. Data were collected on emergence and final stand, days to 50 percent flowering, plant height, and seed weight.

2.2.3 Results and Discussions.

There were no significant differences for any of the parameters measured. The local check Russian 4 outyielded all the other lines tested with a yield of 7.9 tonnes/ha. Only SNK 34 had a seed yield greater than the overall mean, though the difference between other hybrids was insignificant

Table1: Evaluation of yield and its components in sunflower grown at Pandamatenga.

Variety Name	Emergence Plants/ha 'ooo	Days to 50% flower	Plant height (cm)	Seed weight Tonnes/ha
SNK 37	38	71	113	4.8
SNK 43	47	69	118	2.1
SNK 33	51	70	115	3.8
SNK 34	47	71	107	6.5
Russian 4	52	70	131	7.9
Mean	42	70	117	5.2
CV (%)	20.8	2.4	11.5	158.8
SE	8.7	1.7	13.4	7.3

2.2.4 Conclusion

Russian 4 has shown a lot of potential in Botswana, especially since it is well adapted to the environmental conditions. It has variability in seed colour, from grey to black, with or without stripes. Striped seeds are known to be generally low in oil content. Though this can be a problem for oil production, low oil content is desirable in the chicken feed industry. However there is need to select this cultivar for other end uses.

2.3 Mungbean variety evaluation trial

2.3.1 Introduction

Mungbean research includes variety evaluation, selection, and germplasm screening. Variety evaluation is continuing this season with the newly released cultivar (Mmelegi) used as a check together with the local variety. The lines used were identified from the International mungbean trial supplied by AVRDC as having potential for production in Botswana. The purpose of the trial was to evaluate the lines for performance and adaptability.

2.3.2 Materials and Methods

The trials were conducted at Sebele, Mahalapye,Goodhope and Mpandamatenga. The plots had four rows of 6m length, 0.75m between and 0.15m within row spacing. A completely Randomised Block design was used with three replications. Four seeds were planted per hole and thinned to one plant, two weeks after emergence. 100 kg/ha of single superphosphate and 50kg/ha of LAN were applied before flowering. Data were collected on emergence and final stand, number of days to first mature pod, seed per pod, pod length, and seed weight.

2.3.3 Results and Discussion

At Sebele, significant differences among varieties were observed in emergence and final stand and 1000 seed weight (Table 1). Variety VC 3300A yielded more than the rest of the lines with a yield of 674 kg/ha. Yields were however very low this season due to poor rainfall.

Table 1: Means of parameters measured in mungbean varieties at Sebele

Variety	emerg stand "000 plants/ ha	final stand '000 plants /ha	days to first mature pod	Pods per plant	pod length (cm)	seed per pod	seed wt kg/ha	1000 seed wt.
VC 4176A	92ab	83ab	48	10	6.7	8	633	64.4cde
VC 4143A	56defgh	47cd	47	14	7.5	9	477	63.9cde
VC 2768A	46gh	46cd	53	9	7.7	9	469	71.0ab
VC 3746A	106a	89a	52	8	7.0	8	546	66.5bcd
Local	87abc	64bc	50	8	7.3	9	469	61.3a
VC 2778A	66def	57cd	48	8	7.7	9	519	73.6a
Mmelegi	72cde	59cd	50	9	6.9	8	478	62.0de
VC 4059A	76bcd	51cd	49	8	7.6	8	428	69.5ab
VC 1973A	54efgh	45cde	50	9	8.1	9	483	66.8bcd
VC 3300A	63defg	52cd	51	11	8.0	9	674	71.1ab
VC 4152A	68cdef	53cd	51	8	7.5	9	541	71.2ab
VC 1560A	40h	27cd	49	13	7.9	9	358	67.6bc
VC 4060A	49fgh	43e	48	10	7.7	9	437	61.8de
Mean	67	55	50	10	7.5	8	503	67.0
CV(%)	17.8	21.4	4.3	29.3	10.1	11.3	29.3	4.4
SE	11.4	11.8	2.1	2.9	0.8	0.9	147.4	2.9
LSD (0.05)	20.3	19.8	-	-	-	-	-	5.0

Means with the same letters indicate no significant difference at 0.05 probability level

At Goodhope, there were significant differences among varieties for emergence and final stand, as well as plant height. (Table.2) Seed yields were low at Goodhope compared to good seasons during which all the varieties produce yields over a tonne/ha (Annual Report, 1993).

Table 2 : Means of parameters measured in mungbean varieties at Goodhope

Variety	emerg stand '000 plants/ ha	final stand '000 plants/ ha	days to first mature pod	Pod per plant	pod length (cm)	seed per pod	seed weight kg/ha
VC 4176A	49a	43ab	84	9	7.8	10	138.9
VC 4143A	22e	20ef	89	10	6.5	9	135.4
VC 2768A	35c	32cd	88	6	8.0	11	135.4
VC 3746A	49a	45a	87	8	7.5	10	135.4
Local	45ab	38bc	82	8	7.3	10	118.1
VC 2778A	38bc	31cd	80	10	8.3	10	145.8
Mmelegi	39bc	25de	82	9	7.2	9	142.4
VC 4059A	39bc	31cd	88	6	7.0	8	79.8
VC 1973A	23e	18ef	81	9	7.5	8	128.5
VC 3300A	26de	20ef	82	11	8.5	10	131.9
VC 4152A	32cd	24de	86	9	8.0	9	107.6
VC 1560A	18e	11g	81	11	8.0	10	86.8
VC 4060A	20e	14fg	82	10	8.0	9	145.8
Mean	33	27	84	9	7.6	9	125.5
CV(%)	14.2	16.8	7.6	44.7	12.6	19.3	30.7
SE	4.7	4.5	6.4	4.0	9.6	1.7	38.5
LSD(0.05)	8.1	7.52	-	-	-	-	-

Means with the same letters indicate no significant difference at 0.05 probability level

At Mahalapye, significant differences ($p<0.05$) were observed among varieties in emergence and final stand and pods per plant. (Table 3) The yields were poor at this site but much better when compared to other sites.

Table 3: Means of parameters measured in mungbean varieties at Mahalapye.

Variety	emerg stand '000 plants/ ha	final stand '000 plants/ha	days to first mature pod	Pod per plant	pod length (cm)	seed per pod	seed weight kg/ha
VC 4176A	48abc	41abcde	55	32ab	32	6.8cd	554.5
VC 4143A	38de	30fg	55	33b	33	7.8abc	488.5
VC 2768A	41cde	39abcdef	55	20bc	20	7.7abc	469.4
VC 3746A	55a	47a	56	21bc	21	7.5bcd	552.7
Local	50abc	39abcdef	55	25bc	25	8.9bcd	457.6
VC 2778A	52ab	44ab	54	20bc	20	8.1abc	605.2
Mmelegi	44bcd	42abc	56	27bc	27	7.5abc	591.3
VC 4059A	49abc	37bcdef	54	16c	16	7.3d	471.5
VC 1973A	36de	32defg	55	31ab	31	8.8abc	601.0
VC 3300A	36de	32cdefg	55	30b	30	8.3ab	610.1
VC 4152A	45abcd	41abcd	55	30b	30	7.7abc	651.4
VC 1560A	26f	25g	55	44a	44	7.5bcd	488.4
VC 4060A	34ef	32efg	55	27bc	27	7.8a	555.9
Mean	42	37	55	27	7.6	9	545.2
CV(%)	13.9	15.5	1.6	26.3	7.2	9.4	17.6
SE	5.8	5.7	0.9	7.1	0.5	0.8	95.9
LSD(0.05)	10.0	9.8	-	12.7	-	1.4	-

Means with the same letters indicate no significant difference at 0.05 probability level

Significant differences were observed between varieties in pod length, seed yield, and final stand at Pandamatenga (Table 4). Variety VC 4152A outyielded the rest with a yield of 504 kg/ha, but this yield is still very low.

Table 4: Means of parameters measured in mungbean varieties at Pandamatenga

Variety	emerg stand ' 000 plants/ ha	final stand '000 plants/ha	days to first mature pod	Pod per plant	pod length (cm)	seed per pod	seed weight kg/ha
VC 4176A	84	76ab	64	15	8.0de	9	338.2bcd
VC 4143A	64	58bcde	65	15	8.8abcd	9	358.0abc
VC 2768A	83	66abc	65	13	9.6a	11	432.1ab
VC 3746A	103	78ab	65	16	7.7e	11	344.2bcd
Local	59	48a	66	17	8.9abcd	10	380.3abc
VC 2778A	79	78ab	65	14	9.6ab	11	429.8ab
Mmelegi	91	62bcd	64	14	7.6de	10	273.1cd
VC 4059A	70	70ab	66	14	8.6cd	10	419.3abc
VC 1973A	77	64abc	64	16	8.8abcd	10	311.8bcd
VC 3300A	64	48cde	65	20	8.6bcde	11	375.5abc
VC 4152A	69	61ab	66	15	8.9abcd	11	505.4a
VC 1560A	85	38e	66	17	9.4abc	11	202.8d
VC 4060A	76	41de	66	13	8.6cde	10	205.6d
Mean	77	64	65	15	8.7	10	352.0
CV(%)	25.5	19.6	1.6	29.0	6.6	6.7	25.2
SE	19.6	12.5	1.0	4.3	5.7	0.7	88.7
LSD(0.05)	-	21.3	-	-	1.0	-	149.6

Means with the same letters indicate no significant difference at 0.05 probability level

Combined analysis showed significant differences among varieties and sites in pod weight (Table 5). Line VC 3300 A outperformed the rest of the lines only at Sebele, probably due to a higher rainfall received at that location, while VC4152 A was superior at both Pandamatenga and Mahalapye. This line yielded above average at all the locations, except Goodhope.

Table 5: Multilocational comparison of seed yield of mungbean varieties

Variety	Sebele	Goodhope	Mahalapye	Panda.	Variety mean
		kg/ha			
VC 4176A	634	139	544	338	414
VC 4143A	478	135	488	385	365
VC 2768A	469	135	469	432	376
VC 3746A	546	135	553	344	394
Local	469	118	458	380	356
VC 2778A	519	146	605	430	425
Mmelegi	478	142	591	273	371
VC 4059A	428	80	472	419	350
VC 1973A	483	128	601	312	381
VC 3300A	674	132	610	375	448
VC 4152A	541	108	651	505	451
VC 1560A	358	87	488	203	284
VC 4060A	457	146	556	206	341
Mean	502	125	545	352	381
CV (%)	29	31	18	25	26
SE	145.6	38.75	98.1	88.0	99.1

2.3.4 Conclusion

Generally this season was not good for mungbean because of the incidence of drought. Varieties such as Mmelegi exhibited good agronomic characteristics such as plant type, pod extrusion above the canopy as well as earliness. Since large seeded mungbean germplasm is known for high yield and disease resistance according to Srinives and Yang, (1987), it can be of some benefit to investigate the relationship between seed size and yield. This could be done by comparisons within the local variety, which has large seeded and small seeded genotypes.

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3.0 LEGUME IMPROVEMENT PROGRAMME

3.1 Cowpea variety Evaluation

3.1.1 Introduction

Cowpea is the major grain legume in Botswana hence its research is given priority among other legumes. Despite this effort, cowpea production level is still low(250 kg/ha). This is attributed to the use of varieties with low yield potential, disease and insect pest damage, poor rainfall distribution and low soil fertility. Generally, cowpea is intercropped with a cereal by small scale farmers at subsistence level, and yield usually ranges from 200 to 300 kg/ha. Hence there is a need for improved varieties that are adaptable to Botswana conditions. The objective of this study was therefore to evaluate introduced varieties from the Southern African Development Community (SADC) and the International Institute of Tropical Agriculture (IITA) for adaptability and yield potential.

3.1.2 Materials and Methods

Field experiments were carried out at four locations (Sebele, Mahalapye, Goodhope and Pelotshetlha) in 1995 under rainfed conditions. Planting at Mahalapye, Sebele and Pelotshetlha was done on December 12, 17 and 28, 1994 respectively and at Goodhope was on January 17, 1995. There were two sets of variety evaluation trials: a SADC trial and a Preliminary Cowpea Variety Evaluation trial consisting of twelve and twenty varieties respectively. The SADC trial was planted at all the locations and the Preliminary variety trial was planted at Sebele, Mahalapye and Goodhope. In both trials, Blackeye was the local check. The experimental design was a randomized complete block with four replications, four row-plots 5m in length and 0.75 between row and 0.2 m between plants spacings. A hand driven furrow opener and Dutch hoes were used to open rows, seeds were hand planted at the rate of 25 seeds per row. Pest control was effected and closely monitored throughout the season. Weeds were controlled by hand cultivation and there was no fertilizer application. Data collected was on emergence, days to 50% flowering, days to 95% pod maturity, harvest plant population, growth habit, 100 seed weight and grain yield. The grain yield and emergence stand were analysed within and across locations.

3.1.3 Results and methods

A combined analysis across locations was only done for emergence population and grain yield. Data for other traits were not recorded at some locations, so in those cases the analysis was done by location for both the SADC trial and Preliminary variety evaluation trial.

3.1.3.1 SADC cooperative cowpea trial

Emergence and yield

Emergence population ranged from 21 000 to 55 000 plants/ha across locations with the lowest population at Pelotshetlha, which also had the highest coefficient of variation (Table 1). The lowest emergence stand obtained at Pelotshetlha was influenced by poor rainfall received at planting compared with other locations (Appendix 1). This was 1/3 of the expected plant population which is 67 000 plants/ha. Emergence population among varieties was not variable as reflected by the coefficient variation, except for Pelotshetlha. Myanmar had the lowest emergence population which was attributed to insect damaged seed. The local checks, Blackeye and Tswana had a significantly higher emergence population than four other varieties (Table 1).

Table 1 : Emergence plant population of cowpea varieties at 4 locations -SADC Trial

	Location				
Variety	Sebele	Mahalapye	Goodhope	Pelotshetlha	mean
	plants/ha (thousands)				
INIA 30	56 abcd	43 b	55 abc	19 ab	43 bcd
TSWANA	63 a	56 a	53 abcd	16 b	48 ab
INIA 70	51 bcd	41 b	55 abc	21 ab	41bcde
IT85F-2205	61 a	44 b	57 ab	22 ab	47 abc
IT85F-2020	48 cd	39 bc	51 bcd	17 ab	39 de
TVx 3405	51 bcd	32 cd	45 d	23 ab	37 e
MYANMAR	47 d	28 d	27 e	12 b	28 f
INIA 71	59 ab	47 b	59 a	29 a	49 a
INIA 37	59 ab	43 b	56 abc	31 a	48 ab
IT84D-448	56 abc	41 b	52 abcd	17 ab	41 bcde
IT82E-16	49 bcd	37 bc	49 cd	19 ab	39 de
BLACKEYE	61 a	39 bc	57 ab	25 ab	45 abc
	*	*	**	*	*
location mean	55	41	51	21	42
c.v. (%)	10	14	10	38	15
se	5.5	5.7	5.1	7.9	6.3

*, ** means followed by the same letter(s) are not significantly different at p(0.05 or 0.01) respectively according to Duncan's Multiple Range test.

Although, Tswana had the highest emergence population at Sebele and Mahalapye, it was not significantly different (p<0.05) from IT85F-2205 and Blackeye at Sebele. INIA 71 had a significantly higher emergence population at Goodhope, Pelotshetlha, and the overall mean INIA 37 had a significantly higher emergence population than all the varieties at Pelotshetlha.

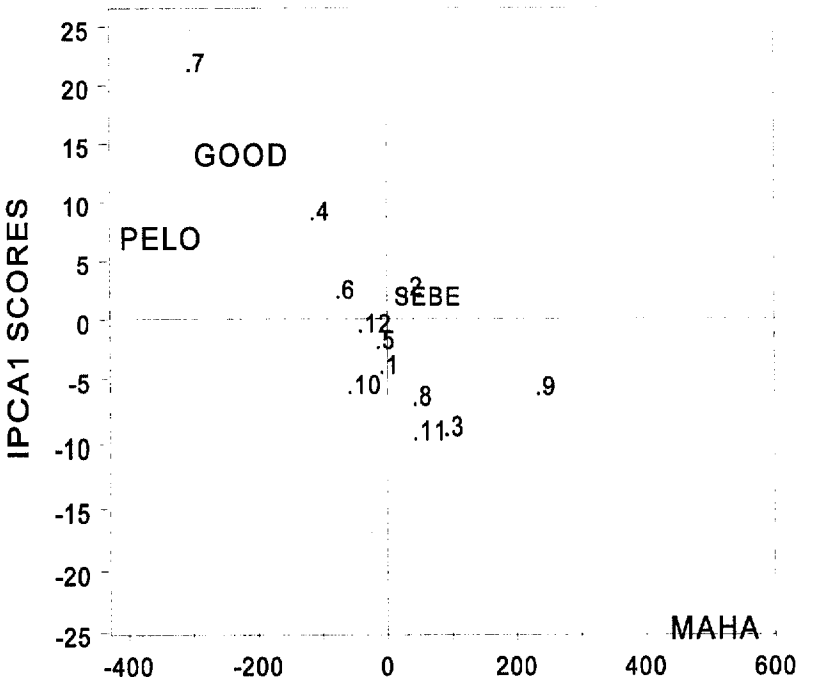
In terms of grain yield across locations, varieties, except at Goodhope and location x variety interaction were significant (p<0.05). The mean grain yield ranged from 214 to 1068 kg/ha across locations with the lowest at Pelotshetlha. The low yield obtained at Pelotshetlha was a result of low population (Table 1). The highest mean grain yield was obtained at Mahalapye which had good rainfall distribution. The overall mean variety grain yield ranged from 268 to 807 kg/ha. INIA 37 had the highest mean grain yield (Table 2). Although, INIA 37 yielded consistently higher across locations, it was less stable compared to Blackeye and Tswana (Figure 1). IT85F-2205 and Myanmar had a high potential to perform well at Goodhope as deduced by their proximity to the location in the bi-plot (Figure 1), similarly for Tswana at Sebele. Six of the varieties were stable across locations. Environmental and genotypic variations were 62% and 9% of the total treatment variation in yield respectively.

Table 2 : Yield and growth habit of cowpea varieties at 4 locations - SADC Trial

		Location				
		Sebele	Mahalapye	Goodhope	Pelo-tshetlha	
		yield (kg/ha)				
Variety	growth habit					mean
INIA 30	SE	324 de	1230 abc	432	255 ab	565 bcd
TSWANA	S	649 abc	1049 bc	478	235 ab	603 bcd
INIA 70	SE	850 ab	1337 ab	256	221 ab	666 b
IT85F-2205	E	705 abc	679 d	249	202 ab	459 d
IT85F-2020	SE	507 cde	1124 abc	469	255 ab	597 bcd
TVx 3405	SE	601 bcd	932 cd	332	126 ab	498 d
MYANMAR	SE	307 e	258 e	418	90 b	268 e
INIA 71	SE	676 abc	1270 abc	319	201 ab	617 bc
INIA 37	SE	924 a	1443 a	561	301 a	807 a
IT84D-448	E	486 cde	1177 abc	332	195 ab	562 bcd
IT82E-16	E	656 abc	1339 ab	323	275 a	670 b
BLACKEYE	SE	804 ab	984 bcd	345	213 ab	621 bc
		*	**		*	***
location mean		626	1068	378	214	571
c.v. (%)		27	21	52	49	31
se		16.9	22.4	19.7	10.5	17.7

*, **, *** means followed by the same letter(s) are not significantly different at p(0.05 or0.01 or 0.001) respectively according to Duncan's Multiple Range test. E = Erect; SE = Semi-erect; = Spreading

FIGURE 1 : YIELD BIPLOT OF SADC COWPEA VARIETIES



DEVIATION FROM THE GRAND MEAN (571 kg/ha)

SEBE = SEBELE MAHA = MAHALAPYE GOOD = GOODHOPE PELO = PELOTSHE

1 = INIA 30 2 = TSWANA 3 = INIA 70 4 = IT85F-2205

5 = IT85F-2020 6 = TVx 3405-O1E 7 = MYANMAR 8 = INIA 71

9 = INIA 37 10 = IT84D-448 11 = IT82E-16 12 = BLACKEYE

Other variables

Sebele

Days to 50% flowering and 95% pod maturity ranged from 39 to 62 and 60 to 82 respectively. Myanmar had a significantly higher number of days to flowering and pod maturity than all the varieties (Table 3). The harvest population ranged from 43 000 to 57 000 plants with a mean of 49 000 plants/ha. Tswana and blackeye had a significantly higher harvest population and Myanmar and INIA 70 were the lowest at Sebele. Hundred seed weight ranged from 10 to 19 grams. Blackeye had a significantly higher 100 seed weight (19 g), and INIA 37 was the small seeded type (Table 3).

Table 3 : Means of 4 traits of cowpea varieties at Sebele - SADC Trial

Variety	DFF	PM	HPP	100 SWT
INIA 30	47 bcd	64 cd	49 abcde	13 efg
TSWANA	49 b	71 b	57 a	16 cd
INIA 70	47 bcd	64 cd	43 e	12 fgh
IT85F-2205	43 f	64 cd	56 ab	17 bc
IT85F-2020	44 ef	66 c	44 de	18 ab
TVx 3405	44 ef	65 c	45 cde	14 ef
MYANMAR	62 a	82 a	43 e	18 ab
INIA 71	46 cde	65 c	52 abc	11 gh
INIA 37	43 ef	60 d	52 abc	10 h
IT84D-448	47 bcd	64 cd	51 abcd	16 cd
IT82E-16	44 ef	63 cd	48 cde	15 de
BLACKEYE	39 e	62 cd	57 a	19 a
	**	**	*	**
mean	47	66	49	15
c.v.(%)	4.4	4.8	12.8	8.1
se	2.1	3.2	6.3	1.2

*, ** means followed by the same letter(s) are not significantly different at p(0.05 or 0.01) respectively according to Duncan's Multiple Range test. DFF = Days to 50% flowering, PM = Days to 95% pod maturity, HPP = Harvest plant population (thousands plants/ha), 100 SWT = 100 seed weight (g)

Mahalapye

Hundred seed weight was variable, ranging from 11 to 18 grams. Blackeye was among the large-seeded varieties and INIA 37 and INIA 71 were the small seeded types (Table 4).

Table 4 : 100 seed weight of cowpea varieties planted at Mahalapye - SADC Trial

Variety	100 seed weight (g)
INIA 30	13 cde
TSWANA	16 ab
INIA 70	14 cd
IT85F-2205	17 ab
IT85F-2020	18 a
TVx 3405	13 cde
MYANMAR	15 bc
INIA 71	12 ef
INIA 37	11 f
IT84D-448	16 ab
IT82E-16	14 cd
BLACKEYE	18 a
	**
mean	15
c.v.(%)	9.1
se	1.4

means followed by the same letter(s) are not significantly different at p(0.01), according to Duncan's Multiple Range test.

Goodhope

Days to 50% flowering ranged from 36 to 56, with Myanmar flowering later than most varieties (Table 5). There was no significant difference in the number of days to pod maturity. However, Blackeye matured earlier than all other varieties. The coefficient of variation was also very high.

Table 5 : Means of 2 traits of cowpea varieties at Goodhope - SADC Trial

Variety	days to 50% flowering	days to 95% pod maturity
INIA 30	52 ab	86
TSWANA	51 b	89
INIA 70	50 ab	84
IT85F-2205	45 c	86
IT85F-2020	48 bc	63
TVx 3405	45 c	87
MYANMAR	56 a	89
INIA 71	52 ab	88
INIA 37	48 bc	83
IT84D-448	50 b	68
IT82E-16	44 c	63
BLACKEYE	36 d	59
	**	
mean	48	77
c.v.(%8)	6.7	33.2
se	3.2	25.6

means followed by the same letter(s) are not significantly different at p(0.01) according to Duncan's Multiple Range test.

Pelotshetlha

Days to 50% flowering were significantly different ($p<0.05$), ranging from 48 to 50. Days to 95% pod maturity were not significantly different. Hundred seed weight ranged from 12 to 20 grams (Table 6). INIA 37, IT84D-448 and INIA 71 were the small-seeded types, consistent with the results from the other locations.

Table 6 : Means of 3 traits of cowpea varieties at Pelotshetlha - SADC Trial

Variety	days to 50% flowering	days to 95% pod maturity	100 seed weight (g)
INIA 30	49 ab	73	15 cde
TSWANA	50 a	73	18 abc
INIA 70	48 b	72	15 bcde
IT85F-2205	48 b	72	17 abcd
IT85F-2020	48 b	72	20 a
TVx 3405	50 a	73	16 abcd
MYANMAR	50 a	73	17 abc
INIA 71	48 b	72	14 cde
INIA 37	48 b	72	12 e
IT84D-448	49 ab	73	13 de
IT82E-16	49 ab	71	16 abcd
BLACKEYE	49 ab	71	19 ab
	*		*
mean	49	72	16
c.v.(%)	0.8	2.8	18.5
se	0.4	2	3

Means followed by the same letter(s) are not significantly different at p(0.05) according to Duncan's Multiple Range test.

3.1.3.2 Preliminary cowpea variety

Emergence population ranged from 36 000 to 52 000 plants/ha across locations, with the lowest population at Mahalapye (Table 7). The poor emergence population at Mahalapye could be attributed to soil capping/crusting. Sebele had the highest emergence population. At Goodhope the population was not significantly different among varieties (Table 7).

Table 7 : Emergence plant population of cowpea varieties at 3 loactions - Preliminary Trial.

	Location			
	Sebele	Mahalapye	Goodhope	Mean
Vareity	plants/ha (thousands)			
IT81D-1189	48 abc	32 abc	47	43 bcde
TVx 3671-14C-O1D	61 ab	44 a	51	52 a
IT82D-635	55 abc	31 bc	45	43 bcde
IT82E-789	47 abc	25 c	47	40 e
IT82E-49	52 abc	44 a	48	48 abcd
IT82E-38	56 abc	32 abc	52	47 abcde
IT82D-905	56 abc	37 abc	47	47 abcde
IT82D-785	45 abc	36 abc	53	45 abcde
IT82D-891	48 abc	29 bc	43	40 e
IT82D-744	45 abc	35 abc	47	43 bcde
PI 250238	45 abc	33 abc	45	41 cde
PI 288845	47 abc	37 abc	44	43 bcde
PI 293570	53 abc	37 abc	43	44 abcde
TVu 3236	57 abc	35 abc	40	44 abcde
TVu 7137	41 c	37 abc	44	41 de
TVx 3380-O1E	53 abc	38 ab	47	47 abcde
Tx 84-294	44 bc	37 abc	45	43 bcde
Tx 84-243	62 a	40 ab	49	49 ab
UCR 239	62 a	36 abc	48	48 abcd
BLACKEYE	55 abc	44 a	48	49 ab
	*	*		**
location mean	52	36	47	44
c.v. %	19	21	15	18
se	9.9	7.6	7	7.9

*, ** means followed by the same letter(s) are not significantly different at p(0.05 or 0.01) respectively according to Duncan's Multiple Range test.

For grain yield, locations, and varieties except at Goodhope and location x variety interaction were significant at $p<0.05$. The environment contributed 43% and the genotypes 14% of the total treatment variation in yield. The mean grain yield across locations ranged from 200 kg/ha at Goodhope to 632 kg/ha at Mahalapye. Differences in grain yield across locations could be attributed to variation in rainfall distribution (Appendix 1).

Table 8 : Yield and growth habit of cowpea varieties at 3 locations : Preliminary Trial

		Location			
		Sebele	Mahalapye	Goodhope	Mean
Variety	growth habit	yield (kg/ha)			
IT81D-1189	SE	739 ab	829 abc	230	633 abc
TVx 3671	SE	810 ab	881 a	221	675 a
IT82D-635	SE	423 cd	382 e	155	335 fgh
IT82E-789	E	668 bc	512 cde	150	470 cdefg
IT82E-49	E	638 bcd	652 abcde	226	505 abcdef
IT82E-38	SE	728 ab	775 abcd	288	625 abc
IT82D-905	E	579 bcd	546 bcde	189	438 defgh
IT82D-785	SE	752 ab	834 abc	109	565 abcde
IT82D-891	E	717 abc	594 abcde	142	484 bcdefg
IT82D-744	SE	531 bcd	689 abcde	192	526 abcde
PI 250238	SE	561 bcd	398 e	339	451 cdefgh
PI 288845	SE	337 d	472 de	79	316 gh
PI 293570	SE	533 bcd	563 abcde	239	486 bcdefg
TVu 3236	SE	346 d	545 bcde	335	409 efgh
TVu 7137	SE	418 cd	398 e	59	292 h
TVx 3380	SE	573 bcd	567 abcde	279	490 bcdefg
Tx 84-294	E	671 bc	874 ab	249	298 abcd
Tx 84-243	E	981 a	828 abc	169	660 ab
UCR 239	E	633 bcd	674 abcde	137	513 abcdef
BLACKEYE	SE	610 bcd *	629 abcde *	305	534 abcde *
location mean		612	632	205	483
c.v. %		29	30	85	36
se		17.7	19	17.4	17.4

means followed by the same letter(s) are not significantly different at p(0.05) according to Duncan's Multiple Range test. E = Erect SE = Semi-erect

Sebele

Days to 50% flowering and 95% pod maturity were significantly different among varieties ($p<0.01$), ranging from 37 to 49 and 59 to 72 respectively (Table 9). Blackeye was amongst the earliest to flower. Harvest population ranged from 39 000 to 59 000 plants/ha with a mean of 48 000 plants/ha. Hundred seed weight was variable, ranging from 10 to 22 grams. TVu 7137 was the smallest-seeded variety (Table 9).

Table 9: Means of 4 other traits of cowpea varieties at Sebele (Preliminary Trial)

Variety	DFF	PM	HPP	100 SWT
IT81D-1189	44 cde	67 bc	44 cd	16 cde
TVx 3671	46 abcd	72 a	59 a	13 efgh
IT82D-635	44 cde	65 cde	52 abc	15 def
IT82E-789	37 h	61 fgh	43 cd	16 cde
IT82E-49	39 gh	60 gh	47 abcd	17 bcd
IT82E-38	44 cde	64 cdef	45 abcd	13 efgh
IT82D-905	42 efg	67 bc	52 abc	14 efg
IT82D-785	43 cdef	67 bc	43 cd	15 cdef
IT82D-891	38 h	59 h	44 cd	18 bc
IT82D-744	45 bcde	69 ab	41 d	15 cdef
PI 250238	48 ab	69 ab	43 bcd	20 ab
PI 288845	49 a	69 ab	43 bcd	14 efg
PI 293570	44 cde	65 cde	51 abcd	17 cde
TVu 2336	46 abc	67 bc	53 abcd	11 gh
TVu 7137	42 efg	63 defg	39 d	10 h
TVx 3380	46 abc	67 bc	52 abcd	16 cde
Tx 84-294	39 gh	61 fgh	41 d	22 a
TX 84-243	40 fgh	63 defg	56 abc	16 cde
UCR 239	42 ef	63 defg	57 ab	12 fgh
BLACKEYE	39 fgh	64 cdef	49 abcd	17 bcd
	**	**	*	*
mean	43	65	48	16
c.v. %	6	4	21.9	15.3
se	2.6	2.6	10.5	2.4

* and ** means followed by the sane letter(s) are not significantly different at p(0.05 or 0.01) respectively according to Duncan's Multiple Range test.

DFF = Days to 50% flowering PM = Days to 95% pod maturity HP = Harvest plant population (thousands plants/ha) 100 SWT = 100 seed weight (g)

Mahalapye

Hundred seed weight was significantly ($p<0.05$) different among varieties, with Tx 84-294 and PI 250238 being the large seeded varieties, and Tvu 3236 the small seeded type (Table 10).

Table 10 : 100 seed weight of cowpea varieties at Mahalapye : Preliminary Trial

Variety	100 seed weight (g)
IT81D-1189	16 cde
TVx 3671-14C-O1D	14 efg
IT82D-635	12 ghi
IT82E-789	17 bcd
IT82E-49	18 b
IT82E-38	13 fghi
IT82D-905	13 fghi
IT82D-785	15 def
IT82D-891	17 bc
IT82D-744	14 efg
PI 250238	21 a
PI 288845	14 efg
PI 293570	16 cde
TVu 3236	11 hi
TVu 7137	9 j
TVx 3380-O1E	17 bc
Tx 84-294	21 a
Tx 84-243	17 bc
UCR 239	11 hi
BLACKEYE	16 cde
	*
mean	15
c.v.	9.3
se	1.4

means followed by the same letter(s) are not significantly different at p(0.05) according to Duncan's Multiple Range test.

Goodhope

Days to 50% flowering were variable, ranging from 32 to 53 with PI 250238 and PI 288845 being the latest flowering varieties. Days to 95% pod maturity were not significantly different among varieties (Table 11).

Table 11 : Means of 2 traits of cowpea varieties at Goodhope : Preliminary Trial

Variety	days to 50% flowering	days to 95% pod maturity
IT81D-1189	46 bcd	70
TVx 3671-14C-O1D	50 ab	77
IT82D-635	43 defg	80
IT82E-789	33 kl	63
IT82E-49	35 jkl	76
IT82E-38	46 bcd	62
IT82D-905	40 ghi	88
IT82D-785	41 fgh	75
IT82D-891	32 l	74
IT82D-744	46 bcd	63
PI 250238	52 a	68
PI 288845	53 a	78
PI 293570	45 cdef	66
TVu 3236	50 ab	98
TVu 7137	36 ijkl	83
TVx 3380-O1E	47 bc	76
Tx 84-294	35 jkl	75
Tx 84-243	36 ijk	73
UCR 239	38 hij	66
BLACKEYE	42 efgh***	71
mean	42	71
c.v. %	7	32
se	3	2.3

means followed by the same letter(s) are not significantly different at p(0.001) according to Duncan's Multiple Range test.

3.1.4 Conclusion

The results of SADC trial have shown that most of cowpea varieties have high yielding potential across locations. Therefore, these cowpea varieties will be tested again to verify yielding potential, stability and suitability to various conditions. Ten cowpea varieties from Preliminary Cowpea Evaluation trial will be further tested to identify those varieties with high yielding potential and other agronomic traits.

3.2 Alectra screening trials

3.2.1 Introduction

Alectra vogellii is a serious parasitic weed of cowpeas which can cause yield losses exceeding 80%. It attaches its roots to those of cowpea and competes with the plant for nutrients. Resistance to *Alectra* has been found in two landraces B359 and B319. Crosses between these landraces and TVx 3236 were made to incorporate resistance into TVx 3236. Plant growth characteristics and yield of ten selections tested for *Alectra* last season in pots and in a field trial were evaluated.

The objective of this study was to evaluate progenies from crosses between TVx 3236 and B359 or B319 for their resistance to *A. vogelii* and other agronomic traits. This will provide both farmers and cowpea breeders with lines which have high yielding potential particularly in *A. vogelii* infested fields.

3.2.2 Materials and Methods

The study was carried out in two parts; a pot trial and a field trial at Sebele.

3.2.2.1 Pot trial

The experimental design was a randomised complete block with five replications. The treatments were ten selections (F5) from the crosses between TVx 3236 and B359 or B319. The susceptible checks were Blackeye and TVx 3236, and the resistant checks were B319 and B359; resulting with a total of fourteen entries.

The pot in the ground technique was used. GP45 black polyethylene bags were half filled with soil that was thoroughly mixed with 800 *Alectra vogelii* seeds. The bags were placed in holes made on the ground in the field and set at a spacing of 1m x 1m. Planting was done on January 13th, 1995. Three seeds of each line were planted per pot and later thinned to one plant per pot.

Records of flowering and pod formation were made every three days from appearance of first flower. These were recorded as date to first flower and date to first pod. A.vogellii emergence counts were made every three days from the time the first shoots were observed. At maturity the pots were removed from planting holes after harvest and the total number of emerged and non-emerged parasite shoots recorded. The length of the five longest parasite shoots was also measured in millimetres.

3.2.2.2 Field trial

The same ten lines screened in the pot trial were planted in an infested field site at Sebele (Lab field) to allow evaluation of their performance under field conditions. Each test plot was adjacent to a plot of the susceptible check, TVx 3236. The design was a randomised complete block with four replicates.

The plot length was 5m and between row spacing of 1m. Four rows were planted per plot with about 20cm spacing between the plants in a row. The experiment was planted on the 1 February, 1995 but germination was poor due to low soil moisture, so replanting was done on the 20 February, 1995. Data was collected on plant stand, flowering and pod formation on the two centre rows of each plot except for yield which was done on the whole plot. Plant stand count was done three weeks after emergence when the crop was well established. The plant population was then estimated on per hectare basis.

After harvest, ten plants were selected in the two centre rows at an interval of 1m apart. The total number of *Alectra vogelii* emerged and non-emerged shoots and total number of attachments on the root system of each cowpea plant were counted. The length of five longest *Alectra vogelii* shoots were measured in millimetres for each cowpea plant dug out. The Chi-square test was used for analysis of the number of Alectra shoots per plant while ANOVA was used on other variables.

3.2.3 Results and Discussion

Emergence of *Alectra* seedlings on susceptible plants began six weeks after planting. The infected plants showed leaf chlorosis, stunted growth and partial leaf defoliation even before the *Alectra* emerged.

3.2.3.1 Pot trial

The susceptible checks, Blackeye and TVx 3236 had a significant number of total *Alectra* attachment. The resistant check, B319 had no *Alectra* attachment. Six crosses had few *Alectra* attachment, even lower than the resistant check B359 (Table 1). The susceptible checks had the longest five *Alectra* shoots. The resistant checks had insignificant shoot length confirming their resistance. The selections had measurable shoots but were significantly lower than the susceptible checks (Table 1). The coefficient of variation for length was high, over 197% and this could make the conclusions unreliable. Some shoot length data was lost due to the parasite rotting before harvest and some of the Alectra vogelii shoots counted during the growing season were lost.

The lines have different responses to the parasite. This is shown by the yield per plant obtained for the season. B319 had significantly high yield per plant at $p = 0.05$ followed by B359 which was not significant from two selections (Table 1). The susceptible check Blackeye had the lowest yield. The Chi-square test showed that Alectra emergence was dependant on the Cowpea line that is significant at $p < 0.05$.

Table 1: Emerged Alectra shoots, length of five longest shoots and yield per plant from the pot experiment.

Accession	Five	Alectra emerged	Grain yield
BE	45.6	2.0	28
TVx 3236	26.2	1.2	84
156	9.4	0.2	77
76	8.2	0.6	27
132	18.4	0.4	44
81	10.0	0.2	80
B359	0	0	138
138	7.0	0.4	30
103	3.9	0.6	108
120	0.9	0	74
48	2.0	0	99
B319	0	0	158
86	0	0	82
125	0	0	76
CV% Chisquare	198	45	59
SED	12	-	29
Mean	78	-	9

3.2.3.2 Field trial

Most lines did not have a good stand even after replanting and there was a shortage of seed for some plots. However, assessments of *A.vogelii* infestation and yield data were obtained. TVx 3236 had a good stand in all the plots and this resulted in good yield for this accession. About half of the selections had plant populations below average of the trial (Table 2).

Table 2: Total number of Alectra shoots, emerged shoots, length of five longest shoots and grain yield.(field trial)

Accession	GrainYield kg/ha	Total No.of Alectra shoots	Length of 5 longest shoots (cm)	Number emerged for ten plants
81	258.4	6.5	29.5	0.5
76	212.6	4.25	23.25	0.5
48	171.0	1.25	2.75	0.0
138	156.4	0.50	0.37	0.0
120	146.1	5.00	14.75	0.25
125	133.2	3.25	5.5	0.25
156	126.7	15.50	56.25	1.0
TVx	124.6	26.75	226.62	10.1
86	93.7	0.00	0.00	0.0
132	48.5	15.00	52.37	1.0
103	17.8	2.25	22.75	0.0
CV%	59	124	145	250
Chisquare	-	-	-	33.6
SED	40	8	572	3.5
Mean	134	9.5	551	2

Tvx 3236 had *Alectra* shoot length of over 200 mm. The rest of the accessions had 50 mm and below. Among the selections, two had the longest shoots of about 50 cm (Table 2).

There has been only a few selections with no *Alectra* emerged. TVx 3236 had the highest number of emerged shoots. This confirms the susceptibility of TVx 3236 to the parasitic weed. The yield data shows there was no significant difference ($p>.05$) in yield among the selections. Three selections had the lowest yield probably due to poor stand (Table 2).

The analysis of the total *Alectra* data showed that TVx 3236 had the highest number of *Alectra* shoots. The selections had similar total number of *Alectra* and were not significantly different from one another. Selection 86 had no parasite attachment. In both trials, selection 81 had high yield. It has also shown few total Alectra shoots in both trials. Apart from the poor crop establishment in the field trial, most of the selections had a much higher yield than TVx 3236 except 103 and 132.

3.2.4 Conclusion

The results indicated that the parasite is dependant on the cowpea line to establish. The best accessions which supported the least *A. vogelii* attachments had the least number of emerged shoots as well as limited shoot length and produced good yield. The two trials were variable but some selections were consistent in their resistance. Most of the selections could not be described as resistant, tolerant or susceptible because of the variation between replicates which was especially high this season. Compared to the local landraces, all the selections have acquired most of the agronomic traits of TVx 3236 and are high yielding. There is need to further improve some of the good selections such as 138, 125, 120, 86 and 48 by backcrossing to the parent B359.

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3.3 Evaluation of flowering in indigenuous cowpea landraces

3.3.1 Introduction

Cowpea (*Vigna unguiculata* (L) walp) is commonly grown in agriculturally difficult conditions in the diverse cropping systems of both semi-arid and humid tropics. It is a warm season crop of generally short duration, taking less than 100 days to mature when grown in areas to which it is agronomically adapted (Ellis et al., 1994). Timely flowering is widely recognized to be a major component in cowpea adaptation in relation to both climate and the farming system.

Research has shown that the time of flowering is determined by either mean temperature, photoperiod or both, whichever causes the greatest delay (Summerfield et al., 1991; Mutters et al., 1989; Dagnall and King, 1987). Cowpeas show extreme variation in the start and end of the reproductive period. Indigenous cowpea landraces in Botswana have a highly variable flowering pattern which sometimes results in complete crop failure. Introduced cowpea varieties grown under the same environmental conditions with indigenous landraces do not show the same degree of inconsistency in flowering when planted on different dates. This, then makes one to wonder as to what really happens with indigenous landraces.

The aim of this study was therefore to determine the cause of delayed flowering in indigenous cowpea landraces. An understanding of this problem will help develop useful solutions since some of these indigenous landraces are important sources of genetic resistance to pests and diseases, which can therefore be used in the breeding improvement program.

3.3.2 Materials and Methods

The evaluation of flowering was carried out both in the field and in the greenhouse.

3.3.2.1 Field Experiment

The experiment was planted at the research field at Sebele during the 1994/95 cropping season under rainfed conditions. Supplementary, irrigation was provided in case of prolonged (2-3 weeks) moisture stress to prevent crop failure. Four dates of planting were used to provide variable daylength and temperature. The difference in the date of planting was approximately 30 days. The experimental design was a modified split plot with three replications. The date of planting was confounded with site in that all plots for each date of planting were grouped together. Varieties and replications were randomized within each date of planting block. Each plot had four rows of 10 m length with the spacing of 1 m between rows and 1 m within rows.. The varieties used were Blackeye, Tswana and ER_7 which were the checks, and the indigenous landraces were B342, B097, B359, B319 and B005-C. The planting dates were as follows:

First planting date: 23-11-94 Third planting date: 31-01-95

Second planting date: 29-12-94 Fourth planting date: 23-02-95

Weeding was done regularly and plots were sprayed twice to control aphids. Data recorded were on emergence plant population, number of pods per plant, days to 50% flowering, days to 95% pod maturity, harvest plant population, 100 seed weight and grain yield. The two center rows were harvested for yield. SAS and Matmodel packages were used for data analysis.

3.3.2.2 Greenhouse Experiment:

Evaluation of flowering in the greenhouse was done by controlling the daylength. The experimental design was a randomised complete block with 2 factors. The main treatment was daylength and the sub-treatment was varieties. There were two levels of daylengths, 1120 hrs and 1320 hrs. The varieties used were the same as those for the field experiment above. There were six replications. Two seeds per pot were planted in the soil medium and later thinned to one plant per pot. The experiment was planted on August 8, 1995 and harvested in October/November. The plants were watered daily. The greenhouse temperature was maintained at a maximum of 33°C and a minimum of 21°C.

Data were recorded on days to first flower, number of flowers per plant, pods per plant, days to maturity, 10 seed weight and seed yield. SAS package was used for data analysis.

3.3.3 Results and Discussion

3.3.3.1 Field Experiment

A count of the number of flowers per plant was made but the data was too variable to be used. Soil moisture data was also not recordered as planned due to equipment malfunction.

a) Plant Population

Emergence was variable for the different planting dates. December and January planting had a significantly lower plant emergence than November and February planting (Table 1). The poor plant emergence in December could be due to seed rot caused by excessive soil moisture. On December 26, 69 mm of rain fell and planting was done three days later on the 29th. In January, the problem could have been soil moisture stress. There was a total of 37.5 mm which fell in 5 days and was not well distributed (Appendix 1). On the overall though, plant emergence was poor because not even half of the intended plant population of 20 000 plants/ha was achieved. This indicates the serious problem of plant emergence in cowpeas. The plant population at harvesting was lower than emergence plant population because plants were lost due to seedling rot and insect damage. Both emergence and harvest plant populations were significantly ($p<0.05$) different between varieties. ER_7 had the lowest emergence and harvest plant populations. There was no significant difference for the planting date x variety interaction (Table 1).

b) Flowering and Pod Maturity

The mean daylength and maximum temperature for the months when planting was done were as follows:

November - 1320 hrs and 32.9°C December - 1340 hrs and 34.7°C

January - 1325 hrs and 33.6°C February - 1250 hrs and 33.1°C

November planting resulted in delayed flowering and January planting had a significantly ($p<0.001$) short number of days to 50% flowering (Table 1). There was also a significant ($p<0.001$) difference among varieties in days to 50% flowering. B097 flowered earliest at 50 days and B005-C was the most late, flowering at 76 days. The interaction (planting date x variety) was significant ($p<0.001$). The flowering of B005-C was more sensitive to the date of planting, taking more than 100 days to reach 50% flowering when planted in November (Fig 1). The long days (> 13 hrs) delayed the flowering of both B005-C and B319. Dow-El-Madina and Hall (1986) observed delayed flowering with some cowpea genotypes grown at a maximum/minimum temperature of 36/27°C and daylength of 15 hours. ER_7 showed delayed flowering when planted in February. In this case, short days and high temperature delayed the flowering of ER_7. The association between the date of planting and variety is shown in Fig 2. The varieties B342, B359 and Tswana showed higher stability in flowering. They did not change their flowering pattern irrespective of when they were planted, which was an effect of differences in daylength (Fig 3) They were also clustered together with the second date of planting (PD2), indicating a high interaction when planted in December which had the longest daylength and the highest temperature. B005-C and ER_7 were the least stable in flowering. Their flowering pattern changed with the date of planting which is attributed to daylength changes. Therefore they were not photosensitive.

All the varieties took longer than 100 days to mature when planted in February (Fig 3), even though flowering was not affected by late planting for some of them. This implies that the pod filling period was increased. Maturity of B342, B359 and Tswana was not stable as their flowering pattern. However, pod maturity at the second date of planting was consistent for the three varieties. The other varieties had variable pod maturity at all dates of planting (Fig 4).

Table 1: Parameters of Cowpea Varieties Planted at Four Dates at Sebele, 1994/95

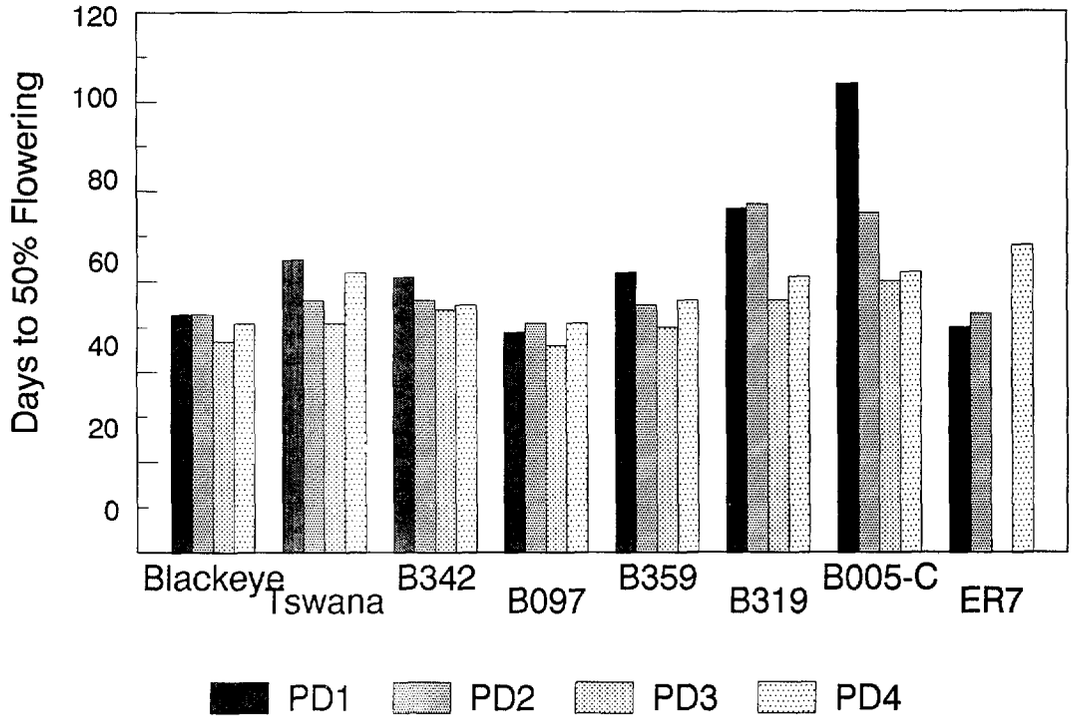
TREATMENT	DAYS TO 50% FLOWERING	DAYS TO 95% POD MATURITY	EMERGENCE PLANT POPULATION (Plants/ha)	HARVEST PLANT POPULATION (Plants/ ha)
PLANTING DATE				
23-11-94	65 a	92 b	9021 a	8688 a
29-12-94	58 b	83 c	6091 b	6000 b
31-01-95	52 c	80 c	6550 b	5691 b
23-02-95	58 b	109 a	9229 a	8833 a
	***	***	***	***
Mean	58	91	7723	7303
VARIETY				
Blackeye	51 de	80 d	8917 a	8375 ab
Tswana	59 c	93 c	8875 a	8667 a
B342	56 cde	91 c	8875 a	8708 a
B097	50 e	81 d	7227 bc	6864 bc
B359	56 cde	87 cd	6375 cd	6000 c
B319	66 b	105 b	8250 ab	7864 ab
B005-C	76 a	116 a	8167 ab	8046 ab
ER7	58 cd	79 d	5167 d	4050 d
	***	***	***	***
Mean	59	92	7732	7322
CV (%)	13.0	10.6	21.4	24.4

*** Different letters within a column indicate a significant difference at p= 0.001 according to Duncan Multiple Range Test.

c) Yield and Yield Components

The number of pods per plant, 100 seed weight and yield were significantly different forboth the dates of planting and varieties. February planting and vatiety ER_7 had the lowest number of pods per plant, 100 seed weight and yield (Table 2). The planting date x variety interaction was significant for 100 seed weight and yield, but not for pods per plant. November and December planting resulted with a high 100 seed weight for B319. Most varieties had the highest 100 seed weight when planted in January (Fig 5).

Figure 1. Flowering of Cowpeas at Four Dates of Planting at Sebele, 1994/95.



PD1= 23/11/94 PD2=29/12/94 PD3=31/01/95 PD4=22/02/95

Figure 2. Biplot for Days to 50% Flowering

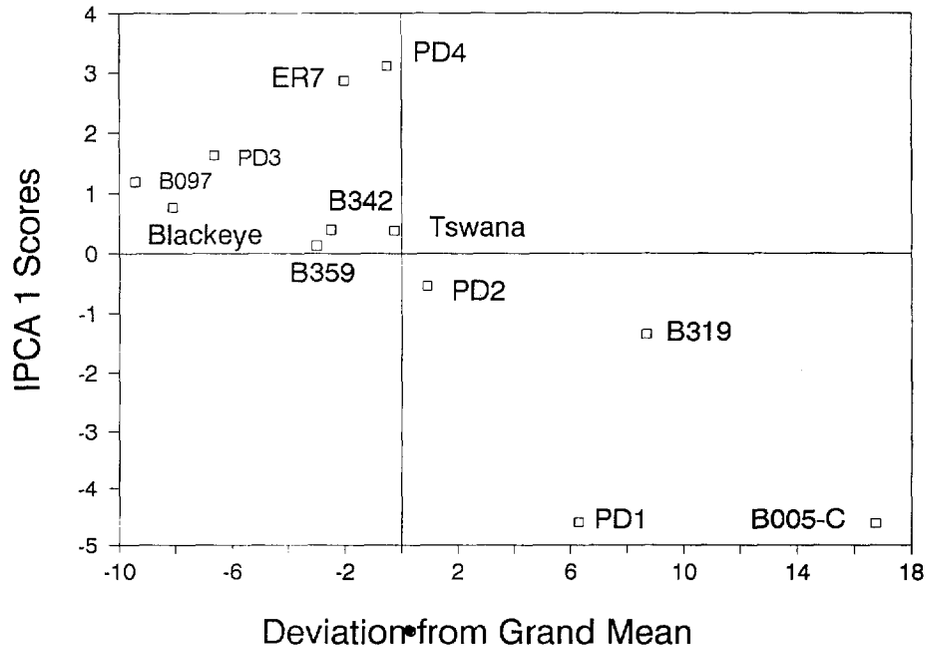
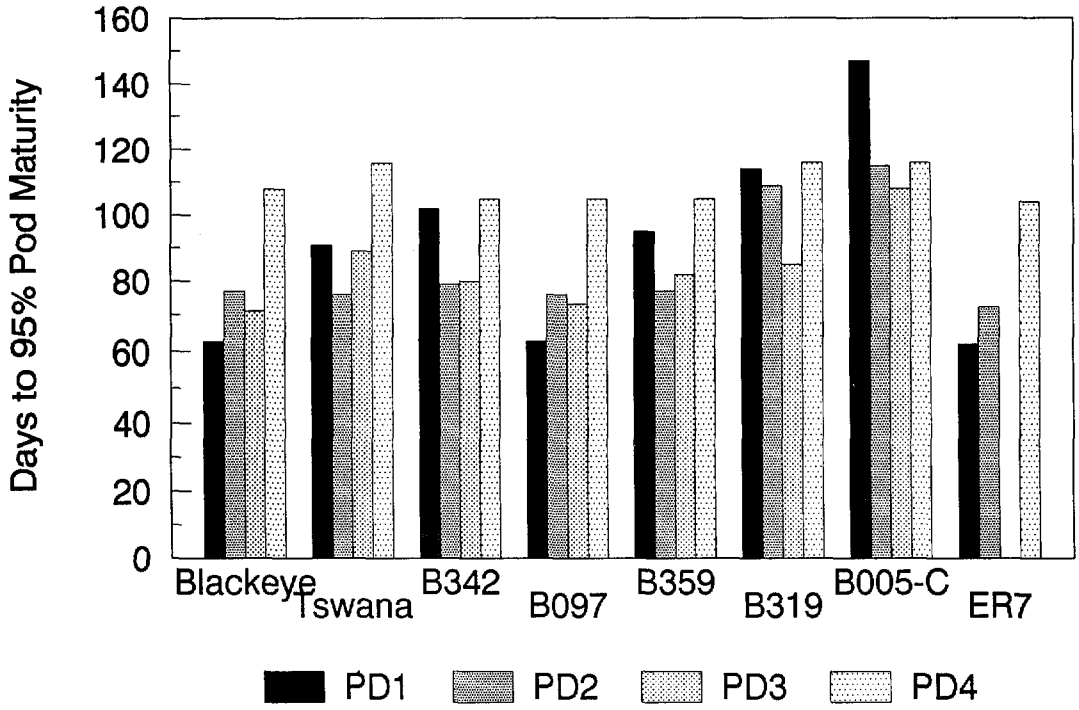


Figure 3. Pod Maturity of Cowpeas at Four Dates of Planting at Sebele, 1994/95.



PD1=23/11/94 PD2=29/12/94 PD3=31/01/95 PD4=22/02/95

Figure 4. Biplot for Days to 95% Pod Maturity

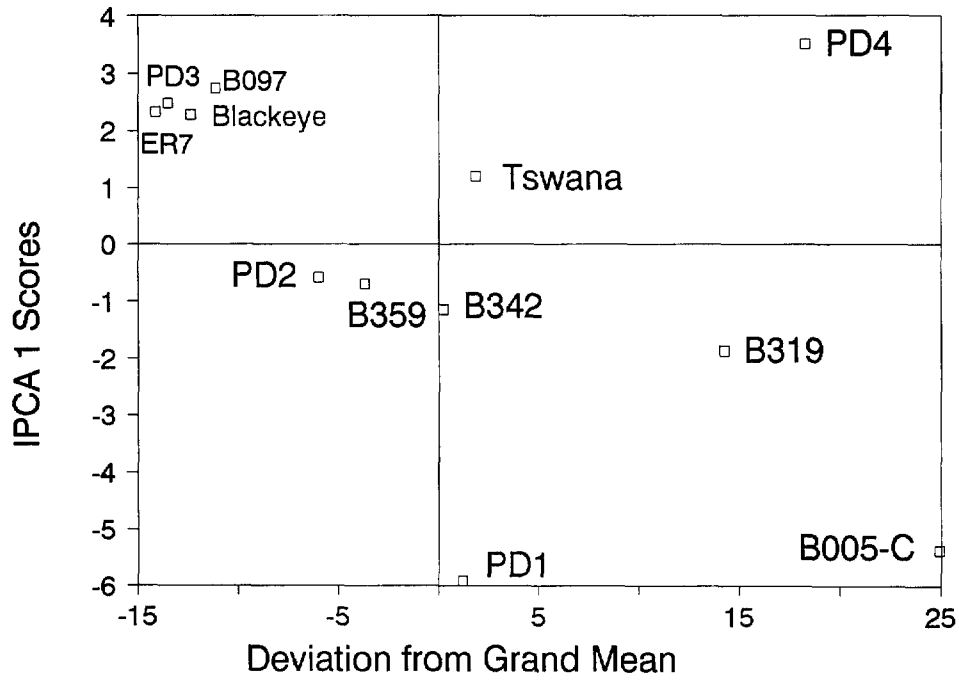


Table 2: Yield and Yield Components of Cowpeas Planted at Four Dates at Sebele, 1994/95.

TREATMENT	PODS PER PLANT	100 SEED WEIGHT (g)	YIELD (Kg/ha)
PLANTING DATE			
23-11-94	34 a	16.7 a	281.4 a
29-12-94	37 a	18.0 b	246.7 a
31-01-95	26 b	20.8 a	302.7 a
23-02-95	17 c ***	13.6 c ***	129.8 b *
Mean	28	17.3	240.2
VARIETY			
Blackeye	21 bc	16.1 bcd	194.7 ab
Tswana	25 bc	18.1 bc	255.3 ab
B342	30 bc	15.3 cd	284.4 a
B097	24 bc	16.8 bcd	119.4 bc
B359	29 bc	13.3 d	345.1 a
B319	31 b	24.0 a	261.5 ab
B005-C	45 a	19.9 b	341.6 a
ER7	19 c ***	12.9 d ***	41.0 c **
Mean	28	17.1	230.4
CV (%)	42.3	26.1	67.9

, * Different letters within a column indicate significant difference at p= 0.01 or 0.001 respectively according to Duncan Multiple Range Test.

Yield was generally low but there was a significant difference among planting dates, February planting having the lowest yield (Table 2). There were also varietal differences, the lowest yielding variety was ER_7 followed by B097 both of which are early maturing. Ludlow (1989) suggested that varieties with short phenology had low yield potential. The interaction (variety x planting date) was significant, and the highest yield for all varieties except B319 and B005-C was achieved by planting in November (Fig 7). The indigenous late maturing varieties (B359, B319 and B005-C) had higher yield when planted in January. B359 and B005-C had a positive interaction and a high yield potential with the third date of planting. B359 was also the most stable variety followed by B319 and ER_7. However, ER_7 had a negative interaction (Fig 8).

Figure 5. 100 Seed Weight of Cowpeas at Four Dates of Planting at Sebele, 1994/95

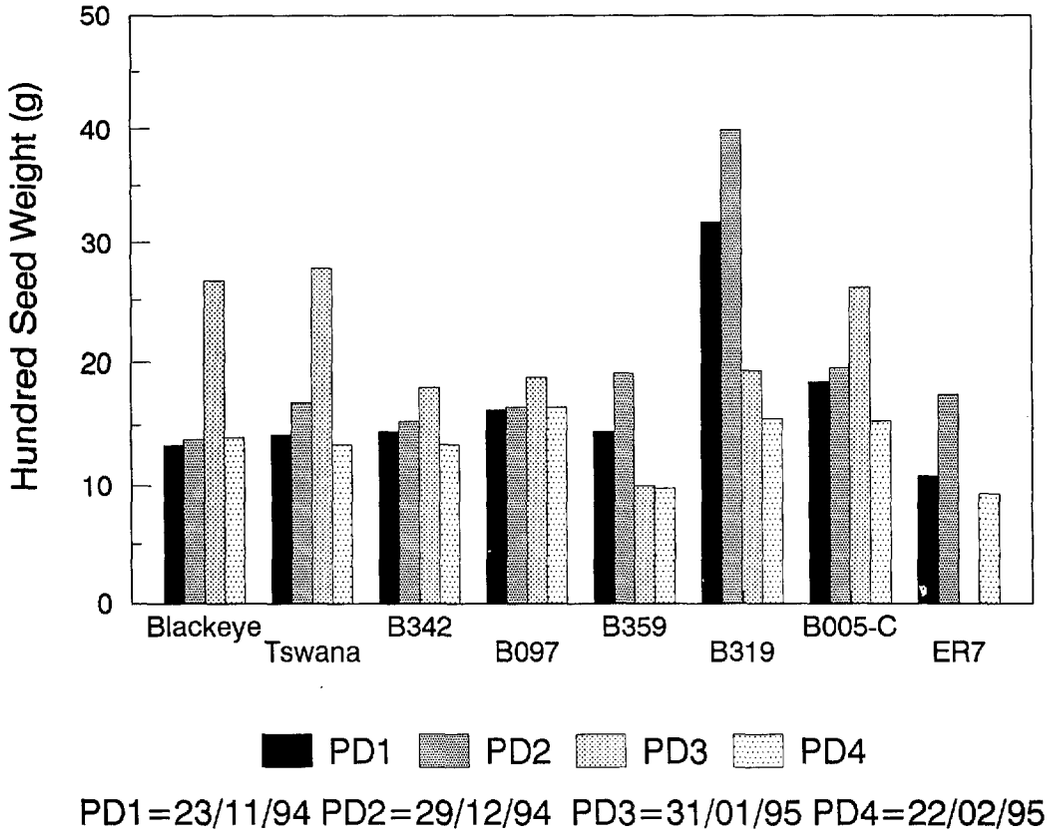


Figure 6. Biplot for 100 Seed Weight (g)

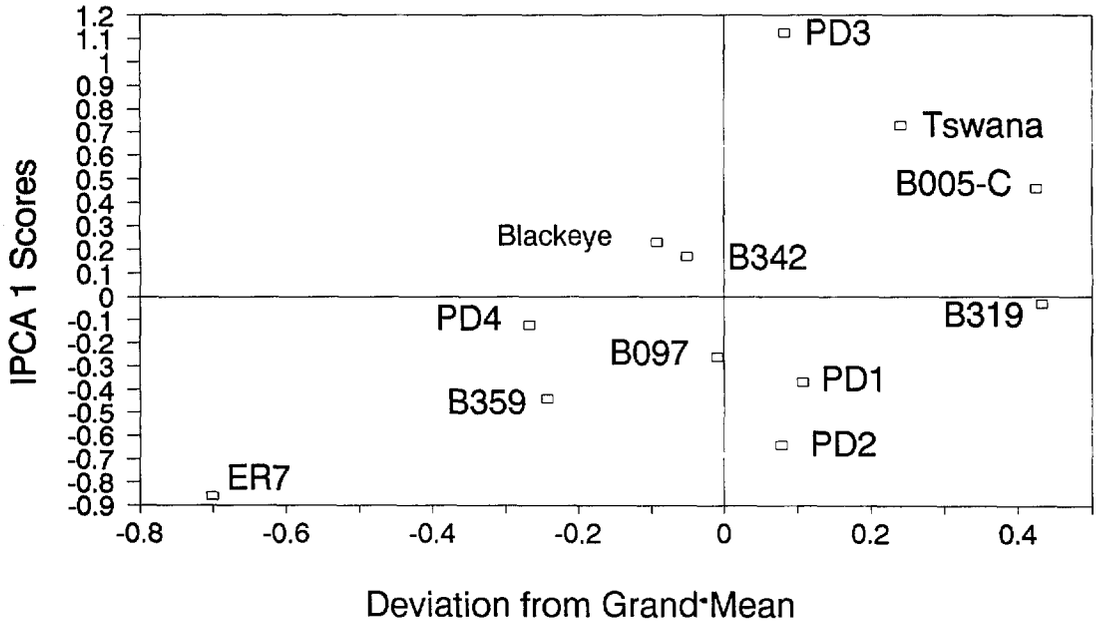
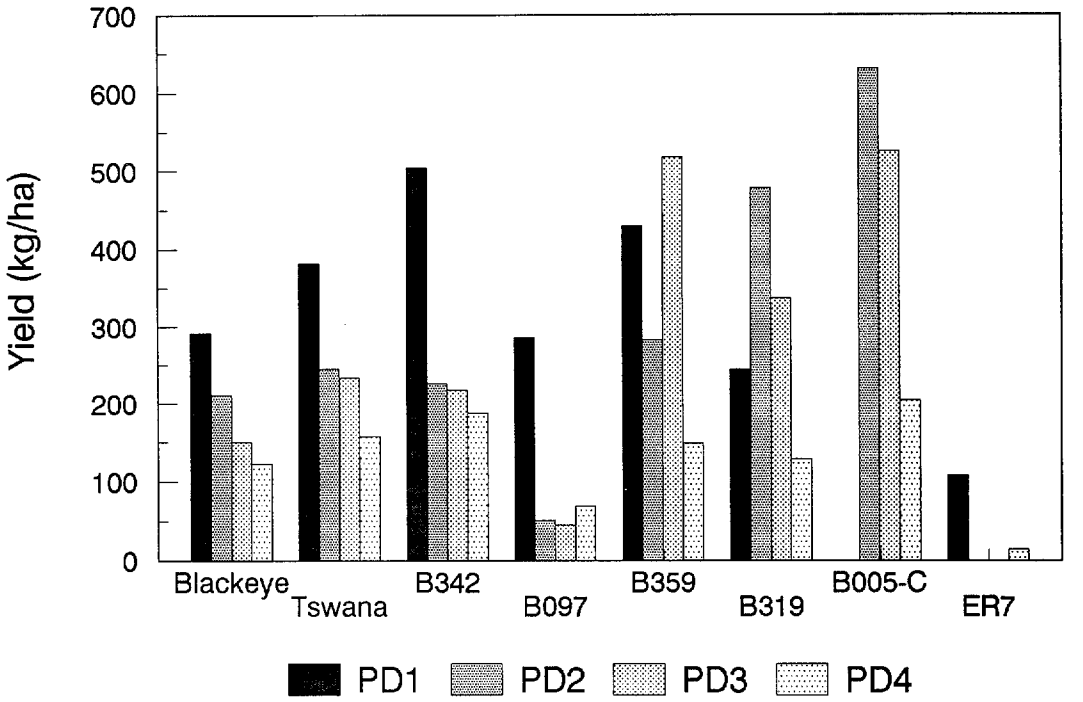
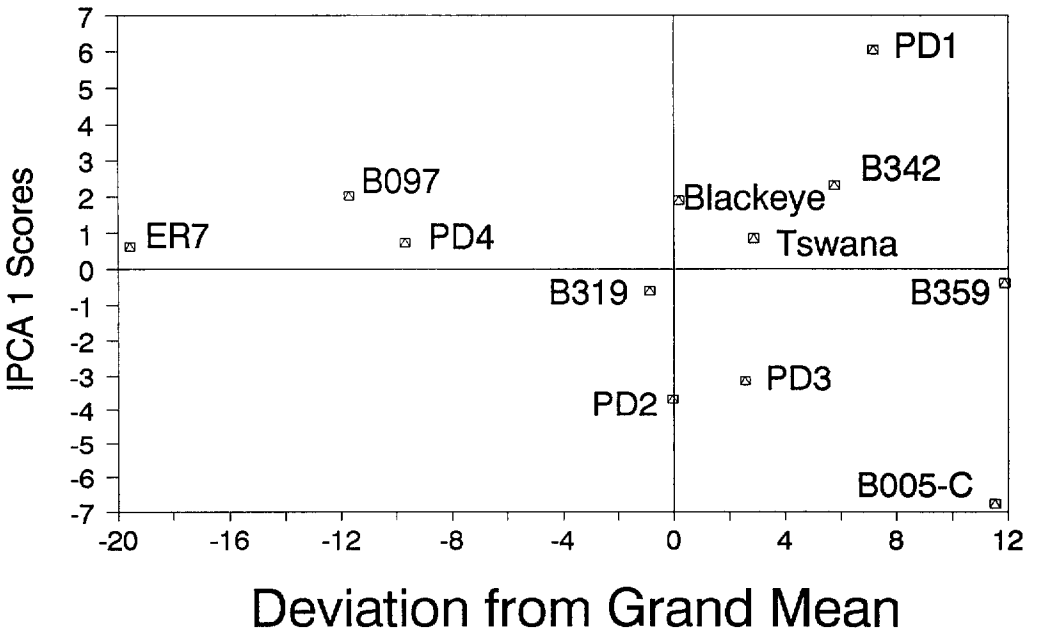


Figure 7. Cowpea Yield at Four Dates of Planting at Sebele, 1994/95.



PD1=23/11/94 PD2=29/12/94 PD3=31/01/95 PD4=22/02/95

Figure 8. Biplot for Cowpea Yield (Kg/ha)



3.3.3.2 Greenhouse experiment

There was a significant difference between the two daylengths for days to first flower, number of flowers per plant, pods per plant and days to maturity (Table 3). Long daylength delayed the onset of flowering and days to maturity. It also reduced the number of flowers per plant and pods per plant. Varietal differences were observed for days to first flower, flowers per plant, pods per plant, days to maturity and 10 seed weight. B097 flowed earliest at 42 days and B005-C latest at 61 days, as observed in the field experiment. ER_7 had the highest number of flowers per plant and pods per plant. The interaction (daylength x variety) was not significant for all the parameters probably due to the high coefficient of variation observed.

Table 3: Plant Growth Parameters and Yield of Cowpeas in the Greenhouse

TREATMENT	DAYS TO FIRST FLOWER	FLOWERS PER PLANT	PODS PER PLANT	DAYS TO MATURITY	10 SEED WEIGHT (g)	SEED YIELD (g/ plant)
DAYLENGTH						
1120 hrs	50	22	14	69	1.48	6.29
1320 hrs	53 *	13 ***	9	73 *	1.47	6.24
VARIETY						
Blackeye	46 cd	18 abc	15 ab	68 ab	1.85 a	7.39
Tswana	57 ab	12 c	9 c	76 ab	1.25 b	7.63
B342	57 ab	17 abc	10 c	77 a	1.48 ab	6.53
B097	42 d	21 ab	11 bc	68 ab	1.69 ab	6.22
B359	50 bc	20 ab	13 bc	68 ab	1.23 b	6.06
B319	52 bc	15 bc	8 c	67 ab	1.63 ab	5.35
B005-C	61 a	14 bc	9 c	77 a	1.50 ab	6.12
ER_7	50 bc ***	24 a **	18 a ***	66 b **	1.33 ab **	4.87
Mean	52	18	12	71	1.50	6.27
CV(%)	12.9	36.6	35.5	12.4	30.1	53.7

** *** Means followed by the same letter within a column are not significantly different at p= 0.05 or 0.001 respectively according to Duncan Multiple Range Test.

3.3.4 Conclusion

Long days of over 13 hrs and high temperatures of more than 32^{0}C delayed flowering of the indigenous varieties (B359, B319 and B005-C) especially B005-C except in the greenhouse study. Short days and high temperature delayed flowering of the early maturing introduced variety ER_7. This also affected the number of pods per plant, subsequently yield was drastically reduced. Work needs to be done to separate the effect of daylength from that of temperature, particularly that the maximum temperatures were way above the super-optimal for cowpeas.

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3.4 Physiological and morphological screening of cowpeas for drought resistance

3.4.1 Introduction

Although cowpea (*Vigna unguiculata* (L) walp) is the third most important crop after maize and sorghum in Botswana, the national production level is low. Several factors contribute to this, one being the lack of well adapted, high yielding and drought resistant varieties. Generally, cowpeas are adapted to relatively dry areas. However, their yield is greatly influenced by variation in the amount and distribution of rainfall. Within the rainy season, dry periods of two to four weeks can occur in an unpredictable fashion. Yield losses are particularly high when drought occurs at flowering or at pod filling stage (Diputado and Rosario, 1985; Gwathmey and Hall, 1992). Cowpea yield losses in water stressed areas can easily go up to 50% or more (Shouse et al., 1981; Summerfield et al., 1985).

In Botswana, screening of local and exotic germplasm has always been under rainfed conditions. This is effective as long as there is no variation in rainfall distribution from one season to the next. With deviations from the usual rainfall distribution pattern, varieties which were thought to be resistant failed because they were selected through drought escape mechanism which is not effective under unpredictable rainfall conditions. Recent climatic changes shows an unpredictable rainfall distribution pattern in Botswana. It is therefore important to employ other drought mechanisms such as drought avoidance or tolerance. Drought avoidance increases the ability of a plant to maintain a relatively high water status despite a shortage of moisture in the environment. Tolerance is the ability to produce despite loss of plant water status (Fischer and Turner, 1978; Fischer and Sanchez, 1979; O'Toole and Chang, 1979).

The aim of this study was to identify drought resistant varieties with high yield potential and to evaluate relative water content as a screening tool for drought resistance.

3.4.2 Materials and Methods

Eight cowpea varieties were planted in the field at Sebele during the 1994/95 cropping season under sufficient (rainfed plus irrigated) and insufficient (rainfed) soil moisture conditions with the aim of categorizing them according to their yield potential based on the geometric mean, drought resistance or susceptibility computed from the Fischer index, and percent yield reduction under moisture stress. The experimental design was a modified split plot with four replications. The moisture treatment was confounded by site difference in that all plots for insufficient (stressed) moisture were grouped together separate from those of sufficient (non-stressed) moisture. Each plot had four rows of 5 m length with the spacing of 0.75 m betwen rows and 0.20 m within rows. The varieties used were Blackeye, Tswana, B342, TVX 3504, IT85F-2020, IT83S-742-11, IT83S-742-2 and IT83S-720-2. Planting was done on December 29, 1994. The plots were weeded regularly and sprayed twice to control aphids and pod sucking bugs.

Data collected were on days to 50% flowering, days to 95% pod maturity, surface soil temperature, soil temperature at 10 cm depth, leaf temperature, pods per plant, seeds per pod, harvest plant population, 100 seed weight and yield.

3.4.3 Results and Discussion

The soil moisture data was not recorded because of equipment malfunction. However, visual observations indicated that the stress level intended was not achieved because of poor rainfall distribution during the season. This is because a week after planting, there was no rain and the situation went on like that for about 2 weeks. Therefore all the plots (stressed and non-stressed) were irrigated to promote germination and emergence. However, subsequent to this irrigation, there was a lot of rain for a week, leaving both the stressed and non-stressed plots wet. As a result, the intended stressed plot was not different from the non-stressed plot.

a) Soil and Leaf Temperature

There was a significant ($p<0.05$) difference between the stressed and non-stressed treatment for the surface soil temperature but not for the soil temperature at 10 cm depth (Table 1). Significant (p,0.05) varietal differences were also found for surface soil temperature and not for the 10 cm depth temperature, and the interaction was not significant ($p>0.05$) for both soil temperatures.

Leaf temperature of the non-stressed treatment was significantly ($p<0.05$) higher than that of the stressed treatment. This suggests that the stressed treatment may have cooled the leaves by transpiration, thereby sightly reducing its temperature. There was also a significant difference among the varieties, but the interaction (moisture x variety) was not significant for both soil and leaf temperatures.

b) Flowering and Pod Maturity

A significant ($p<0.05$) difference among varieties for both days to 50% flowering and days to 95% pod maturity was observed (Table 1). All the varieties flowered and matured earlier than the indeterminate varieties, Tswana and B342. The stressed and non-stressed treatment, and the interaction were not significant ($p>0.050$).

Table 1: Leaf and Soil Temperature, Plant Population, and Days to Flowering and Maturity of Cowpeas Planted Under Rainfed and Irrigated Conditions at Sebele, 1994/95.

Treatment	Days to 50% Flowering	Days to 95% Maturity	Surface Soil Temperature (°C)	10 cm depth Soil Temperature (°C)	Leaf Temperature (°C)
MOISTURE					
Stressed	47	63	29.0	30.5	30.7
Non-stressed	47	64	28.8 *	30.0	31.5 *
VARIETY					
Blackeye	46 b	62 b	28.6 b	29.9	30.6 b
Tswana	57 a	76 a	29.3 a	30.8	30.7 b
B342	56 a	75 a	28.9 ab	30.0	31.0 ab
TVX 3504	46 b	61 b	28.6 b	30.2	30.8 b
IT85F-2020	48 b	64 b	29.1 ab	30.1	31.1 ab
IT85S-742-11	42 c	58 c	28.9 ab	30.0	31.5 ab
IT83S-742-2	42 c	58 c	28.5 b	30.5	30.4 b
IT83S-720-2	41 c *	56 c *	29.4 a *	30.6 ns	32.5 a *
Mean	47	64	28.9	30.3	31.1
CV (%)	3.4	4.9	2.0	2.9	4.6

* Different letters within a column indicate significant difference at p= 0.05 according to Duncan Multiple Range Test

c) Plant Population, Yield and Yield Components

Significant differences between the stress and non-stress treatment, and the interaction were not observed for the plant population, yield and yield components (Table 2). The intended plant population was 66 667 plants/ha but the highest harvest plant population was 23 500 plant/ha for IT83S-720-2. B342 had the lowest plant population. IT83S-742-2 had the lowest number of pods per plant. Blackeye had the largest seed sizeas indicated by 100 seed weight. There was no yield difference between Blackeye and Tswana. However, they yielded significantly ($p<0.05$) higher than some of the exotic varieties such as IT85F-2020.

Table 2: Yield and Yield Components of Cowpea Varieties Evaluated Under Rainfed and Irrigated Conditions at Sebele, 1994/95.

TREATMENT	PODS PER PLANT	SEEDS PER POD	100 SEED WEIGHT (g)	YIELD (Kg/ ha)	HARVEST PLANT POPULATION (Plants/ha)
SOIL MOISTURE					
Stress	12.6	11.1	14.6	513.6	22150
Non-stressed	12.8	10.9	14.5	497.8	19699
VARIETY					
Blackeye	12 ab	10 c	18.9 a	762.1 a	23667 a
Tswana	17 a	12 a	13.8 bcd	540.9 bc	21778 ab
B342	17 a	12 a	15.3 b	573.3 ab	13333 c
TVX 3504	15 a	12 a	14.6 bc	620.8 ab	19000 abc
IT85F-2020	17 a	10 c	15.7 b	528.6 bc	14300 c
IT83S-742-11	9 bc	11 b	12.7 cd	452.1 bc	23667 a
IT83S-742-2	7 c	11 b	12.8 cd	227.1 d	16333 bc
IT83S-720-2	9 bc	10 c	12.5 d	349.6 cd	23500 a
Mean	13	11	14.5	506.8	1794.7
CV (%)	32.5	13.6	12.6	38.2	27.6

Different letters within a column indicate significant difference at p(0.05) according to Duncan Multiple Range Test.

3.4.4 Conclusion

The results were variable due to inconsistency in soil moisture content across the treatments. This made it difficult to intepret the results since for most varieties the stressed plots yield was higher than the non-stressed plots. Close monitoring of soil moisture need to be done in the next season.

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3.5 Early generation selected cowpea families (b097 x er_7 crosses)

3.5.1 Introduction

One of the aims of cowpea research is to develop varieties that are adapted to climatic conditions in Botswana and also have good plant growth characteristics. This can be achieved through making crosses between high yielding varieties with good plant characteristics and selecting lines with desirable traits.

The aim of this study was to evaluate bulked selections of crosses between B097 and ER_7 for desirable agronomic characteristics and high yield potential.

5.5.2 Materials and Methods

The experiment was carried out in the field at Sebele during the 1994/95 cropping season under rainfed conditions. Eight selections of B097 x ER_7 crosses, one selection of TVX 3236 x B165 cross and the checks ER_7, B097, Blackeye and Tswana were evaluated. The experimental design was a randomized complete block with four replications. Each plot had four rows of 5 m length and the between and within row spacing were 0.75 and 0.20 m respectively. Planting was done on January 4, 1995. The plots were weeded regularly and sprayed twice for aphids.

Data recorded include plant growth habit, twinning habit, determinancy, days to 50% flowering, days to 95% pod maturity, pods per plant, 100 seed weight and yield.

3.5.3 Results and Discussion

Three selections had an intermediate growth habit while the rest were semi-erect. Both parents for the crosses (ER_7 and B097) have erect growth habit. Selection 101 had no twinning habit and 110 had a pronounced twinning habit, and the other selections had moderate twinning habit. Only two selections were determinate and the rest were indeterminate (Table 1).

Although the parents flowered and matured early, all the selections flowered significantly ($p<0.050$) later than the parents and had medium maturity. Plant population on average was consistent for all the selection crosses. Blackeye had the lowest plant population. Seeds per pod, pods per plant and yield were not significantly different (Table 2). However, there were numeric differences but probably because of the high coefficient of variation (52%) the differences were not detected. Some of the selection crosses outyielded the parents and Blackeye. Selection 101 had the highest 100 seed weight.

Table 1: Plant Growth Characteristics of Bulked Selections of Cowpea Crosses.

SELECTION CROSSES	GROWTH HABIT	TWINNING HABIT	DETERMINANCY	DAYS TO 50% FLOWERING	DAYS TO 95% POD MATURITY	PLANT POPULATION (Plants/ ha)
B097 x ER7 - 3	3	2	2	50 de	71 def	22000 ab
" -10	3	2	1	53 bcd	76 bcd	19333 abc
" - 15	3	2	2	53 bcd	74 bcd	18333 abc
" - 20	3	2	2	51 cde	72 de	10667 ab
" - 30	4	2	2	56 b	79 b	8000 cde
" - 52	3	2	2	54 bcd	76 bcd	17000 acbd
" - 57	4	2	2	51 cde	74 bcd	24000 a
" - 101	3	1	2	52 bcde	74 bcd	11000 bcde
" - 106	3	2	2	53 bcde	73 cd	19333 abc
" - 110	4	3	2	52 bcde	74 cd	20000 abc
TVX 3236 x B165	3	2	1	55 bc	77 bc	16667 abcd
Tswana	5	1	2	63 a	87 a	25000 a
ER7	2	1	1	48 ef	68 ef	6000 de
B097	2	1	2	45 f	66 f	19333 abc
Blackeye	5	2	2	55 bc	78 bc	5000 e
Mean	3	2	2	53	75	6111
CV (%)	19.7	28.1	32.9	4.2	3.1	32.9

Different letters within a column indicate significant difference at p= 0.05 according to Duncan Multiple Range Test

Growth habit: 2= erect 3= semi-erect 4= intermediate 5= semi-prostrate

Twining habit: 1= no twinning 2= moderate 3= pronounced

Deteminancy: 1= determinate 2= indeterminate

Table 2: Yield and Yield Components of Bulked Selections of Cowpea Crosses

SELECTION CROSSES	SEEDS PER POD	PODS PER PLANT	100 SEED WEIGHT (g)	YIELD (Kg/ha)
B097 x ER7 - 3	9	10	17.0 abc	586.9
" - 10	8	10	16.3 bcd	309.8
" - 15	13	10	15.5 bcdef	359.1
" - 20	11	15	15.2 cdef	458.7
" - 30	12	11	14.0 ef	280.9
" - 52	10	12	17.0 abc	472.2
" - 57	11	13	15.0 cdef	443.9
" - 101	11	11	18.7 a	387.7
" - 106	11	9	14.7 def	270.5
" - 110	12	9	17.7 ab	564.3
TVX 3236 x B165	13	12	13.8 f	515.6
Tswana	12	9	15.8 bcdef	620.0
ER7	10	14	10.3 g	186.2
B097	9	15	16.2 bcde	390.5
Blackeye	9	9	16.8 abcd	260.4
Mean	11	11	15.6	407.1
CV (%)	20.4	36.5	6.6	52.0

Different letters within a column indicate significant difference at p= 0.05 according to Duncan Multiple Range Test.

3.5.4 Conclusion

Selections that had desired agronomic characteristics will be evaluated in the next season.

3.6 Evaluation of Bambara Groundnut Germplasm

3.6.1 Introduction

Bambara groundnut (*Vigna Subterranea* (L) verdc) is one of the indigenous grain legumes grown in Botswana. However, it is planted by farmers on a small scale and mostly intercropped with other crops. It is an underutilized legume which can provide food security for many farmers because of its nutritional importance and resistance to various environmental stresses such as drought and poor soils. It is suited to production in marginal areas where low-input farming is practiced (Harris and Azam-Ali, 1993; Lawn, 1989; Linnemann, 1994).

The aim of this study was to evaluate bambara groundnut germplasm so that accesions can be identified that may be incorporated into a yield trial or a breeding program for improvement. The objective is to eventually release a variety that farmers can use since at present the unavailability of varieties and appropriate agronomic information seem to limit the production of bambara groundnuts.

3.6.2 Materials and Methods

The experiment was carried out at Sebele under rainfed conditions. The experimental design was a randomized complete block with four replications. Each plot was four rows, 5 m long, and the between and within row spacing were 0.75 and 0. 20 m respectively. Fifteen bambara groundnut accessions from Botswana germplasm collection were evaluated. The experiment was planted on January 4, 1995 and harvested on June 19, 1996. Weeding was done when necessary and there was no fertilizer application.

Data recorded were emergence plant population, harvest plant population, days to 50% flowering, growth habit, 100 seed weight and seed yield. The two centre rows were harvested for yield. MSTAT-C and SAS packages were used for data analysis.

3.6.3 Results and Discussion

Out of the 15 accessions planted, only one (Mark-1A) failed to emerge in all the replications and therefore the analysis was based on 14 accessions. Both emergence and harvest plant populations were not significantly ($p>0.05$) different among accessions. The emergence plant population was half the intended population of 66 667 plant/ha. Between emergence and harvesting some plants were lost due to termites. The accessions evaluated flowered uniformly at 78 days after planting (Table 1). The growth habit was either bunch type or semi bunch type. The seed size was not significantly different among accessions. Seed yield was significantly different among accessions, ranging from 220-1170 kg/ha.

Table 1: Plant Growth Characteristics and Yield of Bambara Groundnut Germplasm

ACCESSION NUMBER	EMERGENCE PLANT POPULATION (Plants/ ha)	HARVEST PLANT POPULATION (Plants/ ha)	GROWTH HABIT	DAYS TO 50% FLOWERING	100 SEED WEIGHT (g)	SEED YIELD (Kg/ ha)
010-B	36 000	22 334	1	78	28.2	223 c
014-B	35 334	22 667	2	78	30.7	530 bc
015-B	35 334	30 667	1	78	31.4	740 abc
016-A	35 000	18 333	1	78	28.5	350 c
034-G	35 334	23 000	1	78	34.3	453 c
047-A	35 000	23 333	2	78	24.5	338 c
050-C	35 334	29 334	1	77	30.1	467 c
051-D	36 000	24 334	1	79	31.3	549 bc
053-C	36 333	28 667	2	78	30.5	607 bc
056-C	35 667	25 334	1	78	30.7	1174 a
056-E	35 334	22 000	2	80	27.7	512 bc
062-C	35 667	25 333	2	78	32.3	656 abc
MA-15	35 334	24 333	1	78	33.7	1078 ab
MAM-5	35 000	24 334	1	78	29.0	711 abc
Mean	37 405	24 572	1	78	30.2	599
CV (%)	2.9	19.2	4.3	1.8	14.2	68.5

Means followed by the same letter within a column are not significantly different at p= 0.1 according to Duncan Multiple Range Test.

Growth Habit: 1= Bunch type 2= semi bunch type

3.1.4 Conclusion

Some of the accessions show potential for high yield. The experiment will be continued in the next season.

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3.7 Evaluation of pigeonpea varieties

3.7.1 Introduction

Pigeonpea (*Cajanus cajan* (L) millsp) is one of the major grain legume crops widely grown in South Asia, East Africa, the Caribbean and some parts of Southern Africa (Natarajan and Mafongonya, 1992). It ranks sixth in area and production compared to other grain legumes, and is used in more diverse ways than others. Besides its main use as dhal (dry, dehulled, split seed used for cooking), its tender green seeds and leaves are used as a vegetable. Crushed dry seeds as animal feed, green leaves as fodder, stems as fuel wood and to make huts, baskets etc.. The plants are also used to culture the lac-producing insect. Pigeonpea plants are often used as a living fence around small farms. It is also grown on mountain slopes to reduce soil erosion. Its seed protein content (approx. 21%) compares well with that of other grain legumes (Nene and Sheila, 1990).

Pigeonpea provide several benefits to the soil. Being a legume, it fixes nitrogen. The leaf fall at maturity not only adds organic matter to the soil, but also provides additional nitrogen. It is drought tolerant because of its outstanding depth and lateral spread of its root system. Pigeonpeas can adapt to a wide range of soil types from gravelly stones to heavy clay loams of close texture and high moisture content, provided there is no standing water on the soil surface. They can tolerate salinity and alkalinity. Pigeonpea grow over a wide range of temperatures, from 19°C to 43°C; and rapid seedling growth occurs between 29°C and 36°C. It is also well adapted to soils of moderate to poor fertility (Whiteman et al., 1985). These attractive characteristics makes pigeonpea a potential crop for farmers in Botswana. Though it is not grown in the traditional cropping system in Botswana, it can provide additional option for diversification in the cropping system of Botswana.

The agricultural policy emphasizes diversification as one area of improving food security and increasing farm income. Pigeonpeas have a diversified use which will lead to increased farm income and subsequently food security at household level. The objective of this study is therefore to evaluate pigeonpeas from ICRISAT for adaptability to Botswana and determine their yield potential, so that eventually they can be introduced into the farmers' cropping system.

3.7.2 Materials and Methods

Two sets of pigeonpea trials each consisting of four were planted at Sebele: the short and long duration yield observation trials. The experimental design for both trials was a randomized complete block with three replications. There were four rows per plot and the plot length was 5 m. The spacing for the short duration trial was 0.45 m between rows and 0.10 m within rows, and for the long duration trial it was 0.45 m between rows and o.40 m within rows. Both trials were planted on December 29, 1994. The plots were weeded twice during the season and sprayed twice with cypermethrin at the rate of 15 ml/ 1500 ml water for African ballworm.

Data recorded were days to first flower, days to 50% flowering, plant height at full flowering, emergence and harvest plant populations, number of plants damaged by termites for the two centre rows, 100 seed weight, seed yield and dry matter yield. MSTAT-C and SAS packages were used for data analysis.

3.7.3 Results and Discussion

3.7.3.1 Short duration trial

Emergence was consistent for all varieties and was within the intended plant population, ranging from 110 000 to 138 000 plants/ha. The harvest plant population was slightly lower than the intended plant population due to termite damage. The plant population ranged from 90 000 to 97 000 plants/ha. There were no significant ($p>0.05$) varietal differences for both plant populations, days to first flower appearance, dry matter and seed yield (Table 1). Plant height, days to 50% flowering and 100 seed weight were significantly different among varieties. IPCL 86005 flowered later that the other varieties. The late flowering variety was also the tallest. Akinola and Oyejola (1994) made the same observation. ICPL 86005 and 87105 were the largest seeded. These varieties also happen to flower later and grow taller than the others. Numerically ICPL 86005 and 87105 had higher dry matter and seed yield than other varieties. Previous studies also showed that ICPL 86005 had high yield potential (Anon, 1989).

Table 1: Plant Growth Parameters and Yield of Short Duration Pigeonpeas

VARIETY	EMERGENCE PLANT POPULATION	HARVEST PLANT POPULATION	DAYS TO FIRST FLOWER	DAYS TO 50% FLOWERING	PLANT HEIGHT (cm)	100 SEED WEIGHT (g)	DRY MATTER (kg/ha)	SEED YIELD (kg/ha)
ICPL 86005	110 370	90 370	58	76 a	70.8 a	13.9 ab	1296	1782
ICPL 86012	111 851	89 629	55	68 b	56.8 ab	12.5 bc	970	948
ICPL 87	121 481	97 037	55	68 b	56.4 b	11.9 c	963	1419
ICPL 87105	133 518	90 370	58	72 ab	71.0 a	14.5 a	1348	1886
Mean	119 305	91 851	57	71	63.8	13.2	1144	1509
CV (%)	20.9	18.3	3.9	4.3	7.1	4.0	24.8	31.4

3.7.3.2 Long duration trial

Emergence and harvest plant populations were not significantly ($p>0.05$) different among varieties and they were within the intended plant population range. However, a few plants were lost due to termites. Plant height, 100 seed weight, dry matter and seed weight were also not significantly different among varieties. Both the days to first flower appearance and 50% flowering were significantly different among varieties (Table 2).ICP 9145 flowered later than the other varieties. The coefficient of variation for dry matter and seed yield were high and may have contributed to the lack of significance.

Table 2: Plant Growth Parameters and Yield of Long Duration Pigeonpeas

VARIETY	EMERGENCE POPULATION (Plants/ha)	HARVEST POPULATION (Plants/ha)	PLANTS KILLED BY TERMITES	DAYS TO FIRST FLOWER	DAYS TO 50% FLOWERING	PLANT HEIGHT (cm)	100 SEED WEIGHT (g)	DRY MATTER (kg/ha)	SEED YIELD (kg/ha)
ICP 9145	31 111	32 592	4	123 a	154 a	149.1	12.0	1370	240
QP 38	31 851	32 592	8	93 b	120 b	141.2	10.7	1259	324
HY 3C	21 481	20 741	4	103 b	123 b	136.5	10.7	2348	97
ROYES	28 889	27 407	3	104 b	128 b	140.6	9.3	1518	219
Mean	28 333	28 333	5	106	131	141.9	10.7	1624	220
CV (%)	48.4	45.5	65.1	7.7	3.0	10.4	19.1	80.2	68.4

Means followed by the same letter within a column are not significantly different at p=0.05 according to Duncan Multiple Range Test.

3.7.4 Conclusion

The short duration varieties had high dry matter and seed yield which in most cases were higher than 1 t/ha. The long duration varieties had high dry matter and low seed yield because the pod and seed development were reduced by the cold weather since the crop grew into the winter months. This therefore suggests that the long duration varieties should be planted earlier than December. On the overall though, pigeonpeas have great potential to be developed in Botswana. Work will continue in the future to evaluate more pigeonpea varieties.

References

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3.8 Cowpea row spacing/plant population trial

3.8.1 Introduction

In Botswana, the traditional cowpea varieties grown are the spreading type which often flower and mature late (>100 days). The recommended spacing is 0.75 by 0.20m or 67 000 plants per hectare (DAR, 1990) which is more appropriate for the erect varieties. Morphological differences between the spreading and erect cowpea genotypes make it necessary to determine the optimum spacing for genotypes with these different growth habits. Plant populations ranging from 8 333 to 133 333 plants per hectare with between row spacings of 0.375, 0.750 and 1.50 m and within row spacings 0.20, 0.40 and 0.80 m showed no significant differences in yield for the Tswana cowpea variety (DAR, 1981). However, a significantly higher yield was obtained for Blackeye at wider rows. In another experiment, using the same inter-row and within- row spacings, Blackeye yield and hundred seed significantly increased with decreases in inter-row pacing. Yield of ER7 and Blackeye was not different for within row spacings of 0.10, 0.20, 0.40, and 0.60 m and between row spacing of 0.75 m (DAR, 1982). In a preliminary trial in 1994, B005-C, a spreading genotype, had slightly greater yields at a spacing of 1.00 m x 0.20 m than at the recommended 0.75 x 0.20 m or 66 667 plants per hectare (Unpublished). The aim of this experiment was to further investigate the effect of between and within row spacing on the performance of the spreading and erect cowpea genotypes.

3.8.2 Materials and Methods

Two spreading cowpea genotypes, Tswana and Blackeye, and two erect genotypes, ER7 and B097, were planted at Sebele, Hukuntsi, Mpandamatenga and Maun in January, 1995. At Sebele, B005-C a spreading genotype, was also included in the experiment. Four inter-row spacings 0.50, 0.75, 1.00 and 1.25 m were used with different within row spacings to achieve plant populations of 20 000, 67 000 and 100 000 per hectare. A two factor randomised complete block experimental design with three replications was used for each of the three population levels. To achieve each population level within row spacings were set as follows:-

Between Row Spacing (m)		Population level (plants/ha) (1) 20 000	(2) 67 000	(3) 100 000
		---------- Within row spacing (m) ----------		
(1)	0.50	1.00	0.30	0.20
(2)	0.75	0.67	0.20	0.13
(3)	1.00	0.50	0.15	0.10
(4)	1.25	0.40	0.12	0.08

Days to first flower, days to 50% flowering, hundred seed weight and grain yield were recorded. Data for each population level was analysed separately.

3.8.3 Results and Discussion

The required population levels were not achieved at Mpandamatenga, Hukuntsi and Maun due to poor moisture conditions at planting. At Sebele only the highest population (100 000 plants/ha) was not achieved.The discusion below is based on the results from the low and medium populations (20 000 and 67 000 plants/ha) achieved at Sebele.

Low plant population (20 000/ha)

Row spacing had no significant ($p>0.05$) effect on days to first flower, days to 50% flowering, and hundred seed weight. Grain yield per hectare was significantly higher ($p<0.001$) at the 0.50m spacing than at the other spacings (Table 1). Yields among the other spacings were not significantly different. Actual plant populations were significantly lower ($p<0.05$) at the widest row spacing (1.25m).

Hundred seed weight and grain yield were significantly higher ($p<0.001$) for B005-C than for the other genotypes. Yields were not significantly different between the other four genotypes. ER7 had the lowest hundred seed weight. The plant populations were not significantly different ($p<0.05$) for genotypes.

The interaction between row spacing and genotype was only significant ($p<0.001$) for hundred seed weight (Table 1 and Figure 1). B097 had higher seed weight than the other genotypes at the 0.50m row spacing, but significantly lower seed weight at the 1.00m row spacing than B005-C, Tswana and Blackeye (Figure 1).

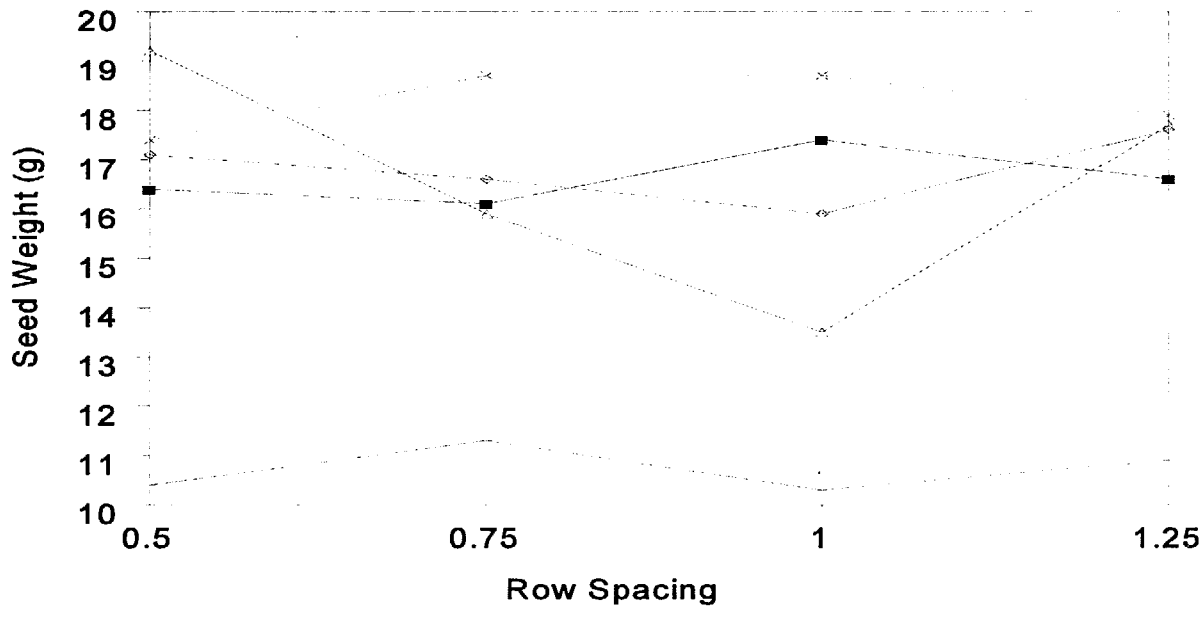
Table 1: Cowpea row spacing and genotype effects on growth/development characteristics and yield at low pant population level (20 000 plants/ha)

Treatment		Plant population	Days to First Flower	Days to 50% Flowering	**100 Seed Weight (g)**	**GrainYield (kg/ha)**
Row Spacing	0.50	19992 a	41.5	48.7	16.1	879.1 a
	0.75	19998 a	41.1	48.7	15.7	622.9 b
	1.00	19881 a	41.6	48.2	15.2	496.5 b
	1.25	19092 b	41.4	48.6	16.2	618.7 b
		*		ns	ns	***
Genotype	Tswana	19852	46.3 b	53.0 b	16.6 b	661.1 b
	ER7	19547	38.6 c	44.0 d	10.7 c	552.6 b
	Blackeye	19991	39.0 c	47.7 c	16.8 b	610.8 b
	BO97	19324	33.0 d	39.3 e	16.6 b	507.3 b
	B005-C	19991	50.0 a	58.9 a	18.2 a	939.8 a
		ns	***	***	***	***
Interaction		ns	ns	ns	***	ns

* and *** Different letters within a column indicate significant significant differences at p=0.05 and 0.001 respectively according to the Least Significant Difference.

ns=not significant

Figure 1: Genotype x row spacing interaction on hundred seed weight low plant population (20 000/ha)



■ Tswana ER7 Blackeye BO97 B005-C

Table 2: Cowpea row spacing and genotype effects on growth/development characteristics and grain yield (kg/ha) at the medium plant population level (67 000 plants/ha)

Treatment		Plant population	Days to First Flower	Days to 50% flowering	100 Seed Weight	**Grain Yield**
Row Spacing	0.50	64752 a	41.2	48.9	15.9	900.2 a
	0.75	58290 b	40.9	49.3	15.5	649.9 b
	1.00	56255 b	42.2	49.7	15.9	571.0 b
	1.25	46093 c	42.2	50.8	15.8	492.8 b
		***	ns	ns	ns	***
Genotype	Tswana	60345 a	45.5 b	52.8 b	15.9 b	689.1
	ER7	46989 b	39.3 c	46.8 c	10.8 c	634.1
	Blackeye	57826 a	40.6 c	48.6 c	16.9 b	624.5
	BO97	60113 a	34.0 d	40.5 d	16.7 b	653.4
	B005-C	56466 a	48.7 a	59.7 a	18.6 a	666.3
		***	***	***	***	ns
Interaction		ns	ns	ns	ns	ns

* and ** Different letters within a column indicate significant differences at p=0.05 and p=0.001 respectively according to the Least Significant Difference.

ns=not significant

Medium plant population (67 000/ha)

The 0.50m row spacing significanly higher grain yield than the other spacings. However, actual plant population decreased as inter-row spacing increased from 0.50m. The interaction between row spacing and genotype was not significant for all the parameters measured (Table 2).

3.8.4 Conclusions

- Overall grain yield for the 0.50 row spacing was significantly higher than for the other spacings at both plant population levels, but conclusions are complicated by differences in actual populations between the different row spacings. These differences in actual populations are due to the fact that at narrow row spacing it is easier to achieve the desired population since the within row spacing is greater.

- Differences between genotypes were not obvious, since the two populations were planted separately.

The experiment will be modified in the next season to include genotype, row spacing and plant population in one experimewnt.

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Appendix 1: Rainfall figures (mm) for the 1994/95 cropping season

Month	Site			
	Sebele	Maun	Hukuntsi	Pandamatenga
August	0.0	0.0	0.0	0.0
September	0.0	0.0	0.0	0.0
October	54.8	0.0	0.0	14.2
November	6.3	44.0	0.0	39.1
December	76.8	15.2	3.9	46.2
January	39.7	27.0	35.4	81.6
February	25.0	14.4	0.0	38.8
March	135.1	48.3	0.0	16.9
April	31.8	0.0	0.0	20.0
May	3.7	2.0	0.0	0.0
June	0.0	0.0	0.0	0.0
July	0.0	0.0	0.0	0.0

3.9 Evaluation of fungicides as seed dressings to control stem rot and seedling blight.

3.9.1 Introduction

Grain legumes are particularly vulnerable to attack by soil-borne pathogens during the seedling establishment stage. At Sebele and Goodhope, seedling mortality of up to 100% has been observed on Bean Variety Trials and *Macrophomina phaseolina* was identified as the major pathogen involved (Personal observations. In some root-knot nematode infested soils, mature cowpea plants have been killed by a complex of both *M. phaseolina* and *Fusarium.* Local plant disease surveys have revealed presence of *M. phaseolina* causing charcoal rot in cereals, groundnuts and sunflower and also ashy stem blight on cowpeas, mungbeans and tepary beans (Anon, 1980, FAO 1990). There is therefore an indication that the pathogen is abundant in Botswana especially in sandy soils and could be partly responsible for seedling mortality.

The benefit of fungicidal seed dressings in controlling diseases caused by soil-borne pathogens has been established through the years and seed treatment is a routine practice by seed producing companies. In Botswana captan is the standard fungicide used by the Seed Multiplication Unit of the Department of Agricultural Research. As a broad spectrum fungicide, captan is effective, however, it has a short residual effect under field conditions. Although cowpeas are normally not affected by seedling mortality, symptoms of ashy stem blight usually become evident later on in plant growth such that non systemic fungicides like captan will most probably not control the disease at that stage.

The objectives of the present study were:-

1) To evaluate the efficacy of several fungicides in controlling seedling blight and stem rot in grain legumes.

ii) To determine effect of fungicides on ashy stem blight incidence

3.9.2 Materials and Methods

Three bean varieties (Droebone SSB10, Bonus and Kamberg), two cowpea varieties (Blackeye and ER7), a newly released mungbean variety (Mmelegi) and a local tepary cultivar from Bobonong were used in the study.

The seeds of the above legumes were dry coated with the following fungicides at a rate of 2 grams of product per kilogram of seed:-

Captan
Apron
Thiram
Rizolex
Captan followed by Chloroneb.
Untreated seed was used as control

The trial was conducted in a field known to be naturally infested with *M. phaseolina*. The experimental design was a randomised complete block with 4 replications. Plots consisted of four 5-metre rows, 75 cm apart. Seeds were sown at 20 cm spacings in the rows such that 100 seeds were planted in each plot. Carbofuran was applied in the planting furrow at a rate of 6g/5 metre row to control bean-fly and root-knot nematodes.

The legumes were planted on January 17, 1995. By four weeks after planting all the plants in the plots initially planted to Droebone SSB10 and Bonus had died and therefore these were replanted on February 23, 1995 with another bean variety, Kamberg.

Initial stand was taken two weeks after emergence and post emergence damping off was recorded four weeks after planting. At crop maturity the incidence of ashy stem blight was also recorded.

3.9.3 Results and Discussion

Emergence of Droebone SSB10, Bonus, Kamberg and ER7 was low (ranging from 9-26.5%), indicating a possibility of pre-emergence damping off. The other cultivars had an emergence of over 50% (Table 1).

Table 1: Emergence (%) of grain legumes treated with various fungicides under field conditions.

Treat/ Cultivar	Droeb SSB10	Kam berg	Bonus	Black eye	ER7	Mung bean	Tepary bean
Captan	26.5	9.0	0.0	53.8	22.0	69.0	95.0
Apron-C	21.5	12.3	0.0	50.3	22.0	74.8	77.3
Thiram	18.5	7.3	0.0	70.8	19.0	81.0	77.3
Rizolex	16.5	10.8	0.5	50.3	14.5	71.8	62.3
Captan/ Chloroneb	12.0	12.0	0.5	49.5	22.3	57.3	82.3
Control	9.0	12.8	0.0	62.3	20.0	81.3	79.5
Fungicide Means	17.3	10.7	0.2	59.2	20.0	72.5	78.9

Post emergence damping off was worst on Droebone SSB10, Bonus and Kamberg. ER7 was the least affected among the rest of the legumes (Table 2).

Table 2: Post Emergence damping-off under field conditions for grain legume cultivars treated with various fungicide seed dressings.

Treat/ Cultivar	Droebone SSB10	Bl/eye	ER7	Mn/bean	Tepary
Captan	43.07	3.75	0.0	1.26	6.05
Apron-C	66.96	2.58	0.0	0.79	3.52
Thiram	56.81	2.18	0.93	2.64	2.54
Rizolex	99.90	2.55	0.0	0.56	3.20
Captan/ Chloroneb	63.04	1.17	1.56	0.0	4.67
Control	70.00	0.79	0.0	0.73	8.88
Fungicide Means	10.9	2.17	0.41	1.00	4.81

Since dry beans did not survive to maturity, ashy stem blight was observed only on the other four legumes and Blackeye had the highest incidence (Table 3).

Table 3: Ashy Stem Blight Incidence on Mature Grain Legumes treated with various fungicide seed-dressings

Treat/ Cultivar	Blackeye	ER7	Mungbean	Tepary
Captan	4.25	4.75	1.50	2.25
Apron-C	8.75	2.50	2.75	4.25
Thiram	8.75	0.50	0.75	7.50
Rizolex	7.00	0.50	3.00	2.50
Captan/ Chloroneb	9.00	2.50	1.50	3.50
Control	15.25	4.25	2.75	4.75
Fungicide Means	8.83	2.50	2.04	4.13

The results indicate that the fungicide treatments had no significant effect on stand establishment, damping off or ashy stem blight. In fact in some cases e.g. Mungbeans, the untreated plots were least affected by stem rot (Table 2). This could mean that the stand establishment was influenced by other undetermined factors. Since very small amounts of the chemicals were handled it is possible that the effective dosages were not attained. The possibility of some of the chemical being lost through handling cannot be ruled out since the seed was hand planted.

The study confirmed that dry beans are the most susceptible legume to pre- and post-emergence damping off. The susceptibility of Blackeye to ashy stem blight has been previously reported (Anon 1988) but the fact that symptoms become apparent very late in the season could mean it has some tolerance to the disease.

More studies need to be done on individual cultivar resistance to *Macrophomina*. The study will be repeated in the following season.

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4.0 HORTICULTURE IMPROVEMENT PROGRAMME

4.1 Vegetable varietity evaluation

4.1.1 Introduction

The main objectives of the Horticultural Research Program is to provide Botswana horticultural producers with superior vegetable and fruit cultivars and appropriate cultural practices that can help raise the crop yields in the country. To achieve these are conducted yearly at Sebele, Bobonong and Maun Research stations to determine the suitability of the various vegetable and fruit crops. Other trials include determination of the storability of the different onion cultivars.

4.2 Tomato (*Lycopersion esculentum*)

4.2.1 Material and Methods

Two tomato cultivar trials composed of 12 and 10 cultivars were planted at Sebele and Bobonong on September 12 and October 4, 1994 respectively. Both trials were transplanted five (5) weeks after planting. A Randomized Complete Block Design with four (4) replications was used. A basal application of 2:3:2 (22) at the rate of 1000 kg/ha and 125 kg/ha potassium chloride (KCL) was given. The trials were top-dressed twice with sulphate of Ammonia at the rate of 200 kg/ha at flowering and four weeks later. The plants were spaced at 1.2 m between the rows and 40 cm within the row. The parallel wire staking method was used to support the plants. Dithane 45 and Copper oxychloride were used to control Early Blight (A. *solani*) infestation.

Data were analyzed using the analysis of variance procedure (ANOVA). Differences between pairs of means were tested using LSD at the 0.05 level of significance.

4.2.2 Results and Discussions

Significant ($P<0.05$) yield differences were observed at both sites (Table 1). At Sebele the cultivar Zeal produced the highest yield of 96.8t/ha which was not significantly different from that of Zest, Sunny, Sixpack, Hotstuff, Heinz and Floradade. The lowest proportion of marketable yield for Casino Royal (78 percent)was due to cracking of the fruits. The cultivar Hotstuff produced significantly ($P<0.05$) largest fruits while Money-maker the smallest fruits.

At Bobonong, the cultivar Expresso yielded highest, though not significantly different from Zest, Sixpack, Floradade, Hotstuff and Sunny (Table 2). The cultivar Expresso, Floradade, Sunny and Hotstuff produced significantly ($P<0.05$) higher mean marketable fruit weight. The cultivars Money maker, Sixpack and Velox produced the lowest mean marketable fruit weight.

Table 1: Mean yield and marketable fruit weight of 12 tomato cultivars planted on September 12, 1994 at Sebele.

Cultivars	Mean marketable yield	Mean marketable fruit weight
	(t/ha)	(g)
Zeal (H)	96.8 (90.7)	117
Zest (H)	89.8 (91.3)	101
Sunny (H)	89.6 (91.5)	111
Sixpack (O)	85.9 (86.5)	78
Hotstuff (H)	82.7 (84.5)	138
Heinz 1370 (O)	80.4 (94.4)	88
Floradade (O)	79.1 (90.7)	97
Casino Royal (H)	77.6 (78.0)	116
Money Maker (O)	76.1 (90.9)	52
Velox (O)	76.0 (85.0)	85
Expresso (O)	70.1 (87.9)	95
Red Khakhi (O)	68.9 (81.3)	82
Trial Mean	81.0	97
LSD (5%)	17.89	11.11
SE	6.21	3.86
CV (%)	15	8

(H) denotes Hybrid (O) denotes open pollinated cultivar
( ) percentage of marketable yield.

Table 2: Mean yield and marketable fruit weight of 10 tomato cultivars planted on October 4, 1994 at Bobonong.

Cultivars	Mean marketable yield	Mean marketable fruit weight
	(t/ha)	(g)
Expresso (H)	80.1 (88.9)	121
Zest (H)	77.6 (87.9)	113
Sixpack (O)	68.5 (85.8)	79
Floradade (O)	66.2 (81.8)	121
Hotstuff (H)	63.7 (83.5)	129
Sunny (H)	62.4 (81.8)	138
Heinz 1370 (O)	61.9 (86.9)	97
Velox (O)	60.5 (83.8)	89
Money maker (O)	57.9 (91.2)	59
Red Khakhi (O)	45.4 (83.2)	102
Trial Mean	64.5	105
LDS (0.05)	18.32	14.0
SE	6.31	4.81
CV (%)	20	9

(H) denotes Hybrid (O) denotes open pollinated cultivar
( ) percentage of marketable yield

4.3 Cabbage (Brassica oleracea var Capitata)

4.3.1 Materials and Methods

Two cabbage cultivar trials composed of 11 and 12 cultivars were planted at Bobonong and Sebele on March 31 and July 13, 1994 respectively. A randomised complete block design with 4 replications was used. The trials were transplanted after seven and five weeks after planting. A basal application of 2:3:2 (22) at the rate of 1000 kg/ha was given.

The trials also received two top-dressing of Ammonium Sulphate at the rate of 325 kg/ha at four (4) and six (6) weeks after transplanting. The plants were spaced at 50 cm between the rows and within the row. Pest control was carried out whenever necessary.

The data were analyzed using the analysis of variance procedure (ANOVA). Differences between pairs of means were tested using LSD at the (0.05) level.

4.3.2 Results and Discussions

The performance of the varieties at Bobonong was generally poor due to, to infrequent (Table 3). K.K Cross, the standard summer cultivar produced the highest yields, but similar to most cultivars with exception of, Grandslam and Drumhead. The water stress seems to have affected head size since all the cultivars produced medium size heads,except of K.K. Cross with head weight of over 2.0 kg heads.

The maturity period was not significantly different among cultivars. At Sebele significant ($P<0.05$) yield differences were observed among cultivars (Table 4). The cultivar Transmark produced the highest yield but similar to Grandslam, Hercules, Big Cropper and Gloria. The cultivars Drumhead, Giant Drumhead and Conquistador have consistently produced the lowest yields. Mean head ranged from 1.4-1.9kg size. All cultivars matured at the same time (90 days).

4.4 Green Mealies (Zea mays)

4.4.1 Materials and Methods

Three green mealies cultivar trials were planted at Bobonong and Sebele. At Bobonong, two trials were planted on the 29th September and 24th October, 1994 consisting of fifteen (15) and thirteen (13) cultivars respectively. Thirteen (13) cultivars were planted on the 10th August, 1994 at Sebele. All the trials were laid out in a Randomized Complete Block Design with four (4) replications. The trials received a basal dressing of 500 kg/ha 2:3:2 and 300 kg/ha ammonium sulphate as top dressing. The plants were spaced at 75 cm and 30 cm between and within rows respectively in plots measuring 3m wide and 6m long.

The only pest identified to be causing damage was stalkborer and it was controlled with carbofuran at Sebele while at Bobonong alphamethrin was used.

Table 3: Mean yield and head weight and days to maturity cabbage cultivars at Bobonong.

Cultivar	Mean marketable yield	Mean head weight	Days to maturity after transplanting
	(t/ha)	(kg)	
K.K. Cross	60.6	2.05	106
Top most	60.2	1.66	106
Riana	56.1	1.82	106
Gloria	54.4	1.82	106
Hercules	53.7	1.67	106
Transmark	52.3	1.74	107
Greenstar	51.9	1.84	106
Big Cropper	49.7	1.82	106
Conquistador	48.5	1.76	106
Grandslam	44.0	1.62	106
Drumhead	42.2	1.82	131
Trial Mean	52.1	1.85	108
LSD	12.10	0.21	
SE	4.18	0.08	
CV	16.1	9.2	

( ) percentage of the marketable yield

Table 4: Mean yield and head weight and number of days after transplanting of 12 cabbage cultivars planted on July 13, 1994 at Sebele.

Cultivars	Mean yield	Mean head weight	No. of days after transplanting
	(t/ha)	(kg)	
Transmark	69.8	1.9	90
Grandslam	66.3	1.9	90
Hercules	64.2	1.8	90
Big Cropper	59.7	1.7	90
Gloria Kid	59.6	1.7	90
Topmost	56.6	1.6	90
Greenstar	56.2	1.6	90
Ofuji	51.0	1.6	90
Riana	50.6	1.5	90
Conquistador	40.9	1.6	94
Giant Drumhead	38.2	1.4	92
Drumhead	37.5	1.4	90
Trial Mean	54.2	1.6	91
LSD (5%)	12.79	0.22	-
SE	3.77	0.06	-
CV (%)	14	8	-

4.4.2 Results and Discussions

At Sebele, A1257W performed significantly better than the other cultivars with a mean yield of 6.3 t/ha while SR 52 and SC 701 gave the lowest yields which were significantly different from other cultivars (Table 5). The results also showed that a significant amount of the produce was unmarketable, this being attributed to stalkborer damage. The greatest damage was recorded on SR 52 and SC 701. The extent of the damage may suggest among other things that the pest control measure employed was not effective.

The mean yields of the two trials at Bobonong were 7.42 t/ha and 10.20 t/ha for the first and second plantings respectively (Table 6 and 7). The proportion of the marketable to the total cob number ranged from 75-95% in the 1st planting and from 92-98 in the second planting. The plants in the first trial took 90 days to harvest while the second took 82 days.

4.5 Onion (Allium cepa L.)

4.5.1 Materials and Methods

Two Onion cultivar trials composed of six cultivars namely, Granex 33, Texas Grano Pyramid, Brownsville and Hojem were planted on April 1 and 13, 1994. Both trials were transplanted at eight (8) weeks after planting. A Randomized Complete Block Design with four (4) replications was used. The trials received a basal fertilizer application of 2:3:2 (22) at the rate of 1000 kg/ha and were top-dressed with 300 kg/ha Sulphate of Ammonia. Onion spacing of 30 cm between the rows and 7.5 cm within the rows was used. Mercaptothion (Malathion) was used to control Onion thrips (*Thrip Tabacii*).

The data were analyzed using the analysis of variance procedure (ANOVA). Differences between pairs of means were tested using LSD at 0.05 significant level.

4.5.2 Results and Discussions

Significant yield differences ($P<0.05$) were observed among the cultivar in both trials (Table 8). In the first trial Brownsville significantly ($P<.05$) out-yielded Pyramid, while in the second trial it significantly out-yielded Hojem, Texas Grano and Pyramid.

The cultivar Pyramid produced significantly ($P<0.05$) lower bulb size compared to the other cultivars in both plantings. In the second planting (April 13) the cultivars Brownsville and Granex 33 produced significantly ($P<0.05$) larger bulbs. Lower yields and bulb size of the cultivar Pyramid could be attributed to early maturity.

Table 5: Performance of thirteen (13) maize cultivars planted on August 10, 1994 at Sebele.

Cultivar	Mkt yield
	(t/ha)
A 1257 W	6.3 (72)
AX 305 W	5.6 (75)
PNR 6428	5.6 (65)
PNR 6549	5.6 (68)
A 1305 W	5.2 (78)
SC 501	5.1 (57)
PNR 4403	4.9 (66)
R 215	4.6 (58)
KEP	4.4 (61)
ZS 225	4.2 (70)
PNR 6663	4.0 (64)
SC 701	1.5 (52)
SR 52	1.3 (50)
Mean	4.49
LSD (5%	3.8
CV (%)	2

( ) Marketable percentage

Table 6: Performance of fifteen (15) maize cultivars planted on September 29, 1994, at Bobonong.

Cultivar	Mkt yield (t/ha)	Days to maturity
PNR 6549	9.58 (85)	90
R215	9.05 (89)	90
PNR 6428	8.65 (88)	90
SC 501	8.40 (92)	90
ZS 225	8.08 (88)	90
A 1257 W	8.05 (95)	90
AX 305 W	7.70 (90)	90
PNR 4403	7.43 (94)	90
A 1305 W	7.28 (95)	90
KEP	7.13 (94)	90
SR52	6.78 (77)	92
PNR6671	6.33 (88)	90
SC 701	5.80 (75)	90
PNR 6663	5.78 (88)	90
PNR 6463	5.30 (80)	90
Mean	7.42	90
LSD (5%)	2.04	
CV (%)	19	

( ) Marketable percentage

Table 7: Performance of thirteen (13) maize cultivars planted on the 24th October, 1994 at Bobonong

Cultivar	Mkt yield	Days to maturity
	(t/ha)	82
AX 305 W	13.68 (93)	82
R215	13.45 (93)	82
PNR4403	13.15 (94)	82
SC 501	12.20 (93)	82
PNR 6549	10.65 (92)	82
PNR 6428	10.38 (89)	82
SC 701	9.10 (72)	82
KEP	8.65 (86)	82
PNR6463	8.35 (87)	82
SR 52	8.10 (98)	82
A 1305 W	7.88 (97)	82
PNR 6671	7.38 (90)	82
PNR 6663	7.03 (87)	82
Mean	10.2 (90)	82
LSD (5%)	4.01	-
CV (%)	28	-

Table 8: Mean Yield (t/ha) of Onion cultivars planted on April 1 and 13 in 1994, at Bobonong.

Cultivars	01-04-94	13-04-94	Mean
	t/ha	t/ha	t/ha
Brownsville	86.3	73.7	80.0
Hojem	82.1	53.7	67.9
Texas Grano	75.0	55.9	65.5
Granex 33	71.1	72.0	71.6
Pyramid	47.4	55.1	56.3
Trial Mean	74.4	62.1	68.3
LSD (0.05)	26.78	16.06	-
SE	8.68	5.21	-
CV (%)	24.42	16.78	-

Table 9: Mean Bulb Weight and days to maturity of Onion cultivars planted on April 1 and 2 at Bobonong in 1994.

Cultivar	Mean bulb weight		Maturity days	
	April 1	April 13	April 1	April 13
Brownsville	272	228	163	155
Hojem	239	179	149	125
Texas Grano	235	178	163	153
Granex 33	237	216	135	125
Pyramid	156	128	122	116
Trial Mean	228	186	146	134
LSD (0.05)	64.17	22.14	-	-
SE	20.82	7.18	-	-
CV %	19.02	7.74	-	-

4.6 Onion collaborative trials

Collaborative work on short-day tropical Onion cultivars for early maturity, bolting resistance, high yielding potential and shelf-life evaluation is continuing with Horticultural Research Interational and Natural Research Institute of the United Kingdom. The studies are expected to identify superior cultivars in these atributes.

4.6.1 Materials and Methods

4.6.1.1 Field Trial

Two Onion cultivar trials constisting of 23 cultivars were planted on March 3, and 31, 1994 at Sebele. The seedlings were transplanted to the field after seven weeks. A randomised complete Block Design with three (3) replications was used. The trials received a basal application of 2:3:2 (22) at the rate of 1000 kg/ha and top-dressed with 300 kg/ha of Sulphate of Ammonia at six (6) weeks after transplanting. Onion spacing of 30 cm between the rows and 7.5 cm within the row was used. Marcaptothion (Malathion) was used to control Onion thrips (*Thrip tabaii*). The data were analyzed using the analysis of variance procedure (ANOVA). Differences between pairs of means were tested using LSD at the (0.05) level.

4.6.1.2 Storage trial

Twenty two short-day Onion cultivars were evaluated for storage life under ambient temperatures. A total of 180 bulbs per cultivar were selected to be used in the study. Samples of 60 bulbs were picked from each cultivar and placed in 15 cm x 15 cm x 60 cm black chicken freezing crates with all sides perforated to allow free air circulation. The bulbs were weighed to determine the initial weight. The trial started on October 25, 1994 and continued until May 24, 1995.

The trial was arranged in Randomized Complete Block Design with three replicates. The crates were stacked on top of each other in three layers, each layer making up a replicate. The bulbs were inspected every 2 weeks and at each inspection the weight and number of sound, rotten, sprouted and *Aspergillus niger* (Black Mold) infected bulbs as recorded. All the bulbs that were considered unmarketable were discarded.

4.6.2 Results and Discussions

4.6.2.1 Field trial

The yields in the first planting were low due to a high percentage of bolting. Some cultivars produced over 50 percent bolters thus affecting overall yield since such bulbs are unmarketable. Bolters are onion plants that produce a flower stalk instead of a proper bulb.

In the 1st planting the cultivar Savanna Sweet produced the highest yield, probably attributable to a combination of low bolting percentage and large bulb size.

However, the yields were not significantly (P>0.05) different from the cultivars Rio Ringo, Sivan, Superex, Granex 33, Mr Max and Rio Bravo.

The cultivar Rio Blanco Grande produced the highest bolting percentage which was not significantly (P>0.05) different from that of Bon Accord, Equanex, Glandalon Brown and Arad. In the second planting the cultivar Superex produced the highest yields although it was similar to Equanex. Good performance by the two cultivars could be attributed to large bulb size. The cultivar Bon Accord produced significantly (P<0.05) lower yields.

Conclusion

Planting time of Onions is critical to achieving high yields. It has been demonstrated there is variability for bolting resistance and selection for this matter is possible. Selection of the cultivar and planting time therefore cannot be divorced from one another as both can result in low yields or crop losses to the farmer. For good yields the choice of cultivar and planting time is important.

4.6.2.2 Storage trial

The total weight loss varied significantly among cultivars at most dates recorded (Table 12). The cultivars Gladalan Brown, Mr Max, supply and Granex 33, had the fastest weight loss (Fig.1). These cultivars lost 50% of their original weight in less than 71 days in storage compared to Sivan and H-226 which took 133 days (19 weeks). The standard recommended cultivars grown in Botswana performed poorly, with Pyramid losing 56% of its original weight in 71 days, 62 days less than sivan and H-226. However, Bon Accord a recommended cultivar lost 50% weight in 119 days (17 weeks) and compared favourably to sivan and H-226.

Figure 2 shows that Granex 33 and Pyramid experienced sharp increases in cumulative rots weight starting from 40 days compared to Sivan and H-226. At 90 days Granex 33 had lost 11 kg of its weight through rotting while Pyramid, Arad, Texas Grano, Sivan and H-226 lost 6.0, 4.0, 2.0, 1.0 and 0.4 kg respectively. Figure 3 shows a cumulative weight loss of the six cultivars resulting from A. niger, Granex 33 and Pyramid were the worst affected, compared to H-226, Sivan and Arad.

Conclusion

The study has demonstrated that onion cultivars with longer storage life exist and that contribution of disease infection, to total weight loss vary among the cultivars.

Table 10: Mean yield and Bulb weight of Onion cultivars planted at Sebele in 1994.

Cultivar	Seed Company	Time of planting			
		March 3		March 31	
		yield (t/ha)	Bulb weight (g)	yield (t/ha)	Bulb weight (g)
Savannah Sweet (H)	PS	77.1	282	70.2	173
Rio Ringo (H)	RC	77.0	267	64.6	164
Sivan (H)	HZ	74.9	239	67.0	179
Superex (H)	TK	73.2	284	89.3	206
Granex 33 (H)	AS	72.7	274	-	-
Mr Max (H)	RC	69.9	220	70.4	183
Rio Bravo (H)	RC	67.5	233	70.8	169
Early Lockyer Brown	YA	51.3	167	49.6	144
Namex BR 1	RC	47.0	228	55.7	161
Galil/ Grandstand (H)	HZ	45.8	187	74.0	189
El Ad/Nissan (H)	HZ	45.6	220	63.6	180
Ori	RC	44.6	175	50.2	137
Supply	YA	43.7	209	48.4	157
Texas Grano 502 PRR	SA	43.4	248	48.1	134
Equanex (H)	PS	43.0	267	78.9	190
Arad (H)	HZ	40.8	234	56.5	171
Gladalan Brown	YA	37.3	240	65.7	218
Yodalef	HZ	35.4	143	44.5	142
H-226 (H)	HZ	34.7	160	42.2	112
Bon Accord	-	25.3	200	28.7	114
Rio Blanco Grande	RC	21.5	172	52.7	155
Hojem	MF	-	-	55.2	161
Pyramid	SA	-	-	59.3	150
Trial Mean		51.0	221	59.4	164
LSD (0.05)		18.65	45.6	10.77	33.3
SE		6.59	16.09	3.81	11.77
CV (%)		26	15	14	14

H - denotes Hybrid

Table 11: Mean bolting percentage of Onion cultivars planted on March 3, 1994 at Sebele.

Cultivars	Bolting (%)
Rio Blanco Grande	69.4
Bon Accord	60.3
Equanex	58.3
Gladalon Brown	54.8
Arad	49.0
Texas Grano 502 PRR	45.4
Supply	41.6
H-226	39.9
Galil/Grandstand	35.1
Granex 33	31.2
Namer BR-1	30.3
El Ad/Nissan	29.0
Savannah Sweet	25.8
Rio Bravo	25.1
Superex	24.2
Rio Ringo	19.5
Sivan	18.4
Mr. Max	17.9
Early Lockyer Brown	1.7
Oni	0.7
Yodalef	0.0
Trial Mean	32.3
LSD (0.05)	18.22
SE	6.44
CV (%)	40

Table 12: Percentage of Original Weight Remaining over the Storage Period (days) form October 25th to May 24,1995

	No of days from beggining of storage																
Cultivar	0	20	34	41	56	71	83	92	105	119	133	147	161	175	195	211	Number of days at which 50% of onions were unmarketable
Gaul/Grandstand	100	97	92	90	85	79	72	60	55	49	46	35	26	15	9	3	117
Rio Ringo	100	94	92	88	82	69	60	42	38	35	28	17	9	6	1	0	88
Superex	100	96	91	85	76	55	41	29	24	13	8	3	0	0	0	0	73
Granex 33	100	96	91	89	69	49	43	29	23	15	10	7	2	2	0	0	68
Equanex	100	95	88	79	72	56	46	34	29	19	17	11	3	2	0	0	50
Rio Blanco Grande	100	95	90	87	81	64	54	45	39	32	21	10	3	2	1	0	76
Numerex BR-1	100	95	90	87	77	70	62	51	40	35	23	13	6	3	1	0	92
Savannah Sweet	100	95	93	89	81	66	58	50	39	29	20	11	3	1	0	0	92
Rio Bravo	100	98	95	92	86	69	60	50	40	30	20	11	6	2	0	0	92
H-226	100	98	95	90	84	76	73	67	61	57	50	39	36	12	0	0	133
Yodalef	100	97	93	90	83	58	50	35	31	25	21	11	6	3	1	0	83
EL Add/Nissan	100	97	94	89	83	75	70	53	50	41	35	25	10	7	2	1	105
Ori	100	97	88	83	72	50	43	29	25	20	11	4	2	1	0	0	71
Supply	100	96	93	87	67	48	41	30	21	16	13	10	5	3	2	0	50
Sivan	100	98	95	93	88	78	72	68	65	58	50	36	21	14	5	1	133
Texas Grano 502 PRR	100	97	90	87	81	61	54	47	41	34	29	17	12	6	1	0	86
Bon Accord	100	95	93	91	85	80	72	65	60	49	42	32	22	17	6	0	106
Early locker Brown	100	96	93	92	85	79	71	60	53	48	39	31	24	18	6	2	112
Arad	100	96	92	88	83	74	67	52	44	39	33	22	12	8	1	0	90
Gladalan Brown	100	91	80	70	60	40	32	23	18	14	11	5	3	2	0	0	63
Mr Max	100	95	88	78	64	48	39	30	26	21	14	6	2	1	0	0	63
Pyramid	100	96	94	90	69	56	45	32	26	18	13	4	0	0	0	0	76

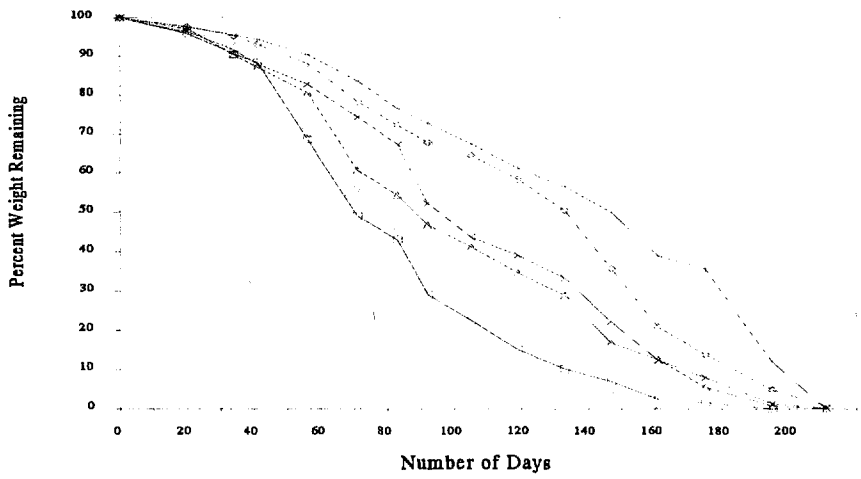

Fig 1. Marketable Weight Loss over storage period

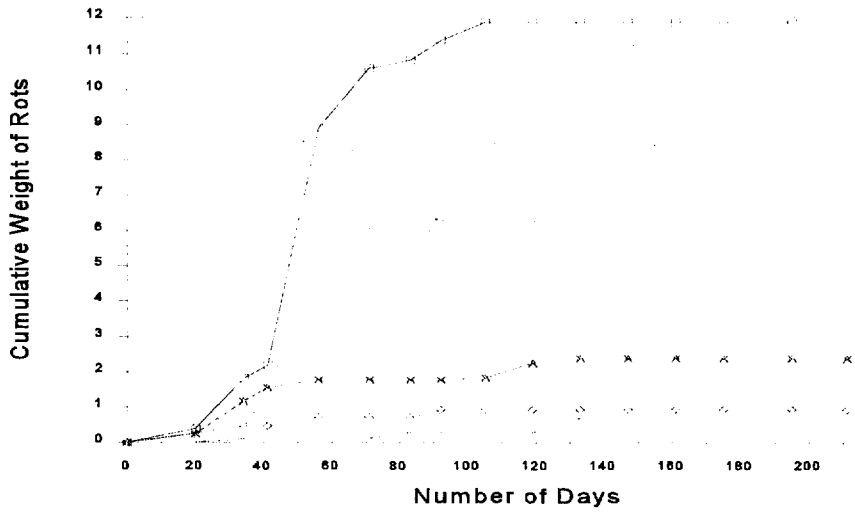

Fig. 2 Cumulative weight of rots over storage period

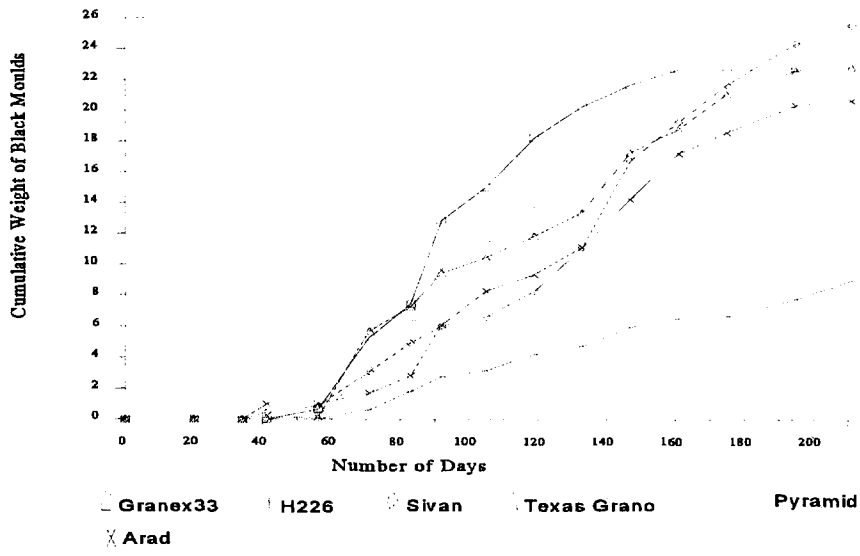

Fig.3 Cumulative weight loss to Black Moulds over storage period

4.7 Comparative efficacy of control methods for root-knot nematodes, meloidogyne spp. On tomato, *lycopersicon esculentum*

4.7.1 Introduction

Based on disease and pest surveys, root-knot nematodes, Meloidogyne spp. have been found to cause substantial damage on vegetable crops especially tomatoes. With the introduction of concrete benches, this problem has become even more serious as the sand is an ideal media for nematode multiplication.

Although nematicides have been proved to be effective in controlling these pests, the average Motswana vegetable grower cannot afford these chemicals especially since the low scale production results in a small profit margin. Organic amendments like kraal and chicken manure have been found to be effective in reducing nematode populations in infested soil subsequently increasing crop yield (3,4). Kraal manure is recommended as a cheap source of nutrients in vegetable production and it is fairly easy to obtain. In urban and peri-urban areas chicken manure is also readily available.

The current study was undertaken to investigate the effect these organic amendments might have on nematode control and how such control methods compare with the recommended nematicide treatment.

4.7.2 Materials and Methods

The experiment was conducted on concrete benches and in pots in the greenhouse.

a) Concrete Bench Study

Inoculum was first raised by infesting non amended sand in the concrete benches with fragmented galled spinach roots. Six-week old tomato seedlings were transplanted into the benches and allowed to grow for 2 months during which time the nematode population was expected to increase. After the above period the tops of the tomato plants were chopped off and the roots mixed throughout the plot by cultivating with a digging fork. The plots were left undisturbed for one week during which time they were kept watered. Each concrete bench was subdivided into 8 subsections using permanent moulded bricks, such that each plot measured 2.5 m and 1.0 m in length and diameter respectively.

The following treatments were applied individually per plot:-

A. Kraal Manure at 6 kg/m^2 (3o tons/hectare)

B. Kraal Manure at 4 kg/m^2 (20 tons/hectare)

C. Kraal Manure at 2 kg/m^2 (10 tons/hectare)

D. Chicken Manure at 3 kg/m^2 (15 tons/hectare)

E. Chicken Manure at 1.5 kg/m^2 (7.5 tons/hectare)

F. Nemacur applied at 2.5 ml/linear metre.

G. Control (no soil amendment)

Prior to application of the treatments soil samples were collected from each subplot by sampling 8-10 cores randomly throughout the plot to estimate the initial population of the nematodes per plot. 500 cm^3 aliquots were taken from each sample and were processed using the combined sieving and centrifugation technique (1). Root fragments from the soil samples were put on double layers of kleenex tissue placed on wiremesh screens resting in a bowl with the water slightly above the screen. After 48 hours the nematodes were collected from the bowl by sieving. The estimation method relied on counting of the hatched infective juveniles (J2 larvae).

A day after applying the treatments, 6 week old tomato seedlings cv. Floradade were transplanted into 2 rows, with a plant spacing of 60 cm between the rows and 40 cm within the row, resulting in 12 plants per plot.

Six weeks (27/03/1995) after transplanting the tomatoes, soil samples were collected to determine the mid-season nematode population. Sampling was done by collecting soil cores using an auger at the root zone of individual plants and composting such cores before processing.

Harvesting of tomatoes commenced on 02/05/1995 and continued through to 30/05/1995 when the final soil samples were collected to determine the end of season populations. Galling indices were also modified to a 1-4 scale (Appendix 1) as below:-

0 = No knots on roots

1 = Few small knots visible

2 = Several large knots visible but main roots clean

3 = 50% of root system with knots

4 = Majority of main roots knotted with reduced root system.

b) Greenhouse Study

Plastic pots of 20.4 cm diameter and 15 cm height were filled with steam sterilised sand mixed with chicken or kraal manure
as below:-

A. 20 g kraal manure per litre of sand (equivalent to 4 kg/m^2)

B. 10 g kraal manure per litre of sand (equivalent to 2 kg/m^2)

C. 15 g chicken manure per litre of sand (equivalent to 3 kg/m^2)

D. 7.5 g chicken manure per litre of sand (equivalent to 1.5 kg/m^2

E. 100% sand with no organic amendment.

5g of 2:3:2: NPK fertiliser per pot was added to the 100% sand treatment while 2.5 g of the same fertilizer was added to the pots with amended mixtures.

Each treatment was replicated 12 times.

Six weeks old tomato seedlings cv. Floradade were transplanted into above pots. Half of the pots in each treatment were inoculated with root-knot nematode eggs extracted from galled tomato roots by agitation and centrifugation (5). The eggs were suspended in distilled water and 5 ml (2875 eggs) were delivered into three small holes made (close to the roots) around each seedling.

The pots were arranged in the greenhouse in a randomised block design with separation of the inoculated and uninoculated pots to minimize contamination.

The plants were allowed to grow for two months after which time the fruits were harvested, counted and weighed. Fresh and dry shoot weights, and fresh root weight were measured.

Galling indices were determined as in the concrete benches experiment.

4.7.3 Results and Discussion

The results for both the concrete benches and the greenhouse experiments are presented in Tables 1 and 2 respectively.

a) Concrete Bench Study

Although precautions were taken to ensure uniform initial populations in the concrete benches these ended up being somewhat different, ranging from 360 to 5275 nematodes per 500 cm^3 of soil (Table 1). It was therefore logical to base comparisons on the effect the individual treatments had on the population build up.

The highest final stand was observed on the high rate (7.5 g/litre) of chicken manure and this was only significantly different from the control. It is believed that the plant stand was low on the plots due to early death of plants severely infected by the root-knot nematode. In fact when such plants were uprooted numerous white females could be seen on decomposed roots. This was true for all the other plants that had died in all the other treatments except nemacur where plants experienced some initial phytotoxicity leading to fatal transplant shock. The low yield on the nemacur treated plots must have resulted from above.

By mid-season there was a general population decline in all treatments except the intermediate kraal manure and the control (Table 1). This trend was expected for the control even though the populations were not the highest possibly due to non-recovery from dead plants. The results for the intermediate kraal manure treatment cannot be logically explained. The lowest mid-season population was on the higher rate of chicken manure and this coincidentally gave the highest yield (fruit weight). At final harvest the decline from mid-season population was only evident on the kraal manure treatments, the other treatments including the control having an increase in population. The increase on the nemacur treatment was however only marginal and the increase on the kraal manure treatments could suggest a prolonged residual effect of the treatment.

On the contrary the increase in nematode population on the chicken manure and nemacur treatments could mean a shorter residual effect. In a similar study in Nigeria it was also observed that nematode population on poultry manure treatment increased at harvest after a sharp decline at mid-season (3).

Greenhouse Study

In the greenhouse the highest final population was achieved on the two kraal manure treatments with the higher rate supporting a higher population (Table 2). Due to high variability in the counts there were no significant differences in the populations among the treatments. The population trend in the control pots was somehow unexpected since it is even lower than the initial population.

The lowest galling index was found on the higher rate of chicken manure and this was significantly different from the kraal manure and control treatments. This low index coincided with the lowest final population but there was no resulting yield (fruit weight) advantage of this treatment over the others.

Fresh and dry shoot weights in the control were significantly lower than all the manure treatments but this might be due to better nutritional status in the latter.

The lowest root weight was observed on the control treatment and this was similar to those for the chicken manure treatments but was significantly lower than those for the kraal manure treatments.

Overall when the inoculated and uninoculated pots within the same treatment were compared for fruit yield it is apparent that the uninoculated pots performed better.

Therefore, even though there seems to be no apparent effect of the individual treatments on yield parameters the effect of the nematode infestation was slightly manifested. A possible explanation could be that the level of inoculum used was not high enough to induce damage that would result in economic yield loss.

The experiment will be repeated using higher rates of manure. Preliminary pathogenicity tests will also have to be done to determine the optimum levels required to induce damage.

Table 1: Effect of soil amendments with chicken or kraal manure, and nematicide on yield of tomato cv. Floradade and development of root-knot nematode in concrete benches.

			Nematode population			
Treatment *	Stand	Yield	Initial	Mid season	Final	Call Index
Kraal Manure (2)	7.5^{ab}	1767^{b}	1992	1856^{abc}	1700	3.28^{ab}
Kraal Manure (4)	10.0^{ab}	1450^{b}	775	2984^{ab}	1880	3.30^{ab}
Kraal Manure (6)	9.5^{ab}	4157^{b}	5275	3592^{a}	1670	3.51^{ab}
Chicken Manure (1.5)	10.5^{ab}	3484^{b}	360	128^{c}	1045	3.02^{abc}
Chicken Manure (3)	11.5^{a}	7680^{a}	426	44^{c}	7860	2.58^{bc}
Nemacur	9.0^{ab}	2800^{b}	3705	220^{c}	260	2.07^{c}
Control	6.0^{b}	908^{b}	1156	1348^{bc}	1820	3.64^{a}
LSD (0.05)			ns		ns	

* Figures in parenthesis indicate the rates, in kg/m^2.
Figures followed by the same letter within a column are not significantly different at 0.05 level of probability.

Table 2: Effect of soil amendments with chicken and kraal manure on yield of tomato cv Floradade and nematode control in the greenhouse.

Treatments *	Fruits		Shoot weight			Nematode Control	
	No.	Wt	Fresh	Dry	Root wt.	Gall	Pop.
Kraal (20)							
Inoc.	5	115.5	90.6[bc]	17.5[b]	51.3[b]	2.67[a]	9881
Control	5	127.0	81.5[b]	16.6[b]	36.4[ab]	-	-
Kraal (10)							
Inoc.	4	128.3	87.5[bc]	16.0[b]	50.3[b]	2.5[a]	7579
Control	6	157.3	90.9[bc]	18.8[bc]	46.5[ab]	-	-
Chicken (15)							
Inoc.	5	111.0	79.5[bc]	16.6[b]	47.5[ab]	1.67[b]	1793
Control	5	132.4	97.8[bc]	19.4[bc]	47.7[b]	-	-
Chicken (7.5)							
Inoc.	5	116.2	76.1[b]	16.3[b]	45.3[ab]	2.0[ab]	6495
Control	5	157.4	86.2[bc]	17.9[bc]	29.2[a]	-	-
Sand							
Inoc.	5	118.0	51.8[a]	11.1[a]	30.4[a]	2.5[a]	2685
Control	6	143.6	48.5[a]	10.8[a]	28.9[a]	-	-
LSD (0.05)	ns	ns	13.09	2.78	18.09		ns

* Figures in parenthesis indicate amount of manure per litre of sand.
Figures followed by the same letter within a column are not significantly different at 0.05 level of probability.

4.7.4 Conclusions

Nemacur was the most effective method of control as evidenced by the lowest galling index and lowest final population in the concrete bench experiment.

In both experiments the chicken manure treatment gave the lowest galling index suggesting a more effective control than the kraal manure.

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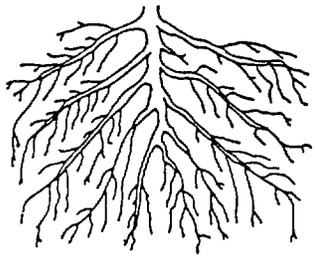
Root-knot Rating Chart



0 No knots on roots

1 Few small knots visible

2 Several large large knots visible
but main roots clean

3 50% of root system with knots

4 Majority of main roots knotted
with reduced root system

5.0 SOIL/WATER MANAGEMENT AND AGRICULTURAL ENGINEERING PROGRAMME

5.1 Small Tractor Evaluations

5.1.1 Introduction

Small scale arable agriculture in Botswana is still dominated by the use of animal draft power, which is also characterised by a variety of problems namely: slow work rate, delayed time of ploughing due to poor condition of animals, untimeliness of operations, poor depth of ploughing and other problems associated with team training.

The new Agricultural Policy recognizes that tractor draft power is uneconomic because of high capital and maintenance costs and that animal draft power will therefore continue to be used by the majority of arable farmers. It however states that investigations into smaller possibly more economic tractors should be carried out for draft capability and suitability to work in Botswana. The objectives of this evaluation was therefore to determine draft capability and suitability of the Daedong 22Hp tractor.

5.1.2 Materials and Methods

For the 1994/95 cropping season of the eight tractors donated by the South Korean Government data was received from only the Farm Machinery Development Unit (FMDU) tractor. For the other tractors data was either not collected or the tractors were not used. The tractor was allowed to plough as much land as possible, so that the durability question could be answered.

Farmers were selected at random, depending on rainfall one hectare was ploughed for each farmer free of charge.

Data on the following variables was collected:

i) Time taken to plough a hectare
ii) Amount of fuel used in ploughing a hectare
iii) Amount of oil used in ploughing a hectare

5.1.3 Results and Discussion

The tractor ploughed a total of 40.5 ha this season, which was the biggest area yet ploughed by any of the tractors. A relatively high work rate of 3.19 hrs/ha and a fuel consumption rate of 12.54 l/ha were achieved. For the first time, oil consumption was high reaching at 1.46 l/ha (Table 1). On the whole the tractor performed better than previous seasons i.e average work rate of 4.6 hrs/ha and fuel consumption rate of 13.4 l/ha (Annual Report 1994). Oil consumption however increased considerably and this could indicate that the engine was beginning to be strained at only 600 hrs. Observations also indicate that oil flowed through the manifold and got burnt within the exhaust pipe. Whether valve leakage or damaged rings were to blame was not ascertained.

Table 1: Means of ploughing trials at Sebele (1994/95)

Soil type	Various
Area ploughed (ha)	40.5
Time taken (hrs)	129.1
Rate of work ha/hr (Hrs/ha)	3.19
Fuel used (l)	507.7
Rate of fuel used l/ha	12.54
Total oil used (l)	59.3
Rate of oil consumption	1.46

5.1.4 Conclusions

The fact that the tractor had done only 600 hrs and already oil consumption was high calls for thorough examination of the tractor by expects so that the causes can be ascertained.

5.2 Evaluation of two row planter prototypes

5.2.1 Introduction

Row planting has been a standing recommendation for a long time now, but though not adequately documented, availability of row planters particularly two row, most of which are imported has inhibited adoption of this recommendation. These planters are expensive and without adequate backup service and supply of spare parts. Single row planters on the other hand are slow in doing the work and farmers have also openly advocated and requested for two row planters to be made available.

Government subsidies on row planting has encouraged farmers to try and this has resulted in increased demand for two row planters. There is therefore a need to develop and/or fabricate two row planters locally.

The Farm Machinery Development Unit and Rural Industries Innovation Centre have developed two and one prototypes respectively, whilst Soilmaster of South Africa developed the fourth prototype (Annual Report 1994, for brief descriptions). The objectives of the evaluation were to compare the four two row prototypes to the S90 planter for planting efficiency, ease of operation and presence of general design faults.

5.2.2 Materials and Methods

Five planters namely: Modified S90, Farm Machinery Development Unit (FMDU), Soilmaster, Rural Industries Innovation Centre (RIIC) and S90 were used in plots 190m long and 12m wide for two plantings on sorghum and 95m long and 10m wide on one planting for maize. During the first sorghum planting, the RIIC planter had not arrived and was therefore only used on the second sorghum and maize plantings. The amount of seed used was determined by weighing seed before and after planting. Together with 1000 seed weights the figures were used to determine expected plant populations.

5.2.3 Results and Discussion

All the five planters were calibrated to give higher than normal rates taking into consideration the experiences of the previous year, when very low plant populations were recorded (Tables 1, 2 and 3). Despite these high rates the first planting recorded only about 20% emergence (Table 1). For the first planting, low moisture, together with high temperatures could still have been responsible for the low emergence. Less than 20mm was recorded within one month of the first planting. The second planting of sorghum had 30mm in the 1st month and achieved less than 10% emergence for all planters (Table 2).

The last planting which was for the maize achieved emergence ranging from 58% for the RIIC planter to 99% for the S90 planter (Table 3). For this planting rainfall was adequate as the planting followed a 22mm rainfall which was followed one week later by 50mm. For this year, good moisture was partly responsible, but in the future seed size and planting depth should be considered.

On ease of operation, all planters gave few or no problems. The RIIC planter whicht is still animal drawn still has to be engaged and disengaged at the head lands, was therefore evaluated. The following observations were made on the planter;

i) Seed continues to be prevented from leaving the delivery chute/spout, particularly if planting is carried out on soil with high moisture content. Previous recommendation was that the delivery chute should be cut at an angle. This has still not been done.

ii) The latest prototype shows that some modifications were made to the 50 x 50mm angle iron which carries the lower seed and fertilizer hoppers. A 35mm flat bar was welded on top of the angle iron. This modification is a disadvantage since the flat bar blocks the view to the seed delivery system and to the seed coming out of the lower hopper onto the seed delivery chute/spout.

iii) Usually the seed plate type used in this planter is secured at the centre, with a small stopper on the outside of the plate. For this prototype the reverse is true and this allows the plate to tilt towards the fastening nut, and hence allows seed to exit from several points.

iv) The seed plates were not numbered and this lead to difficulty in selecting correct hole sizes. All seed plates should be correctly numbered.

v) The lower seed hoppers have 6mm holes meant for holding the upper hoppers. These holes were not used, because the two hoppers were instead joined together by a small weld. These holes be closed as a lot of seed, and hence expected plant populations were not recorded for the RIIC planter on the second sorghum planting.

Table 1: Mean plant populations for sorghum planted on 17-01-95 (expected and observed)

Planter used	Amount of seed used (kg/ha)	Expected population (plants/ha)	Observed population (plants/ha)	Percentage emergence
S90	1.03	39,770	5,913	14.8
Modified S90	2.82	108,938	13,111	12.0
FMDU	1.48	57,063	7,749	13.6
Soilmaster	2.24	86,458	21,118	24.4
RIIC	-	-	-	-

Table 2: Mean plant populations for sorghum planted on 02/02/95 (expected and observed)

Planter used	Amount of seed used (kg/ha)	Expected population (plants/ha)	Observed population (plants/ha)	Percentage emergence
S90	4.21	167,728	9,361	5.6
Modified S90	2.82	112,396	6,847	6.1
FMDU	1.95	77,813	6,166	7.9
Soilmaster	1.30	51,875	2,333	4.5
RIIC	Seed coming out of extra opening	-	5,263	

Table 3: Mean plant populations for maize planted on 24-02/95 (expected and observed)

Planter used	Amount of seed used (kg/ha)	Expected population (plants/ha)	Observed population (plants/ha)	Percentage emergence
S90	8.1	21,003	20,778	98.9
Modified S90	16.3	42,279	25,894	61.2
FMDU	24.2	62,738	56,673	90.3
Soilmaster	15.3	39,552	37,157	93.9
RIIC	16.8	43,643	25,368	58.1

5.2.4 Conclusions

All the four prototypes have potential for development, particularly the RIIC planter which is animal drawn. In future these planters should be exposed to the opinion of farmers.

5.3 Determination of the effectiveness of conically shaped ridges in deep ripping

5.3.1 Introduction

Between 1988 and 1992 the Department of Agricultural Research (DAR) evaluated several tillage systems (deep ripping, double ploughing, plough and cultivate and the conventional system) to determine the one which provides the optimum environment for the highest production of cereal crops. Of these systems, the deep rip gave the lowest yields. Despite these results, the proponents of this system, which is assumed to harvest rain water, attributed its failure to poor formation of the conically shaped ridges in between the rip lines meant to direct water into them. This study was done to determine if the conically shaped ridges enhanced the collection of rain water onto the rip lines.

5.3.2 Materials and Methodology

The following three treatments were evaluated:-

a) deep ripping with ridges (T2)
b) deep ripping without ridges (T3)
c) the conventional system of mouldboard ploughing and row planting on day of ploughing (T1)

Neutron probes were used to measure available moisture on daily basis on the three treatments.

No changes were made to both location, treatments and replications. (Annual Report 1994 for treatment details). Ripping was carried out during August in anticipation of early rains leading to an October planting, but adequate rain for planting only came in late December. Ploughing and planting was therefore done in January.

Data was to be collected on the following varieties:

i) Days to 50% flowering (silking and pollen formation)
ii) Plant height after tasselling
iii) Yield

5.3.3 Results and Discussions

Crop stand establishment was poor due to late virus and high temperatures. No moisture measurements using Neutron probes were taken.

Only fresh cob yield was measured but no data analysis done (Table 1).

Table 1: Average fresh cob yield of maize on three different treatments (kg/ha)

Treatment	Fresh cob yield (kg/ha)
T1	972.86
T2	228.00
T3	731.25

5.3.4 Conclusion

The results are inconclusive as the experiment was patchy.

5.4 Evaluation of Rutec Push Planter

5.4.1 Introduction

The Rutec Push Planter is human powered and manufactured by Rutec in South Africa. It uses the vertical rotating plate seed metering system, which is driven by a chain from a pneumatic tyre and drops seeds by gravity.

The earliest source of farm power was human and it continues to be important (Kaul & Egbo 1985). However, Agricultural Mechanization in Botswana is dominated by the use of animal draught power which has a multiple of disadvantages.

The rate of work of animals is slow and they are also prone to drought effects which further undermine their working ability. Tractors on the other hand are unaffordable to most of small holder farmers and few in number.

Planting depth and seed distribution greatly affect the yield of a crop. Therefore, with proper planting devices most Botswana farmers may produce enough for their subsistence needs even from their backyards. It is in light of this that the Production System Programme (PSP) of the Department of Agricultural Research (DAR) identified the Rutec Push Planter for evaluation. This evaluation was subsequently carried out by the Farm Machinery Development Unit (FMDU) of Department of Agricultural Research.

The objectives of this trial were to:-

i) Determine the planting efficiency of the planter.

ii) Assess its ease of operation.

iii) Identify any operational problems.

5.4.2 Materials and Methods

One push planter (plate 1) was purchased from Rutec in South Africa.

Plastic seed plates for sorghum (4 and 10 holes) and maize (4 and 6 holes). The planter was subjected to a workshop test where it was suspended on a stand, with the seedhopper filled and the drive wheel rotated 10 times. The test was repeted 10 times. The number of seeds dropped was recorded.

The planter was used to plant 2565 square metres of maize and 712 square metres of sorghum in the field. The pushing was done by 8 people alternately, out of which only one was a woman.

The amount of seed dropped was measured by weighing seed before and after planting. The time it took a person to push the planter a complete revolution or a distance of 190 m was also recorded. Plant counts were made 2 weeks after planting.

5.4.3 Results and Discussion

The results of the laboratory test and field experiment are presented in Table 1 below.

Table 1: Mean plant populations for sorghum and maize (expected and observed)

Crop	Number of holes on seed plate	Mean number of seed dropped (ha/)	Mean plant population expected (Plants/ha)	Mean plant population observed (Plants/ha)
Maize	4	36,378	18,185	4,982
	6	54,567	93,766	24,719
Sorghum	4	48,504	45,156	3,321
	10	121,261	101,566	13,590

The observed plant populations were less than half the expected plant population for both maize and sorghum (Table 1). The expected plant population in the field was at least 50% quite good of the number of seed dropped unde lab conditions. In case of maize using the 6 hole seed plate, the number of seeds planted was 72% than the number of seed dropped in the laboratory (54,567). This suggests that emergence could have been affected by other factors such as high temperatures. The seed coverage was considered adequate.

Other observations made were that generally it was difficult to push the planter on ploughed land and on uneven soil surface with large clods. It took an average of eight (8) minutes to push the planter along a row of 190 metres. This translates into 9.2 hrs to plant a hectare, a rate which is low compared to other sources of draft power; 5.6 and 6.3 hrs/ha for oxen and donkeys pulling a single row planter respectively (Evaluation of Farming Systems and Agricultural Implements Project report No. 4 1979/80).

In practical terms the 9.2 hrs/ha recorded is conservative because each of the people who pushed the planter were all exhausted after only 2 to 4 rounds of pushing. The only lady out of a team of eight people who used the planter experienced even more difficulties pushing the planter.

5.4.4 Conclusion

The observed plant population was too low compared to the expected. This could have been a result of any of the several reasons. Each of these reasons have to be eliminated to find the solution to the problem. The planter was found to be difficult to push, and it also took a long time to plant a given area, and the work was exhausting.

Recommendations

More plantings have to be made using the planter, and using seeds which have a higher potency of 97 - 100% germination. Treated seeds which have also been dressed with chemical have to be used to eliminate possibility of soil pests. More people, should use the planter so that a wider opinion on the suitability of this planter is found.

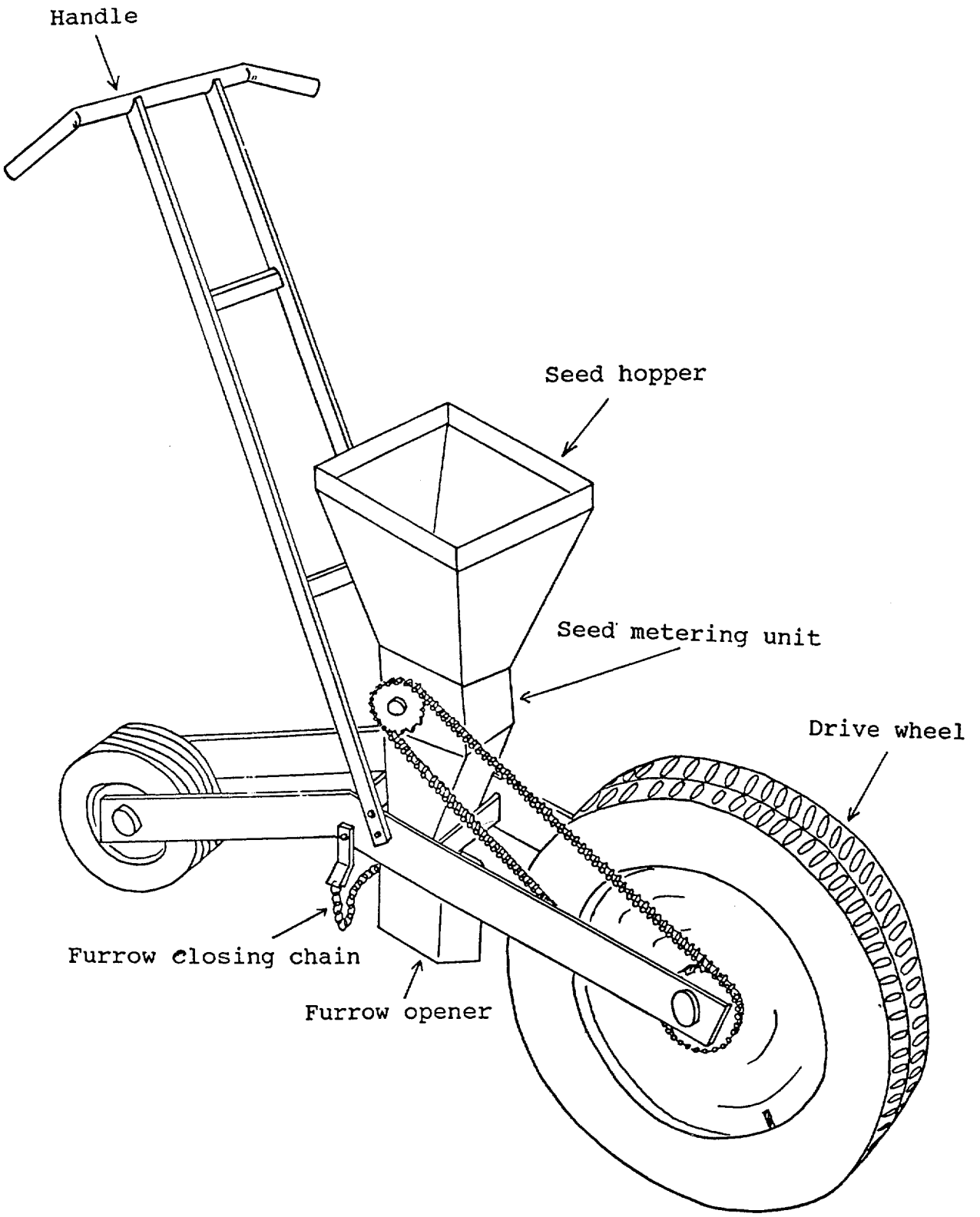


PLATE 1. Rutec Push Planter

5.5 Response of sorghum to phosphate application at three ecological zones

5.5.1 Introduction

Sorghum is an important crop in Botswana where it is used as feed for humans and fodder for livestock. It is also adapted to the dry climate. Farmers rarely use fertilizer. However, P fertilizer application is of importance for crop production in Botswana because most of the soils have below optimal levels of this nutrient (Jones, 1984). Yield response is soil specific (Department of Agricultural Research, 1986; Beynon, 1991), primarily because of differences in their P fixation capacity (Molapong, 1987). Once P has been applied, there is a substantial lessening of crop response to fertilizer with each subsequent season due to the building up of residual P from previous applications (Goswami et al., 1990). Information on the residual effects of fertilizer applied to a previous crop can be used to optimize fertilizer use efficiency of a succeeding crop.

Residual soil test P does not stay constant. Once phosphate fertilizer has been applied to a soil, the amount of plant available P declines with time. Depletion rates of plant available P depends on both plant uptake and change of plant available P into less available forms. Little information is available on Botswana soils about P residual effects and depletion rates of plant available forms following initial soil fertilization (Department of Agricultural Research, 1985, 86, 87), but there are no models available for predicting these changes. Consequently it is still not clear (1) when and how much fertilizer a farmer should apply following an initial application; or (2) how soon a farmer should have his soil tested again and a recommendation made; (3) it is also not clear what yearly dose of fertilizer application would be required to maintain soil test P at or slightly above the optimal level. The latter statement is of relavance when one considers that although there is a free soil testing service, it is not adequately used .

The objectives of this study were to evaluate sorghum yield and soil test P response to P application rate. The long term objective is to study soil P depletion rates and residual effects of P fertilizer on sorghum yield.

5.5.2 Materials and Methods

Three experiments were conducted at three ecological zones; Pandamatenga (18° 27'S, 25° 34'E, elevation 1068 m), Sebele (25° 20'S, 25° 26'E, elevation 990 m) and Goodhope, 100 km south of Sebele (25° 20'S, 25° 26'E elevation 1377 m) in the 1994/95 growing season. An attempt was made to seek sites with no recent history of P fertilization. At Goodhope the experiment was sited on a previously uncultivated soil on the station while at Pandamatenga the area had been cultivated for two seasons with no fertilization. At Sebele the soil had been used for legume or cereal fodder production for more than five years with no fertilization. The soil at Panda is a vertisol, at Goodhope an arenic ferric luvisol and at Sebele a ferric luvisol.

A randomized complete block design with three replications was used at each site. The individual plots consisted of eight rows of sorghum (variety Segaolane), 0.75 m apart and 21 m long (33,333 plants/ha). Treatments were superphosphate (10.5% P) at 0, 20, 40, 80, and 120 kg P/ha). All plots also received 45 kg/ha nitrogen as lime ammonium nitrate (LAN). All fertilizers were broadcast and ploughed into the soil with a mouldboard before planting. Planting dates were 17th January at Goodhope, 1st January at Sebele and 14th February at Pandamatenga. Weeds were controlled by hand hoeing. Grain and straw were harvested from the four middle rows. Surface (0-20 cm) soil was sampled for laboratory analysis at each site before planting and for available P determination after harvest. Rainfall for the season was also recorded (Table 1).

Soil test P was determined by Bray No. 2 extractant (Bray and Kurtz, 1945) for all the soils. For Panda, P was also determined with Olsen's $NaHCO_3$ (Olsen et al., 1954) because the soil has a high pH. Organic carbon was determined by wet oxidation (Walkely and Black, 1954), CEC by 1M ammonium acetate at pH 7, particle size by hydrometer (Day, 1965) method after peroxide pretreatment. Soil pH was determined in 0.01 M $CaCl_2$.

In the succeeding growing season, the main plots will be split into two subplots and P will be applied at 0 and 20 kg/ha to asses soil P depletion rates and maintanance requirements, respectively. The experiment will then continue as a split plot for five years.

5.5.3 Results and Discussion

Grain yields

Grain yields for the three locations ranged from 375-579 kg/ha at Goodhope; 1192-1432 kg/ha at Panda and 2010-3215 kg/ha at Sebele (Table 2.). There were significant ($P<0.001$) differences among the locations. Location contributed 95 % of

Table 1: Initial soil properties and total rainfall for the growing season at Panda, Sebele, and Goodhope.

	Sebele	Panda	Goodhope
Texture: clay(%)	10	55	8
Silt(%)	9	30	6
Sand(%)	81	25	86
pH (0.01 M $CaCl_2$)	4.4	6.3	4.6
Bray No.2 - P (mg/kg)	3.2	15.5	0.6
$NaHCO_3$ - P (mg/kg)	_	6.4	_
CEC (cmol(+)/kg)	3.7	37.8	2.4
Rainfall (mm)	412	324	315

the treatment sum of squares. The primary contributing factors to variation in site mean yield were the amount of rainfall (Table 1.) and its distribution (Fig 1.). The main contributing factor to the significance of the location effect was differences in rainfall. The effect of moisture was further compounded by the erratic distribution during the growing season (Fig 1.). At Panda where sorghum was planted late on 14th February, straw responded significantly to P fertilizer but the crops suffered drought stress at the flowering stage. The stress was shown by clear evidence of heat blast on the panicles and many of the heads with very few kernels. This resulted in a low site mean grain yield of 1.3 tons/ha and no grain yield response to P. After planting at Goodhope, low rainfall conditions resulted in poor plant growth and stand establishment.

There were no significant effects of P rates, on grain yield at each location and in the combined analysis of variance although at Sebele there was an apparent increase with P rate. The location by treatment interaction was not significant. A positive response of grain yield to P application was expected at Sebele and Goodhope because the soil test P (Bray No.2- P) and at Panda $NaHCO_3$-P was less than the critical level of 10 mg/kg. The lack of response at Goodhope and Panda resulted from poor rainfall (Table 1., Fig. 1.) and also non uniform plant stand at Goodhope. The low pH of the soil at Goodhope might have also played a role. The yield at Sebele was good. A response was not observed probably due to the low soil pH and a high intra block variability reflected by a relatively high cv (29%). This variability is attributed to presence of clayey soil patches from termite hills that had been levelled off. These areas were patchy because plants died as a result of poor moisture availability when rainfall was limiting.

Straw yields

Sorghum straw yields are presented in Table 3. Although a significant ($P<0.05$) effect of P was obtained in a combined analysis of variance, differences in the response to P among locations were just significant ($P<0.05$) and this allowed for interpretation only according to locations. Straw response to P application rate at Goodhope was not significant.

Table 2: Sorghum grain yields as influenced by P fertilizer rate at Sebele, Panda and Goodhope.

P - rate	Sebele	Panda	Goodhope
kg/ha	----------kg/ha----------		
0	2010	1425	579
20	2301	1227	375
40	2936	1192	664
80	2703	1361	526
120	3215	1432	574
Mean	2634	1328	544
CV (%)	29	15	20

Table 3: Sorghum straw yields as influenced by P fertilizer rate at three research sites.

	Location		
P Rate	Sebele	Panda	Goodhope
kg/ha	----------kg/ha----------		
0	5423	3034	1546
20	5661	4903	2053
40	6482	5143	2246
80	7811	7012	2228
120	9451	5792	1937
Mean	6966	5177	2002
S.E. (d.f. 8)		530.6	
CV (%)	22.3	17.7	22.6

At Sebele the yield response to fertilizer was just short of the 5% (P =*****) level and the ANOVA model accounted for 69% of the variation. At Panda, straw had a significant ($p<0.001$) quadratic response to P application. A quadratic model given below accounted for 73% of the total variation due to P in mean yields.

yield (kg/ha) = $C + aP + bP^2$
where C = 3045, s.e 439.0 and a = 87.0, s.e 19.35 and b= -0.53, s.e 0.15. All the coefficients were significantly ($p<0.02$) different from zero. The equation implies that maximum yield could be obtained at P = 82 kg/ha. The soil test P levels of this soil by Bray No.2 was 15.5 mg/kg. At this P level, however, a yield response of Segaolane sorghum to P is not expected since the critical level is 10 mg/kg (Beynon, 1991). Therefore, the significant response of the straw suggests that the Bray extractant is not a suitable soil test for P on this soil. The $NaHCO_3$-P might be more relevant because it gives a value that lies within the critical range (critical range 5-10 mg/kg) (Matar et al., 1988). The response to P tended to increase with rainfall. A possible explanation could be that fertilizer induces vigorous vegetative growth and that under limiting moisture the resulting competition suppresses yields.

Residual Phosphate

A combined ANOVA showed that both P application rate and location had significant ($P<0.001$) effects on the level of residual P. There was also a significant location by P application interaction ($P<0.05$). At all sites there was a significant linear increase of residual P by phosphate application rate (Table 4).. This might be expected because these soils have low P fixation capacity (Molapong, 1987) and also because cereal crops remove only about 5 kg/ha P per ton of grain (Gosami et al., 1987).

The mean P content of the control plots had hardly changed at the end of the cropping season at Sebele (from 3.2 to 3.8 mg/kg Bray No. 2-P) and had gone down a little at Panda (from 6.4 to 5.6 $NaHCO_3$-P). At Goodhope, the P content of the control plots had significantly increased from 0.6 to 4.2 mg/kg. It has been found that the P content of control plots may not change (Orphanos, 1988; Halvorson and Black, 1985) or even increase (Orphanos, 1988) after the first season of cultivation and cropping of virgin land. The increase is attributed to mineralization of organic P. It seems that in virgin lands a large quantity of labile P in the surface soil is fixed as organic-P.

Table 4: Regression equations for predicting residual P (in mg/kg) resulting from fertilizer P application rate (x, in kg/ha) at the end of the growing season.

Location	Regression equation	SE of estimate	r^2
Panda	Bray No.2 - P = 2.27+0.0773x	0.016	0.65
	$NaHCO_3$ - P = 5.44+0.0482x	0.007	0.77
Goodhope	Bray No.2 - P = 3.790+0.096x	0.022	0.62
Sebele	Bray No.2 - P = 5.420+0.118x	0.015	0.81

5.5.4 Conclusions

Grain yield response to fertilizer did not occur because of the effect of drought stress. At The response to fertilizer that appear earlier in the season may not be translated to yield if plants suffer drought stress especially at the flowering stage. Phosphate application to a previous crop increased residual plant available P. Fertilizer use efficiency would be increased by taking into account the potential contribution of the residual P to a subsequent crop.

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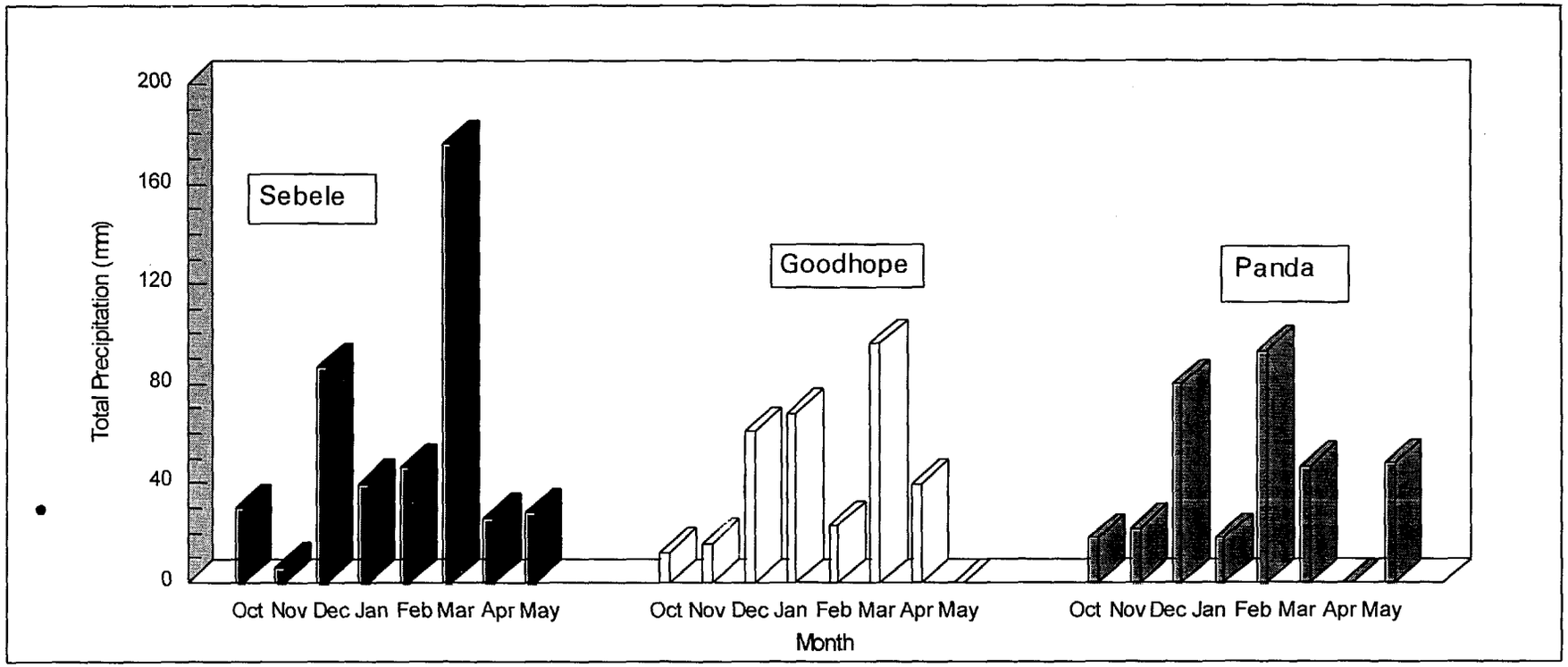

Fig 1.-Monthly precipitation at the three locations from Oct 1994 to May 1995

5.6 Response of yield, yield components and nutrient content of cowpea (*vigna-unguilata* (l.) To phosphate on a sandy loam

5.6.1 Introduction

The climate of Botswana is semi-arid (Harris et al. 1992), with moisture being the most limiting factor for crop production. The strategy for research should be to optimize yield per unit of precipitation. Optimal use of fertilizer, especially P increases yields and water use efficiency thus enabling crops to withstand drought stress.

Soils of Botswana commonly have an inherent deficiency of plant available phosphate and cereal response to P fertilization is known to occur widely (Jones, 1984; DAR, 1989,90,91). However, P nutrition and response to fertilizer of legumes has not been investigated to the same extent. Furthermore, the critical P level in Botswana below which a response of sorghum to P application is expected is about 10 ppm (Beynon, 1991), but no such information is available for cowpea. This study was therefore undertaken to determine the P requirement of cowpea on a sandy loam.

5.6.2 Materials and Methods

The field trial was conducted during the 1994/95 growing season on a loamy sand at Sebele Agricultural Research Station. The initial surface soil (0-20 cm) characteristics are presented in Table 1. Planting was done on 30th December 1994. Cowpea variety blackeye was planted at 75 cm between and 20 cm within the rows (67,000 plants/ha) in 21 x 6 m plots. The experiment was a randomized complete block design with 3 replicates and five P levels (0, 20, 40, 80, 120 kg/ha) as treatments. Phosphate was applied as super phosphate (10.5 % P). All fertilizer was applied to the field before using a mouldboard plough. The plots were kept free of weeds by hand hoeing.

The number of days from sowing to 50 % flowering and leaf samples for chemical analysis were taken at the flowering stage. The most recently matured terminal leaves of 10-15 random plants were selected. At maturity pods were harvested at 1 week intervals starting when 50% of the plants had ripe pods. Pods were considered ripe when they turned yellowish brown. The number of plants harvested, the number of pods/plant5, and seed weight were recorded.

At sowing and after harvest surface soil samples were collected and analyzed for pH in CaCl2 using a 1:5 soil/solution ratio; P by Bray no.2 extractant (Bray and Kurtz, 1945); exchangeable basic cations by ammonium acetate, Zn by HCl extractant (Wear and Evans, 1968), and organic carbon by Walkley and Black (1934) method. Leaf samples were dried, ground and digested with sulphuric-selenium-peroxide mixture using a Tecator 2020 digester and analyzed for N, P, basic cations, and Zn. Total N was determined using a Buchi 323 Distillation Unit. Calcium, Mg, and Zn were determined by atomic absorption, sodium and potassium by flame photometry. Data collected were subjected to analysis of variance and or regression analysis using Statistical Analysis System (SAS).

5.6.3 Results and Discussion

Yield and Components of Yield

An unbalanced data analysis of variance was performed on the yield data whereby data from the application rates 20 and 40 kg/ha of one of the blocks were dropped. Large areas of these plots were severely damaged by the presence of an ant hill.

Phosphate application did not significantly ($p>0.05$) affect the number of days to 50 % flowering, the number of pods per plant and weight of pods per plant were not significantly affected by P application, but weight of seeds per plant and weight of seeds per pod were significantly increased (Table 2). Cowpea grain yields were also significantly increased by phosphate application ($p<0.02$) while seed dry weight was only increased by application rates of up to 80 kg/ha P and then decreased. The response (fig 1.) was best described by the quadratic model equation given below:

$$y = c + a P + b P^2, \quad r^2=0.60 \qquad (1)$$

where y = yield (kg/ha), P = phosphate application rate (kg/ha), c = 550,s.e 48.63, a = 8.237, s.e. 2.159 and
b = -0.061, s.e. 0.0173.

The coefficients were all significantly different from zero at the 0.01 level.

Nutrient Uptake

Results related to the influence of P application rate on nutrient content of cowpea leaves are presented in Table 3. Nitrogen, potassium, calcium and magnesium content of the leaves were not significantly affected by P application whereas P, was linearly increased ($p<0.02$, $r=0.58$) and Zn content linearly decreased ($p<0.001$, $r=-0.76$).

The initial plant available P level in this soil was 3.2 mg/kg (table 1). The observed growth in response to P application would indicate that P nutrition is critical to cowpea production in soils with available P at or below this level. The tendency of Zn content to decrease with P application rate agrees with the known phosphate induced Zn deficiency (Mengel and Kirkby, 1982). It has been suggested that high P affect physiological Zn availability in plant tissues. Thus care must be taken when applying P to supply only adequate amounts in order to avoid P induced Zn deficiency.

Soil Chemical Properties.

Soils under different P applications were analyzed for P content at harvest (Table 4). Soil test P levels were significantly increased by P application. An application rate of 40 kg/ha P resulted in a residual plant available P level of 10 ppm which was found to be the critical level for sorghum (Beynon, 1991). The highest P level did not reflect a further increase in soil P. This anomaly is attributed to high sampling error. (i.e. the number of samples required to obtain a reliable estimate of soil P status).

The large sampling error is caused by the fact that the tillage operation do not achieve uniform mixing of fertilizer with the soil. It is also possible that an error occurred when treatments were applied.

Determination of Fertilizer Requirement

The cowpea grain value increase over the control (in monetary terms) with P application is also described by a quadratic equation as follows

$$y = -0.463 + 7.03 - 0.055P^2, \quad r^2 = 0.60 \qquad (2)$$

Where y = monetary return in Pula and P is P rate (kg/ha). Calculation of the optimal P fertilizer rate for the quadratic equation gives the following result

$$P_o = (C/V - a)/2b = 8.68 \text{ kg P/ha} \qquad (3)$$

where a and b are the linear and quadradic term coefficients from equation 2, C is the cost of phosphorus per kg and V is the selling price of black eye per kg (The prices used here are based on the 1995 prices at Botswana Agricultural Marketing Board. (C=5.16 Pula/kg of P and V=0.849 Pula/kg of black eye). The optimal fertilizer value obtained here is lower than that for sorghum (48 kg P/ha) found by Beynon (1991) on soils with a similar soil test P level. The technique used in the calculation of the optimum application rate is similar to that of Hauser, (1973).

The yield at optimum P is obtained by substituting P_o for P in equation 1. This gives a monetary gain in return over the unfertilized plots of 52 pula/ha and a value to cost ratio of 1.2 making the use of fertilizer P justifiable especially when one considers that there are residual effects to P in the second year.

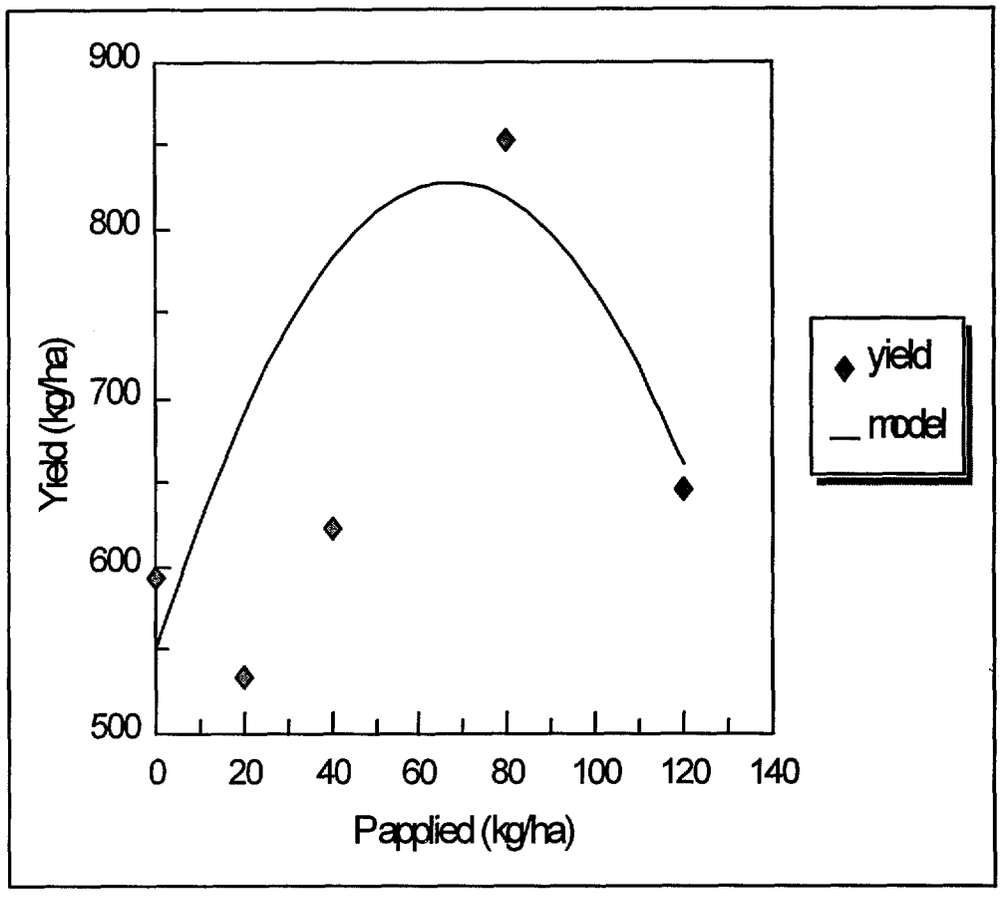

Figure 1.- Response of cowpea yield to P application

5.6.5 Conclusions

An increase in application levels of super phosphate had a significant quadratic increase of cowpea grain yield and linearly increased P uptake. Phosphate fertilizer at the high application rate of 120 kg/ha showed a negative effect on grain yield. A soil P content of 3.2 mg/kg by Bray no. 2. extractant appears inadequate for optimal cowpea growth. Application of phosphate can decrease the uptake of zinc. Therefore only adequate amounts should be applied. For soil testing to be effective in diagnosing deficiency problems, soil test calibration studies should be conducted to establish critical levels and develop fertilizer recommendations for cowpea in different soils.

The cowpea yields were rather low (853 kg/ha for the highest yielding treatment). This may be expected when one considers the low pH of this soil. Soil pH plays an important role in the efficient functioning of a legume grown in the absence of applied nitrogen. In particular the root infection by *Rizhobium* and nodule initiation as well as legume *Rizhobium* symbiotic efficiency is suppressed (Andrew 1978). Efficiency of plant uptake of soil P is also likely to be decreased. One would therefore expect that both the response and yield levels would be much higher and more economic in soils with pH 5 and above.

Table 1: Initial surface soil chemical characteristics before planting.

pH	OM	P	Ca	Mg	K	Na	CEC	Zn
(CaCl2)	%	mg/kg	------ cmol (+)/kg -------					ppm
4.4	0.1	3.2	1.49	0.5	0.36	0.1	3.7	1.1

Table 2: Effect of P on yield, and yield components of cowpea in a sandy loam.

P rate kg/ha	no. of days to 50% flower-ring	yield kg/ha	No. of pods/ plant	Wt. of pods/ plant (g)	Wt. of seeds/ plant (g)	Wt. of seeds/ pod (g)
0	40	592(3)‡	15	19.2	13.6(3)	0.92(3)
20	40	534(2)	12	16.5	11.9(2)	1.00(2)
40	40	622(2)	14	19.7	14.4(2)	0.99(2)
80	40	853(3)	17	25.1	18.2(3)	1.06(3)
120	40	646(3)	15	19.9	14.2(3)	0.95(3)
CV		12.0%			12.5%	3.3%
S.E.D(3 reps)		68.36	NS	NS	1.57	0.027
S.E.D(2reps)		76.36			1.76	0.030

Error d.f 6, ‡ Figures in brackets are the number of replications

Table 3: Effect of P on nutrient composition of cowpea leaf

P rate kg/ha	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn ppm
0	4.40	0.29	2.26	0.71	0.24	42.33
20	4.61	0.35	2.35	0.62	0.23	41.33
40	4.49	0.34	2.28	0.64	0.24	33.00
80	4.23	0.33	2.28	0.61	0.23	33.00
120	4.45	0.36	2.15	0.68	0.23	31.33
S.E.D(8-d.f.)		.014				2.32
CV		5.0%				7.8%

Table 4: Effect of P fertilizer on available P levels

P rate kg/ha	Available P (ppm)
0	2.7
20	5.3
40	10.0
80	19.9
120	16.1
CV	18.5%
SED	1.63

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5.7 Wheat production as influenced by limited irrigation

5.7.1 Introduction

Shortage of irrigation water is perhaps the single most important factor limiting crop diversification and production in Botswana. Thus proper timing and amount of irrigation application is necessary for effective use of scarce and expensive water resources for crop production. Wheat is not a common crop in Botswana, but it provides a possible alternative crop for winter when other field crops such as maize may not survive. Wheat production will reduced the country's dependence on imported wheat.

Information on evapotranspiration is necessary in limited soil moisture environment because it is directly related to yield, quality and water economy. When a certain amount of soil moisture within the root zone is depleted, actual evapotranspiration decreases with maximum evaporation. For efficient irrigation scheduling, relative evapotranspiration can serve as a suitable index because it indicates the combined effects of soil moisture and environmental stress. Evapotranspiration was found to decrease when plant available soil moisture within the root zone was depleted to 30-75% depending on the evaporative demand (Aslyng 1965, Ritchie et al. 1972, Al-Khafaf et al. 1978, Mason et al. 1980, Mogensen 1982, Imtiyaz et al. 1988, Imtiyaz et al. 1990, Imtiyaz et al. 1992, Imtiyaz et al. 1994)

It is difficult to avoid moisture stress in plants when there is but it limited water resources conditions is possible to distribute the available water in such a way that the yield losses are minimized. Soil moisture deficit affects the grain yield of wheat crop by affecting various yield components. Grain yield reduction due to limited water depends on the degree and duration of soil moisture stress, cultivars and stage of crop development (Robins and Domingo 1962, Salim et al. 1965, Misra et al. 1969, Nasser et al 1980, Hockman 1982, Gaur et al.1985, Imtiyaz et al. 1990). Water scarcity in Botswana necessitated the need of its efficient utilization. To achieve better productivity it is important to develop efficient and economic irrigation schedule of wheat under existing agroclimatic conditions. Numerous studies elsewhere were carried out to examine the effects of different irrigation scheduling methods for wheat, but meteorological based irrigation schedule was used more extensively due to its simplicity and adaptability (Prihar et al. 1974, Prihar et al. 1976, Rafey et al. 1978, Misra and Pant, 1981, Sandhu et al. 1984, Ghazy et al. 1987, Talha et al. 1987)

In order to optimize crop production in limited water resources condition, it is important to develop relationships between water applied/water use and crop production. The relationship between water applied/water use and yield is defined as water production function. Information on water production function is important for assessing the priorities for allocating the irrigation water within and between the crops and economic analysis. Various workers have shown that crop production is closely related to water applied/water use (Dewit 1958, Hillel and Guron 1973, Stewart et al. 1977, Sorensen et al. 1980, Dennis et al. 1982, Stegman 1982, Gaur et al. 1985, Imtiyaz et al. 1988, Imtiyaz et al. 1990, Singh et al. 1991, Imtiyaz et al. 1992, Reddy and Reddy 1993).

In Botswana, several studies were carried out to examine the yield potential of wheat cultivars (ref). However, no research work have been carried out to investigate the effect of limited irrigation on crop production of wheat cultivars. The purpose of the present studies was:

i) to investigate the effect of soil moisture deficit during different growth stages on evapotranspiration yield and water expense/water use efficiency of wheat.

ii) to investigate the effect of irrigation schedules on yield and water expense efficiency of wheat cultivars.

iii) to develop relationships between seasonal evapotranspiration/seasonal water application and grain yield of wheat cultivars.

5.7.2 Materials and Methods

Experiment 1

Wheat crop was grown during winter season (April to September) of 1994.

Wheat variety BSP 87/11 was sown on 25th April 1994 at the seed rate of 150 kg/ha. The row spacing was 0.225m. Prior to the sowing, the experimental field received broadcasted fertilizers at the rate of 100 kg/ha N, 60 kg/ha P_20_5 and 70 kg/ha K_20. The crop also received 50 kg/ha N during booting period. The soil in the experimental plot was fertile clay loam.

The experimental design was RCBD with 5 irrigation treatments and three replications. The area of each experimental plot was 36 m^2. The crop was subjected to soil moisture stress at four different growth stages by withholding the irrigation application. Each treatment consisted of single period of moisture stress during which irrigation was withheld. The details of the irrigation treatments were as follows:

I1 - Fully irrigated during the entire crop growth period. Irrigation was applied twice a week to ensure that the soil moisture deficit within the root zone should not exceed 35% of available water.

I2 - Irrigation was withheld from, tillering to partly jointing stages.

I3 - Irrigation was withheld from, booting to beginning of heading.

I4 - Irrigation was withheld from, heading to complete flowering.

I5 - Irrigation was withheld from, about 50% grain filling period to harvest.

Soil moisture content was determined by gravimetric method twice a week by taking soil samples at 10, 20, 30, 40, 50, 75 and 100 cm depths. A short term water balance was made for all the treatments when soil moisture content within the root zone was below field capacity. Evapotranspiration was calculated from the following water balance equation:

$$ET = I + P + S - R - D \text{ ---------- } (1)$$

Where ET is evapotranspiration (mm); I irrigation applied (mm); P precipitation (mm); S change in soil moisture storage (mm); R run-off (mm) and D deep percolation (mm). Irrigation and precipitation were measured. Soil moisture storage was obtained by gravimetric method. Run-off and deep percolation were assumed zero, because irrigation was applied taking moisture storage capacity and infiltration characteristics of soil into account. Irrigation was applied by field installed sprinkler irrigation system.

The wheat crop was harvested on 12th September 1994 for yield analysis. Water expense and water use efficiency were calculated by dividing seasonal water applied and seasonal evapotranspiration with grain yield. Relative evapotranspiration (ETa/ETm) was calculated by dividing evapotranspiration of the crop as influenced by soil moisture stress (Eta) with evapotranspiration of fully irrigated crop (ETm).

Experiment 2

The experiment was conducted during 1994 winter (June to October) to evaluate the effect of irrigation schedules on response of wheat cultivars at Etsha 6.

The experiment was laid out in a split plot design with three replicates. The treatments consisted of five irrigation schedule as main plots and four wheat cultivars GAMTOOS (V1), INIA (V2), BSP 89/14 (V3) and SENGWA (V4) as sub-plots. The size of each experimental plot was 30.25m^2. Irrigation scheduling was based on IW/E-R method, where IW is the amount of irrigation water, E is the cumulative pan evaporation and R is the rainfall. A buffer zone of 1.0 m was provided between the sub-plots. The irrigation schedule treatments consisted of five different ratio of IW/E-R values of 1.2 (I1), 1.0(I2), 0.8(I3), 0.6(I4) and 0.4(I5). In each irrigation a fixed amount of 27mm of water was applied, which was estimated by rooting depth, plant available soil water and permissible soil moisture depletion.

The crop was sown on 10th June 1994 at the seed rate of 150 kg/ha. The row spacing was 0.225m. Prior to sowing experimental field received broadcasted fertilizers at the rate of 100 kg/ha N, 60 kg/ha P_20_5 and 70 kg/ha K_20. The crop also received 50kg/ha N during booting stage. Quick coupling sprinkler irrigation systems was used. Before the experiment, the irrigation system was evaluated under wide range of wind condition.

Wheat cultivars were harvested on 4th October 1994 for yield analysis.

5.7.3 Results and Discussion

Experiment 1

5.7.3.1 Crop Water Use Pattern

The seasonal patterns of daily evapotranspiration of wheat for different irrigation treatments are presented in Fig.1. The daily evapotranspiration of fully irrigated crop (I1) varied considerably due to variation in evaporative demand. I1 reached a maximum of 10.85 mm/day during the flowering period due to high green area index and moderate evaporative demand. After flowering, the daily evapotranspiration decreased continuously due to a decrease in green area index caused by translocation of dry matter for grain filling (Fig. 1). Soil moisture stress at any stage of crop development reduced evapotranspiration due to reduction in green area index and stomatal closure. However, after termination of moisture stress, the crop showed an increase in evapotranspiration but it was low as compared to fully irrigated crop.

The cumulative evapotranspiration for different irrigation treatments is illustrated in Fig. 2. Soil moisture stress during any period of crop development reduced the cumulative evapotranspiration. The lowest cumulative evapotranspiration (602.47 mm) was observed in treatment I3 due to severe reduction in leaf area index. The cumulative evapotranspiration for treatment I2 periods increased considerably due to water use by late tillers. The percentage reduction in cumulative evapotranspiration were 12.7, 22.5, 21.1 and 16.3 in which moisture stress occurred during tillering (I2), booting (I3), flowering (I4) and grain formation (I5) periods.

The relative evapotranspiration in relation to plant available soil moisture depletion of wheat is presented in Fig. 3. The main purpose of illustrating such relationship is to determine appropriate time for irrigation application without affecting crop production. The evapotranspiration of crop during the drying cycle (I2, I3, I4 and I5) continued at potential rate (I1) until the soil moisture deficit within the root zone reached the threshold value. The threshold value of soil moisture at which irrigation is essential for potential crop production depends upon the atmospheric evaporative demands. The relative evapotranspiration for clay loam soil started to decline below unity when soil moisture deficit within the root zone exceeded 40-42%. Similar results were reported by many researchers (Aslyng 1965, Ritchie et al. 1972, AL-Khafaf et al. 1978, Meyer and Green 1981, Imtiyaz et al. 1988, 1990, 1992, 1994). Inspite of some variation in relative evapotranspiration, it is reasonable to conclude that for potential production under the climatic conditions of north western region of Botswana, irrigation should be applied just before 40-42% plant available soil moisture depletion.

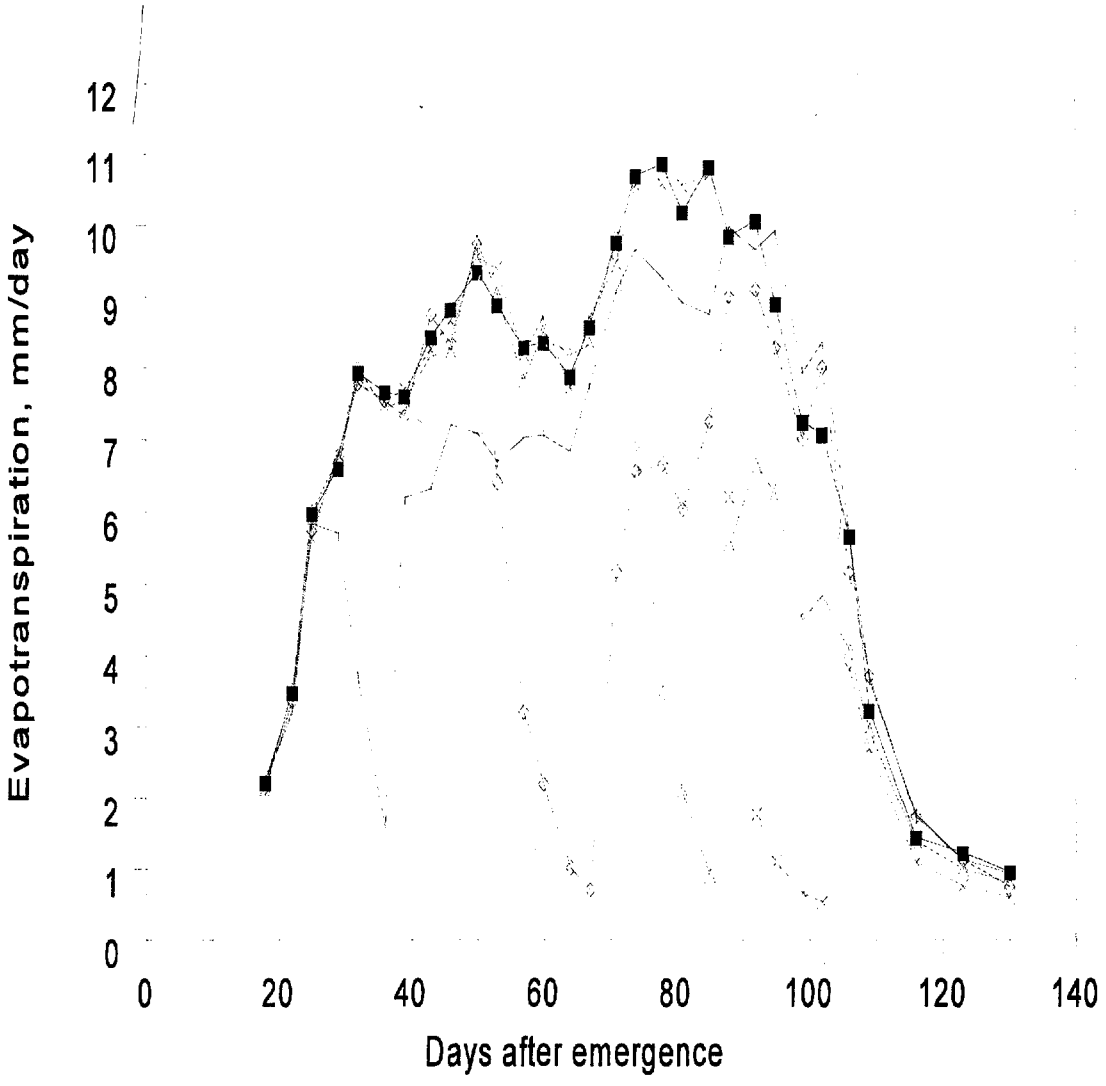

Fig.1.Changes in evapotranspiration of wheat as influenced by soil moisture stress. Symbols for treatments:

■ I1 I2 I3 I4 I5

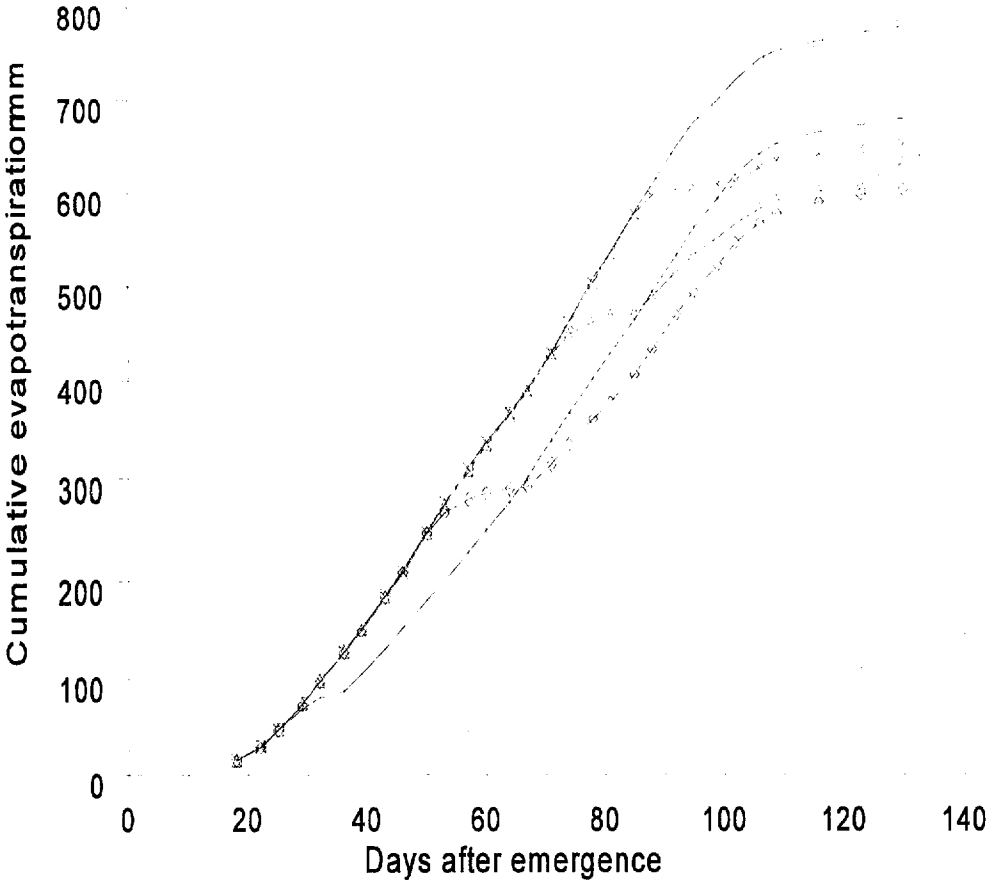

Fig.2.Cumulative evapotranspiration of wheat as influenced by soil moisture stress. Symbols for treatments.

I1 I2 I3 I4 I5

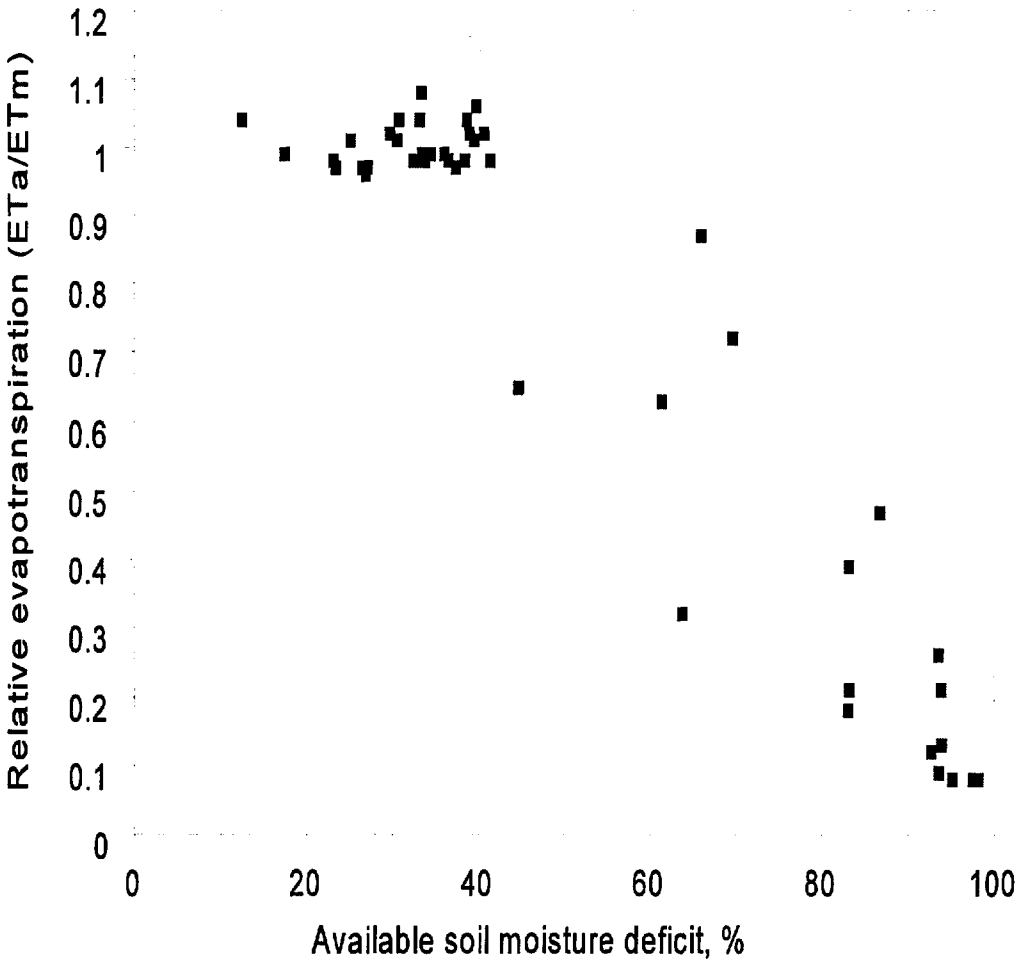

Fig. 3.Relative evapotranspiration in relation to available soil moisture deficit for wheat.

5.7.3.2 Yield, Water Expense and Water Use Efficiency

Grain yield, seasonal evapotranspiration, water expense and water use efficiency of wheat for different irrigation treatments are presented in Table 1. Soil moisture stress in all the growth stages reduced the grain yield of wheat significantly by affecting yield components. Of the moisture stress treatments I2 yielded highest due to contribution of grain yield by late tillers. Grain yield reduction was maximum when moisture stress occurred during flowering period (I4). The percentage yield reductions were 10.3, 22.2, 39.3 and 29.7 when moisture stress occurred during tillering (I2), booting (I3), flowering (I4) and grain filling (I5) periods respectively. This indicates that the flowering period of wheat is most sensitive to soil moisture stress, followed by grain filling, booting and tillering stages.

Soil moisture stress during booting (I3), flowering (I4) and grain filling (I5) periods increased the water expense per ton of grain production (water expense efficiency) significantly, compared with fully irrigated crop (I1) and crop stressed during tillering (I2). Soil moisture stress during tillering did not increase the water expense efficiency significantly because reduction in yield and seasonal water applied were approximately the same. The water expense per ton of grain production was maximum when moisture stress occurred during flowering stage, followed by grain filling and booting stages (Table 1). This is due to the fact that moisture stress during flowering reduced grain yield more than the seasonal water application. Soil moisture stress during flowering (I4) and grain formation (I5) periods increased water use efficiency significantly, because grain yield was more affected than seasonal evapotranspiration. Soil moisture stress during tillering (I2) and booting (I3) stages did not influence the water use efficiency because reduction in grain yield and seasonal evapotranspiration was almost the same. The results clearly indicated that for optimum yield, soil moisture stress should be avoided from flowering to grain formation periods of wheat (Imtiyaz et al. 1990).

Table 1: Grain yield, seasonal evapotranspiration water expense and water use efficiency of wheat as influenced by soil moisture stress

Treatment	Mean grain yield t/ha	Mean seasonal evapo-traspiration mm	Mean water expense efficiency mm/t/ha	Mean water use efficiency mm/t/ha
I1	5.13	777.33	149.22	126.89
I2	5.50	678.33	153.93	123.37
I3	4.77	602.67	159.39	126.21
I4	3.73	613.67	207.61	164.52
I5	4.31	650.67	172.65	151.14
CV, %	2.78	2.23	3.10	1.25
SED	0.11	12.07	4.27	1.41
LSD(P=0.05	0.26	27.84	9.85	3.26

Experiment 2

5.7.3.3 Yield, water expense and water efficiency

Effect of irrigation schedules on grain yield and water expense efficiency of wheat cultivars are presented in Table 2. Irrigation schedules, wheat cultivars and their interaction were significant for grain yield. The highest grain yield was obtained with irrigation scheduled at IW/E-R ratio of 1.2 (I1). There was 15.03, 38.37, 61.21 and 74.47% decrease in grain yield with irrigation at IW/E-R ratios of 1.0 (I2), 0.8(I3), 0.6(I4) and 0.4(I5) respectively compared with IW/E-R ratio of 1.2 (I1). The wheat cultivar SENGWA (V4) produced the maximum grain yield followed by cultivars BSP89/14 (V3), GAMTOOS (V1) and INIA (V2). The percentage reduction in grain yield were 15.59, 31.16 and 40.31 for BSP 89/14, GAMTOOS and INIA respectively compared with SENGWA. Yield response of cultivars was more pronounced at high irrigation levels. SENGWA produced the highest grain yield at all irrigation levels.

The water expense efficiency was also significantly influenced by irrigation schedules, cultivars and their interaction. The water expense per ton of grain production was minimum when irrigation was scheduled at IW/E-R ratio of 1.0 (I2), compared with other IW/E-R ratios. The irrigation schedule above 1.0 IW/E-R ratio increased the water expense per ton of grain production because increase in seasonal water application not accompanied by corresponding increase in grain yield, but the opposite was true for irrigation application below 1.0 IW/E-R ratio. The water expense per ton of grain production was significantly lowest for variety Sengwa.

At all levels of irrigation schedules variety Sengwa produced the highest grain yield per mm of water applied (Table 2). The experimental results indicated that scheduling irrigation at IW/E-R ratio of 1.2 was ideal for maximum crop production, but IW/E-R ratio of 1.0 was appropriate for optimum yield and water economy. Amongst the four wheat cultivars, Sengwa was the best variety in terms of yield and water economy.

5.7.3.4 Water Applied, Seasonal Evapotranspiration and Yield Relationships

Table 2: Grain yield and water expense efficiency of wheat cultivars as influenced by irrigation schedules

Treatment	Mean grain yield t/ha V1 v2 v3 v4	Mean water expense efficiency mm/t/ha v1 v2 v3 v4
I1V1	4.05	259.95
I1V2	3.31	317.87
I1V3	4.78	220.17
I1V4	5.87	179.52
I2V1	3.29	246.22
I2V2	2.82	286.94
I2V3	4.13	196.16
I2V4	5.07	159.90
I3V1	2.38	283.72
I3V2	2.05	328.82
I3V3	3.01	224.51
I3V4	3.66	184.16
I4V1	1.59	322.11
I4V2	1.51	340.58
I4V3	1.88	273.49
I4V4	2.01	255.31
I5V1	1.01	402.49
I5V2	0.99	410.65
I5V3	1.31	308.52
I5V4	1.29	313.22
CV, %	2.35	2.38
LSD (P=0.05)		
IRRIGATION	0.054	5.404
VARIETY	0.048	4.833
INTERACTION	0.108	10.808

The relationship between seasonal water applied (W) and grain yield (Y) of wheat is presented in Fig 4 and is given by the following the regression equation:

$Y = -4.555229 + 0.011691W$ - - - - - - - - - - - - - (2)

with a co-efficient of determination (R^2) = 0.76

The equation shows a moderate linear relationship. This is due to fact that the different growth stages of wheat were not equally sensitive to soil moisture deficit (Imtiyaz and Singh 1990, Singh et al. 1991)

The relationships between grain yield (Y) and seasonal water applied (W) for wheat cultivars are shown in Fig 5 and are given by the following significant ($P<0.05$) quadratic equations: where V1 = Gamtoos, V2 = Inia, V3 = BSP 89/14 and V4 = Sengwa.

V1: $Y = -1.976 + 0.008204W - 0.0000023W^2$, $R^2 = 0.99$ - (3)

V2: $Y = -1.519 + 0.007081W - 0.0000023W^2$, $R^2 = 0.99$ - -(4)

V3: $Y = -2.912 + 0.011834W - 0.0000042W^2$, $R^2 = 0.98$ - -(5)

V4: $Y = -4.714 + 0.016995W - 0.0000065W^2$, $R^2 = 0.98$ - -(6)

The high values of Co-efficient of determination are indicative that the fitted equations can be used to predict the grain yield of wheat cultivars with a high degree of accuracy. The production functions developed in the present investigations can be used in assessing priorities for allocating the irrigation water within and between the wheat cultivars under prevailing agroclimatic conditions in North Western region of Botswana.

The relationship between grain yield (Y) and seasonal evapotranspiration (ET) for wheat is shown in Fig. 6 and is given by the following regression equation:

$Y = -2.626059 + 0.011305\ ET$ - - - - - - - - - - - (7)

with a Co-efficient of determination (R^2) = 0.71

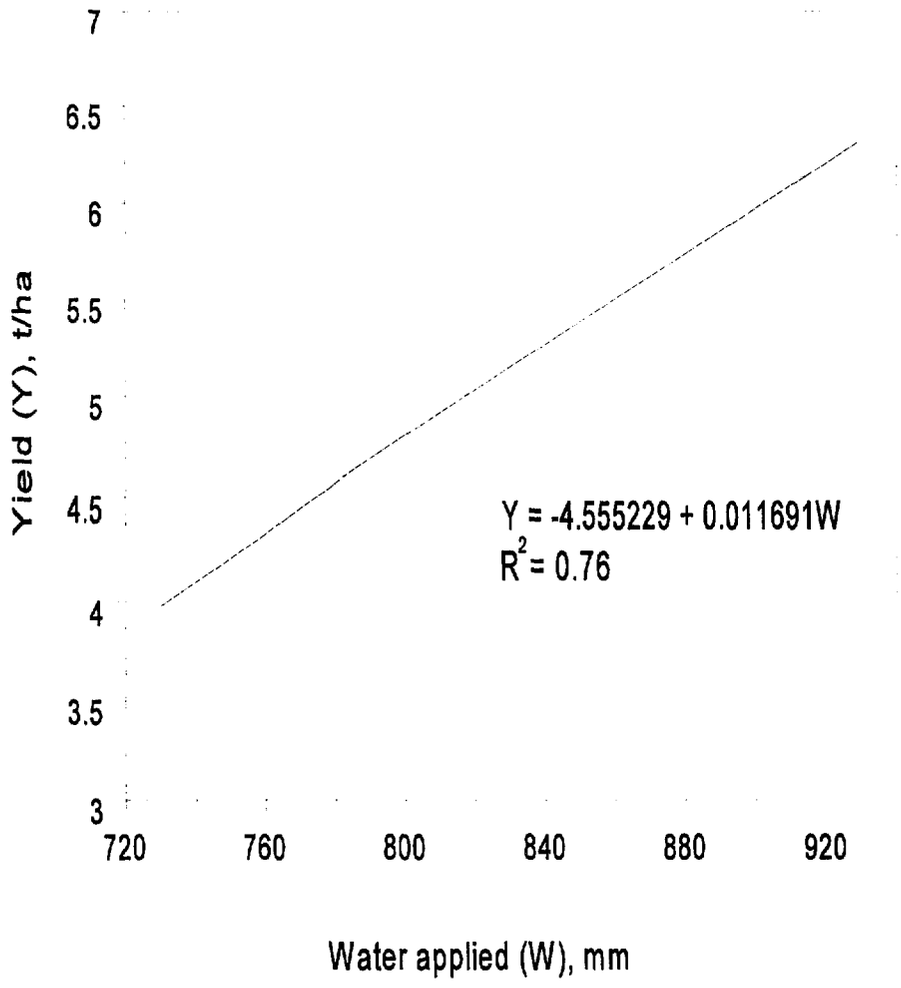

Fig.4.Relationship between water applied and grain yield of wheat.

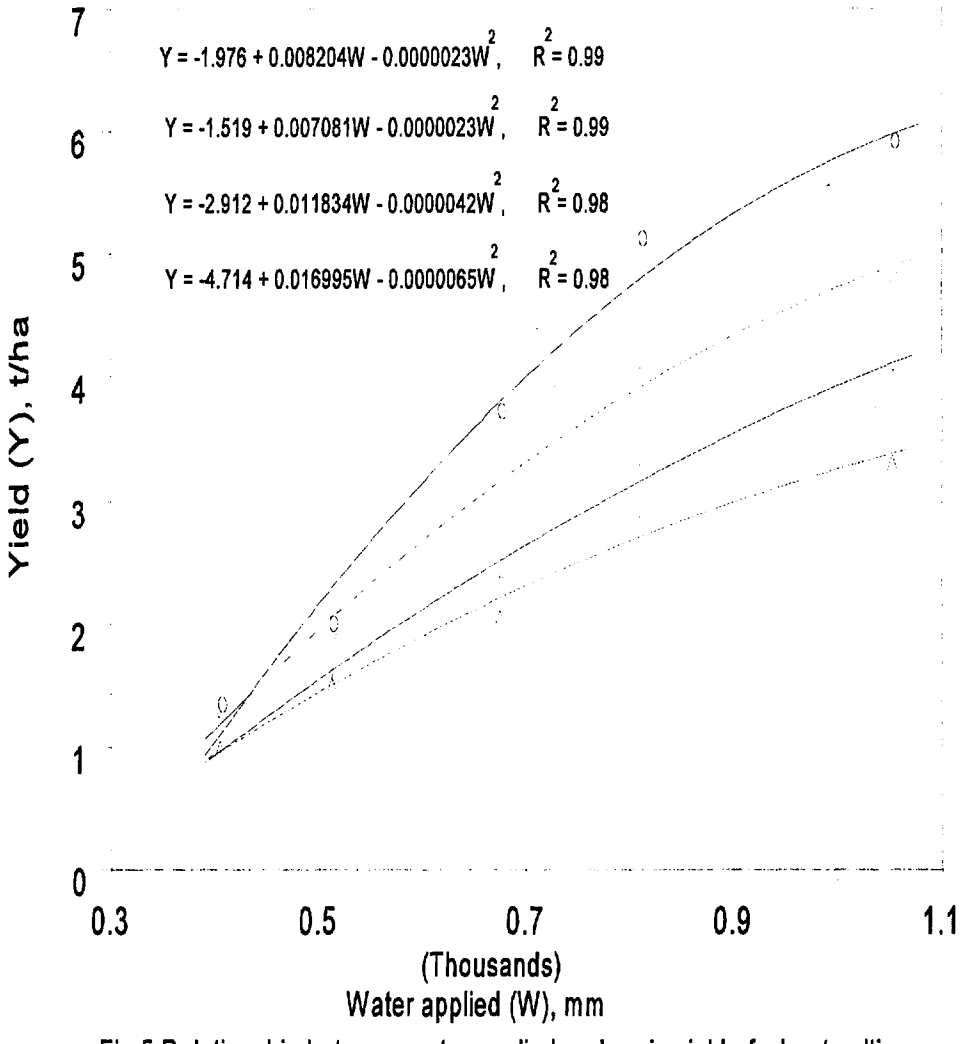

Fig.5.Relationship between water applied and grain yield of wheat cultivars.

Symbols for treatments.

V1 V2 V3 V4

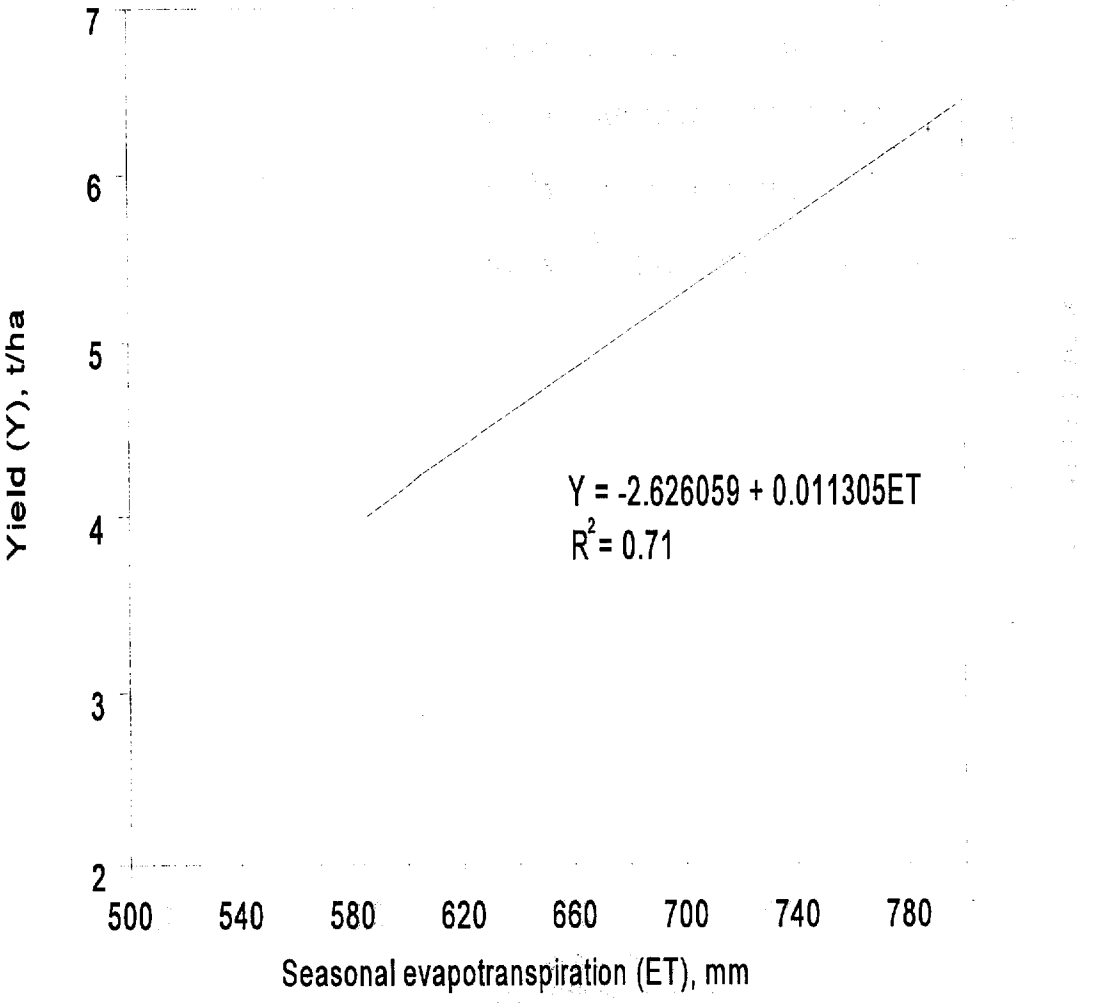

Fig.6.Relationship between seasonal evapotranspiration and average grain yield of wheat.

The equation shows moderate linear relationship ($R^2 = 0.71$) because at the different growth stages wheat crop was not equally sensitive to soil moisture stress (Dewit 1958, Hillel and Guron 1973, Stewart et al. 1977, Retta and Hanks 1980, Imtiyaz and Singh 1990, Imtiyaz and Shiromani 1990, Singh et al. 1991, Imtiyaz et al. 1992).

Conclusions

The following conclusions were drawn from the present studies:

I) Soil moisture stress during any period of crop development reduced the daily and seasonal evapotranspiration. The relative evapotranspiration started to decline below unity when 40-42% of plant available soil moisture had been depleted. The relative evapotranspiration can be used as an index for irrigation scheduling and characterizing the effect of soil moisture stress on plants.

ii) Soil moisture stress during any period of crop development decreased the grain yield of wheat but reduction was maximum when stress occurred during flowering periods. For optimum yield and water economy, soil moisture stress from flowering to grain formation periods should be avoided.

iii) Scheduling irrigation at IW/E-R ratio of 1.2 produced highest grain yield, but irrigation with IW/E-R ratio of 1.0 was appropriate for optimum yield and water economy of wheat cultivars. Amongst the four wheat cultivars Sengwa was superior in terms of grain yield and water economy.

iv) The crop in which moisture stress occurred during different growth periods showed moderate linear relationship between water applied, seasonal evapotranspiration and grain yield ($R^2 = 0.71$ to 0.76).

v) Mathematical equations developed in the present studies can be used to predict grain yield of wheat cultivars under the prevailing agroclimatic conditions, North Western Botswana. The mathematical equations can also be used for allocating limited water resources within and between the wheat cultivars efficiently.

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5.8 Yield and water expense efficiency of onion cabbage tomato and green pepper as influenced by irrigations schedules

5.8.1. Introduction

Botswana is a semi arid country with limited water resources. Water for irrigation is becoming both scarce and expensive due to continuous depletion of surface and sub-surface water resources caused by erratic rainfall. Water undoubtedly remains the most limiting factor for crop production and its scarcity has caused the need for its efficient utilization. Improper irrigation management practices may cause soil and plant water deficit, water logging and salinity which consequently affect yield and quality. Such problems can be prevented by using reliable and efficient irrigation scheduling techniques within and between the crops.

Irrigation schedules must be based on a thorough understanding of soil - water - plant - atmosphere relations and their interaction because yield, quality and water economy are governed by many complex factors. The ultimate aim of irrigation is the maximization of crop production per unit of water application. Numerous studies elsewhere were carried out to develop suitable irrigation scheduling criteria under a wide range of irrigation systems and management, soil and agroclimatic conditions (Richards and Marsh 1961, Hagan and Laborde 1964, Jensen 1969, Jensen et al. 1970, Sandhu et al. 1976, Misra and Pant 1981, Hedge 1986, Imtiyaz and Singh 1990, Imtiyaz and Shiromani 1990, Singh et al. 1991, Imtiyaz et al. 1994)

Meterological based irrigation schedules have been used extensively for vegetable and field crop due to their simplicity and higher adaptability at the farmers level.
(Prihar et al. 1974, Misra and Pant 1981, Singh and Rajput 1989, Pawar and Patil 1990, Dhiwalkar et al. 1990, Jadhav et at. 1992, Patil et al. 1993, Imtiyaz et al. 1994, Rana and Sharma 1994).

Proper irrigation scheduling should determine when and how long to irrigate. Several studies have been carried out to determine the threshold value of soil moisture at which irrigation is essential. The lower limit of soil moisture at which irrigation is required varies with soil, crop characteristics and evaporative demand (Ritchie et al. 1972, Stegman 1982, Sammis and Wu 1986, Talha et al 1987, Ferreyra 1987, Ghazy et al. 1987,EL-Kommos et al. 1989, Imtiyaz et al. 1990, Hussain et al.1991, Imtiyaz et al. 1992, Raghav and Rami 1993, Imtiyaz et al. 1994).

The relationship between crop production and water use/applied is defined as water production function. The information on crop response to water applied is of practical use in deciding upon the allocation of irrigation water within and between the crops to maximize production per unit of water. Relationships between water applied/use and crop production are well documented. (Dewit 1958, Hillel and Guron 1973, Stegman 1982, Ferreyra 1987, Imtiyaz et al. 1988, Dhiwalkar et al. 1990, Imtiyaz and Singh 1990, Imtiyaz and Shiromani 1990, Singh et al. 1991, Imtiyaz et al. 1992).

Onion, cabbage, tomato and green pepper are important crops in Botswana. Alhough agronomic studies for these crops have been done, limited work has been done on irrigation management for vegetable crops. The objectives of the present investigations were:

(i) to examine the effect of irrigation schedules on marketable yield, yield components and water expense efficiency.

(ii) to develop relationship between marketable yield and seasonal water application.

5.8.2 Materials and Methods

The trials were conducted at Boro and Etsha 6 experimental sites. Boro experimental site is located about 12km North East of Maun (19^0 59'S, 23^0 25'E, 945m above MSL) and Etsha 6 35km West of Gumare (19^0 37'S, 22^0 17'E 964m above MSL). Table1 shows soil characteristics of the two sites.

Table 1: Soil characteristicsat experimental sites.

Characteristics	Boro	Etsha 6
Soil type	Clay loam	Sandy with low organic content
Water holding capacity (%)	16.5	7.5
Wilting pointing (%)	8.3	2.45
Bulk density (g/cm^3)	1.61	1.41
Available soil mosture (%)	132	72

Experiment 1

The experiment was conducted in winter (April to August) of 1994. Onion (Texas Grano) seedlings were transplanted on 13th April, 1994 with 0.1 m within and 0.3 m between row spacings. All the experimental plots were pre-irrigated to bring the root zone soil profile to the field capacity. Prior to transplanting, the experimental field received broadcasted fertilizers at rate of 62.9 kg/ha N, K_20 and 94.3 g/ha P_20_5. The crop received second application of nitrogen on 18th May, 1994 at the rate 63 kg/ha. The experimental design was RCBD with 4 irrigation scheduling treatments replicated 3 times. Each experimental plot was 48m^2. Iirrigation treatments were as follows:

I 1 - Irrigation was applied when plant available soil moisture deficit within the root zone reached 20-25%.

I 2 - Irrigation was applied when plant available soil moisture deficit within the root zone reached 40-45%.

I 3 - Irrigation was applied when plant available soil moisture deficit within the root zone reached 60-65%.

I 4 - Irrigation was applied when plant available soil moisture deficit within the root zone reached 90-95%

Soil moisture content was measured twice a week by taking soil samples at 100, 200, 300, 400 and 500 mm depths and determined by gravimetric method. Dragline sprinkler irrigation systems was used. The amount of water required in each experimental plot was determined on the basis of soil moisture deficit (Irrigation, mm = soil moisture at field capacity,mm - soil moisture just before irrigation, mm). The crop was harvested on 22nd August, 1994. Water expense efficiency was determined by culculating the ratio of seasonal water applied and marketable bulb yield.

Experiment 2

Field experiment was conducted in 1994 summer crop growing season (September to December) at Boro experimental station. The experiment was laid out in a randomized complete block design with three replicates. Each experimental plot was 63 m^2. During the crop growing season irrigation was scheduled by approach, where IW is the amount of water applied in each irrigation (mm), E is the cumulative US class A pan evaporation (mm) and R is the rainfall (mm). The irrigation treatments consisted of five different IW/E-R ratios of 1.2 (I1), 0.8 (I2), 0.6 (I3), 0.4 (I4) and 0.3 (I5). A fixed amount of 27 mm of water was applied, determined by plant available soil moisture, rooting depth and permissible soil moisture depletion was applied whenever IW/E-R ratio reached a predetermined value for respective treatments.

After preparing the seedbed, thel field received 62.9 kg/ha N, 94.3 kg/ha P_2O_5 and 62.9 kg/ha K_2O. The fertilizers are incorporated into the soil with a disk harrow. Before planting, the field was irrigated to bring the soil to field capacity. Cabbage (cv.Big cropper) seedlings were transplanted on 19th September, 1994 with 0.5m x 0.5m plant spacing. The crop received second and third application of nitrogen on 15th and 29th October 1994 at the rate of 68.9 kg/ha. Dragline sprinkler irrigation systems was used. Water distribution pattern and application rate for existing sprinkler system was pre-determined.

The crop was harvested during the period 2nd to 15th of December 1994. Water expense efficiency was determined by calculating the ratio of seasonal water application to marketable yield.

Experiment 3

The trial was conducted at Etsha 6 experimental station during summer (September to December) of 1994. The trial was laid out in a randomized complete block design with three replications. The areas of each experimental plot were 90, 54 and 31.2 m^2 for cabbage, tomato and green pepper respectively. The within and between row spacings or cabbage, tomato and green pepper were 0.5 m x 0.5m, 0.3 m x 0.75m and 0.4 m x 0.6 m respectively.

The buffer zone of 1.5 m was provided between the crops. Five treatments based on irrigation schedules at CPE 8-12 (I1), 20-25 (I2), 31-37 (I3), 41-48 (I4) and 52-62 mm (I5) were used. A fixed amount of 18 mm of water calculated on the basis of rooting depth, plant available moisture and permissible soil moisture depletion was applied. Time of irrigation application in the respective treatments was determined by pre-determine cumulative value of daily pan evaporation.

Cabbage (cv. Big cropper), tomato (cv Sixpack) and green pepper (cv Pip) were transplanted on 15th September 1994. Prior to transplanting the experimental plots for cabbage, tomato and green pepper received 50, 75 and 42.5 kg/ha N, 94.3 kg/ha P_20_5, and 62.9, 125 and 62.9 kg/ha K_20 respectively. Cabbage and green pepper crops received 50 and 42.5 kg/ha nitrogen respectively after 3,5 and 7 weeks of transplanting. Tomato crop received 37.5 kg/ha N after 4 and 8 weeks of transplanting. Prior trial planting, the soil water was brought to field capacity by irrigation. The Quick coupling sprinkler irrigation system used was evaluated for water distribution pattern and rate of application before and during the experiment.

The crops were harvested during the period 25th November to 20th December 1994. The water expense efficiency was calculated by dividing seasonal water application with marketable yield.

5.8.3 Results and Discussion

5.8.3.1 Yield, yield components and water expense efficiency

Experiment 1

Water applied, bulb yield and water expense efficiency, yield-water applied relationship of onion for different irrigation schedule treatments are presented in Table.1 and Fig.1. Water application significantly increased bulb yield with maximum marketable yield (60.48t/ha) obtained when irrigation was scheduled at 20-25% plant available soil moisture deficit. Low bulb yields when irrigation was applied at higher soil moisture deficit were associated with a reduction in bulb weight.

Table 1: Marketable yield and water expense efficiency of onion as influenced by irrigation schedules

Treatments	Mean water applied mm	Mean marketable yield t/ha	Mean water expense efficiency mm/t/ha
11: 20 - 25% ASMD	761	60.48	12.59
12: 40 - 45% ASMD	586	52.27	11.22
13: 60 - 55% ASMD	533	38.80	13.75
14: 90 - 95% ASMD	482	29.41	16.40
CV, %	-	2.81	2.76
SED	-	0.90	0.26
LSD (P=0.05)	-	2.03	0.59

The yield reduction were 13.6,35.8 and 51.4%, when irrigation was applied at 40-45, 60-65 and 90-95% compared to 20-25% soil moisture deficit. Water expense per ton of bulb production was significantly different among treatments and minimum when irrigation during the crop growing season was performed at 40-45% soil moisture depletion (Table 1). The results revealed that water application at 20-25% soil moisture deficit was optimum for maximum yield, but irrigation at 40-45% depletion proved beneficial for maximum yield per mm of water expense.

5.8.3.2 Seasonal Water Application - Yield Relationship

Experiment 1

Irrigation schedule at CPE 20-25 mm saved 45% seasonal water application when yield reduction was only 12.4% as compared to CPE 8-12 mm. Considering the marketable yield, and water saving, irrigation schedule at CPE 20-25 mm was found to be appropriate for summer grown green pepper (September to December) in sandy soil.

The regression equation relating marketable yield (Y) and seasonal water application (W) is:

$$Y = -236.54 + 0.83\,W - 0.00057\,W^2 \quad \text{.....(2)}$$

with a coefficient of determination (R^2) = 0.99.

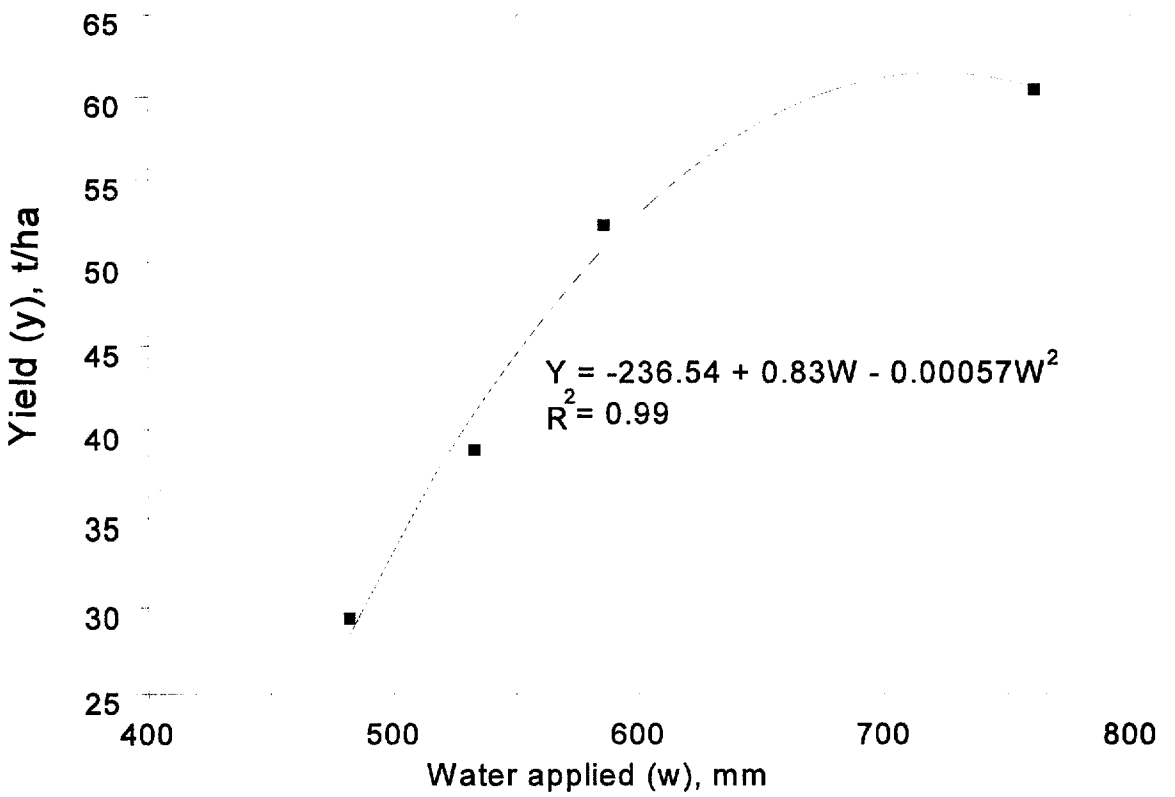

Fig. 1. Relationship between water applied and marketable yield of onion.

The equation exhibites a significant quadratic relationship (Fig 1). The quadratic crop water production function developed in the present study can be used to predict bulb yield of winter onion with a high degree of accuracy restored by the R^2 in the north - western region of Botswana.

Experiment 2

Effect of irrigation schedules on yield, yield components, water expense efficiency and yield-water applied relationship of cabbage are presented in Table.2 and Fig.2. Irrigation schedule at IW/E-R ratio of 1.2 produced maximum head weight marketable heads/m^2 and yield. However irrigation schedule IW/E-R ratio of 1.2 was not significantly different from that of 0.8 in marketable heads/m^2, yield and head weight. Irrigation at IW/E-R ratios lower than 0.8 significantly decreased marketable heads/m^2. Irrigation schedule based on IW/E-R ratio below 0.8 induced soil and plant water stress which subsequently affect the marketable yield of cabbage and its components. The best water expense per tonne of crop production (water expense efficiency) was obtained irrigation was scheduled at 0.8 IW/E-R ratio. Iirrigation scheduled at 0.8 IW/E-R ratio the reduced seasonal water application considerably (31.3%) without

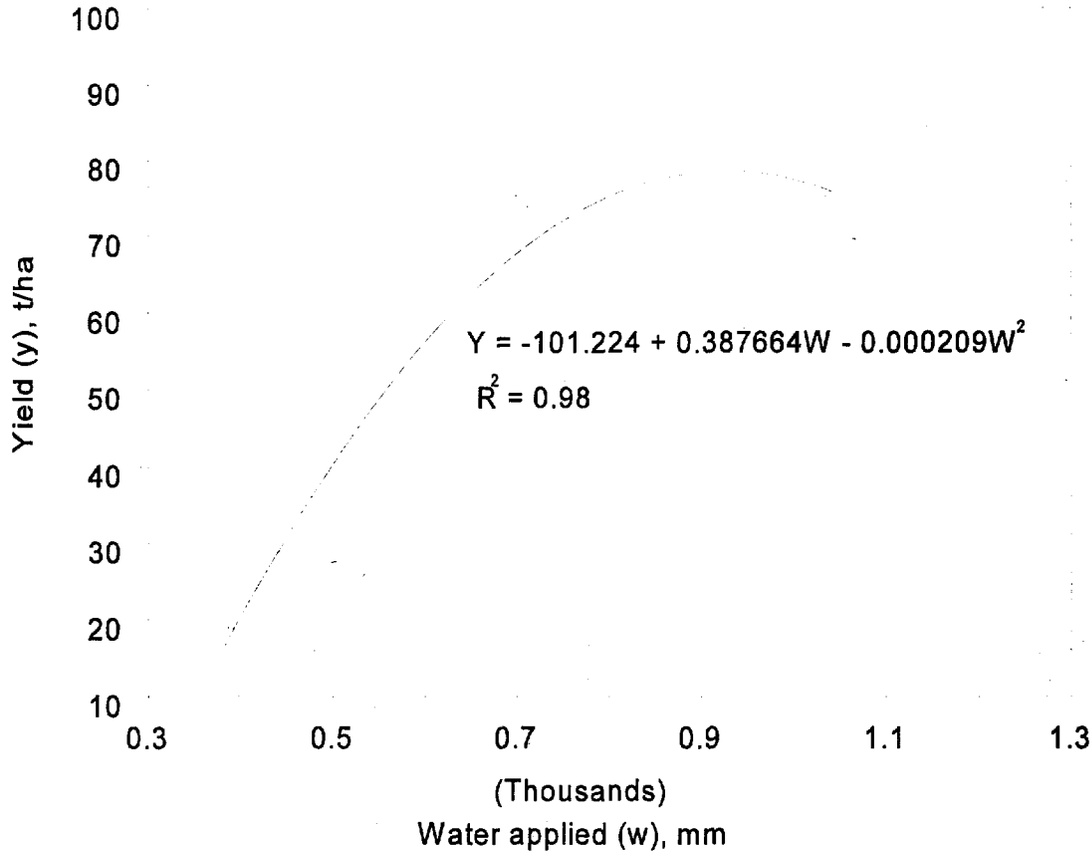

Fig.2. Relationship between water applied and marketable yield of cabbage.

Table 2: Marketable heads, head weight, marketable yield and water expense efficiency of cabbage as influenced by irrigation schedules

Treatments	Mean water applied mm	Mean marketable heads/m^2	Mean head weight kg	Mean marketable yield t/ha	Mean water expense efficiency mm/t/ha
11: IW/E-R = 1.2	1035	3.63	2.07	75.19	13.77
12: IW/E-R = 0.8	711	3.62	2.04	73.79	9.64
13: IW/E-R = 0.6	603	3.23	1.58	50.99	11.83
14: IW/E-R = 0.4	441	2.84	1.02	28.85	15.32
15: IW/E-R = 0.3	387	2.49	0.76	18.93	20.49
CV, %	-	1.71	2.36	3.23	5.43
SED	-	0.04	0.03	1.31	0.63
LSD (P=0.05)	-	0.07	0.07	3.01	1.45

reducing marketable yield significantly when compared to the higher ratio. This irrigation at IW/E-R ratio of 0.8 was found to be suitable for cabbage grown in summer (September to December) in clay loam soil. The relationship between seasonal water application and marketable yield of cabbage is shown in Fig. 2.

Experiment 2

The relationship between mean water applied (W) and marketable yield (Y) for North-Western region of the country can be described by the following significant quadratic equation:

$$Y = -101.224 + 0.387664W - 0.000209W^2 \quad (3)$$

with a coefficient of determination (R^2) = 0.98.

The quadratic crop water production function developed in this study can be used to predict marketable yield of summer cabbage with a high degree of accuracy as shown by RC of 0.98 in north-western region of Botswana.

Experiment 3

The marketable heads/m^2, were not significantly different when irrigation was scheduled at cumulative pan evaporation (CPE) 8-12 mm and 20-25 mm (Table.3 and Fig.3). It decreased significantly when irrigation was scheduled at CPE more than 20 - 25 mm The results revealed that irrigation at CPE more than 20-25mm was inadequate to provide optimum soil moisture for proper plant growth and development, which subsequently reduced the number of marketable heads per unit area. The mean head weight and marketable yield of cabbage increased significantly when irrigation was scheduled at CPE 20-25mm compared with 8-12, 31-37, 41-48 and 52-62mm CPE. Poor performance at lower CPE than 20-25 mm could be due to reduced head weight caused by excess soil moisture which results:- poor aeration and nitrogen leaching. Whereas at CPE higher than 20-25mm the same could atributed to soil moisture deficit. Considering marketable yield and water economy, the scheduling of irrigation at 20-25 mm Cpe was found to be optimum for cabbage grown during summer (September to December) in Sandy soil.

The water applied, fruit weight, marketable yield water expense efficiency and water applied-yield relationship of tomato (Table.4 and Fig.4). The mean fruit weight and marketable yield were significantly influenced by irrigation.

Table 3: Marketable heads, head weight, marketable yield and water expense efficiency of cabbage as influenced by irrigation schedules

Treatments	Mean water applied mm	Mean marketable heads/m^2	Mean head weight kg	Mean marketable yield t/ha	Mean water expense efficiency mm/t/ha
11: CPE = 8 -12mm	1215	3.88	1.94	74.99	16.20
12: CPE = 20 -25 mm	675	3.85	2.01	76.84	8.78
13: CPE = 31 -37 mm	495	3.61	1.50	54.10	9.17
14: CPE = 41 - 48 mm	405	2.99	0.98	28.86	14.04
15: CPE = 52 - 62 mm	351	2.51	0.58	14.61	24.03
CV, %	-	1.56	1.81	1.35	2.08
SED	-	0.04	0.02	0.55	0.24
LSD (P=0.05)	-	0.09	0.05	1.27	0.56

There was 11.3, 28.2, 35.6 and 48.9% decrease in fruit weight with irrigation at CPE 20-25, 31-37, 41-48 and 52-62 mm over CPE 8-12mm. Marketable yield of tomato increased significantly when irrigation was scheduled at CPE 8-12 mm, compared with 20-25, 31-37, 41-48 and 52-62 mm CPE. Percentage reductions in marketable yield were 4.0, 31.9, 49.7 and 74.7 when irrigation was scheduled at CPE 20-25, 31-37, 41-48 and 52-62 mm respectively compared to CPE of 8-12mm due to reduction fruit weight.

The water expense per ton of marketable crop production increased significantly when irrigation was scheduled below than 20mm and above 48 mm CPE (Table 4). On the basis of marketable yield, fruit size and water economy, irrigation schedule at CPE 20-25 mm seem to be optimum for tomato grown during summer (September to December) in sandy soil.

Effect of irrigation schedules on water applied, fruit weight, marketable yield, water expense efficiency and water applied yield relationship of green pepper are presented in Table.5 and Fig.5). Irrigation significantly increased the fruit weight and marketable yield. The minimum fruit weight (55.6g) was recorded with irrigation at CPE 52-62 mm due to severe wilting caused by soil moisture deficit (Table 5). Irrigation scheduled also influenced the water expense efficiency significantly. Irrigation at below and above than 20-25mm CPE increased the water expense per ton of marketable crop production (Table.5).

Irrigated scheduled at below and above than 20-25 mm CPE increased the water expense per ton of marketable crop production (Table 5). Irrigation schedule at CPE 20-25 mm saved 45% seasonal water application when yield reduction was only 12.4% as compared to CPE 8-12 mm. Considering the marketable yield, and water saving, irrigation schedule at CPE 20-25 mm was found to be appropriate for summer grown pepper (September to December) in sandy soil.

Experiment 3

The relationships between mean water applied and marketable yield of cabbage, tomato and green pepper grown under same soil, climate and irrigation regimes as presented in Figures 3 to 5 and Table.3 to 5. The regression equations are:

Cabbage: $Y = -108.567 + 0.436659W - 0.000235W^2, R^2 = 0.99$ ..(4)
Tomato: $Y = -34.397 + 0.152700W - 0.000072W^2, R^2 = 0.95$ ..(5)
Pepper: $Y = -22.404 + 0.079751W - 0.000036W^2, R^2 = 0.98$ ..(6)

The above regression equations. The mean water applied for ranged from 351 to 1215mm and 387 to 1359 mm for tomato and green pepper. The above equations exhibit significant quadratic relationship and can be used. The predict marketable yield of each crop in sandy soil of the north western region of Botswana.

Table 4: Fruit weight, marketable yield and water expense efficiency of tomato as influenced by irrigation schedules

Treatments	Mean water applied mm	Mean fruit weight g	Mean marketable yield t/ha	Mean water expense efficiency mm/t/ha
11: CPE = 8 - 12 mm	1359	98.37	40.87	33.26
12: CPE = 20 - 25 mm	749	87.22	39.23	19.05
13: CPE = 31 - 37 mm	549	70.65	27.84	19.73
14: CPE = 41 - 48 mm	414	63.32	20.55	20.15
15: CPE = 52 - 62 mm	387	50.28	10.36	37.39
CV, %	-	2.99	2.40	3.66
SED	-	1.81	0.54	0.77
LSD (P=0.05)	-	4.16	1.26	1.79

Table 5: Fruit weight, marketable yield and water expense efficiency of green pepper as influenced by irrigation schedules

Treatments	Mean water applied mm	Mean fruit weight g	Mean marketable yield t/ha	Mean water expense efficiency mm/t/ha
11: CPE = 8 - 12 mm	1359	83.40	19.79	68.89
12: CPE = 20 - 25 mm	747	76.93	17.33	43.12
13: CPE = 31 - 37 mm	549	68.66	10.04	54.84
14: CPE = 41 - 48 mm	414	63.15	5.87	70.54
15: CPE = 52 - 62 mm	387	55.61	2.08	186.57
CV, %	-	1.38	3.39	4.99
SED	-	0.78	0.30	3.46
LSD (P=0.05)	-	1.80	0.70	7.98

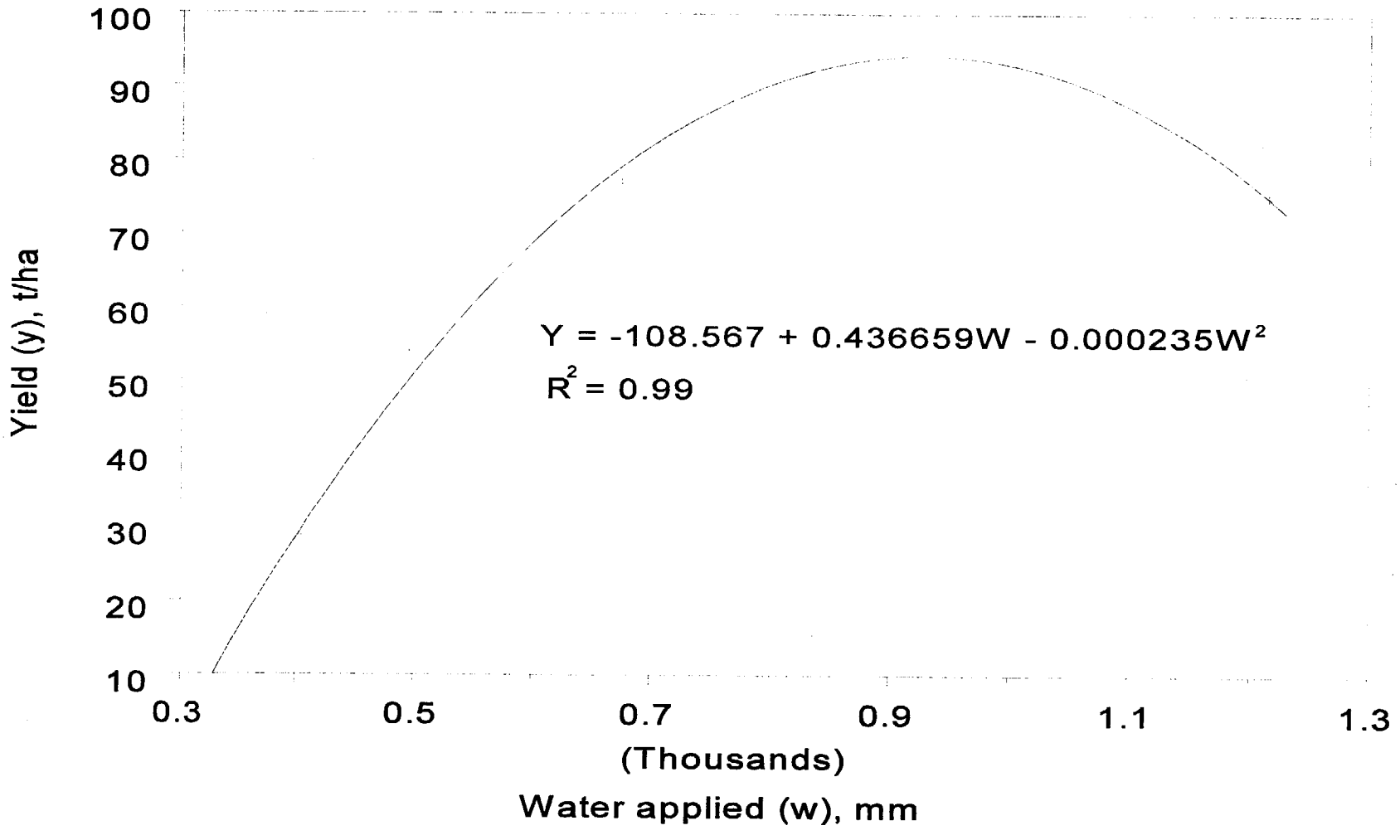

Fig.3. Relationship between water applied and marketable yield of cabbage.

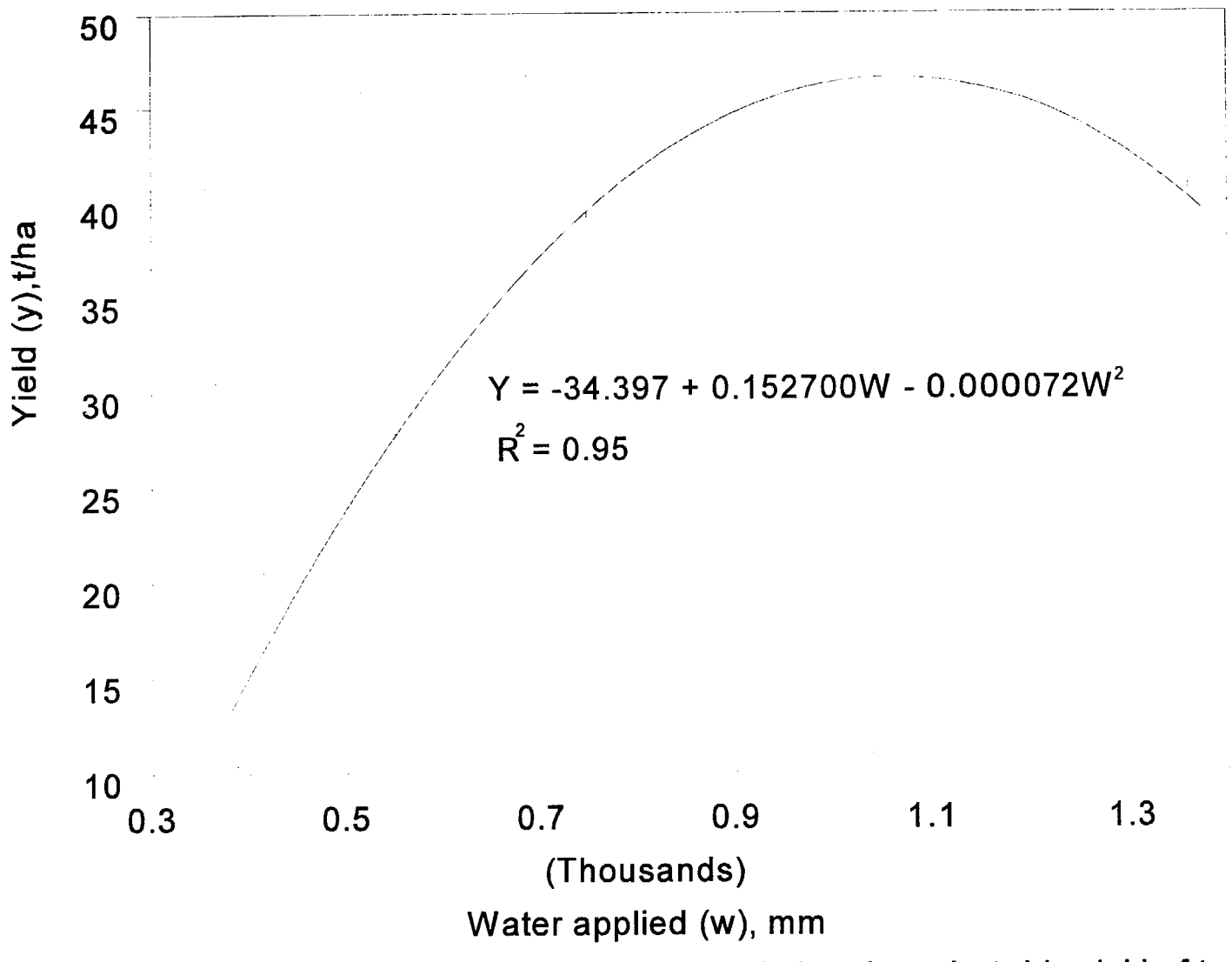

Fig.4. Relationship between water applied and marketable yield of tomato.

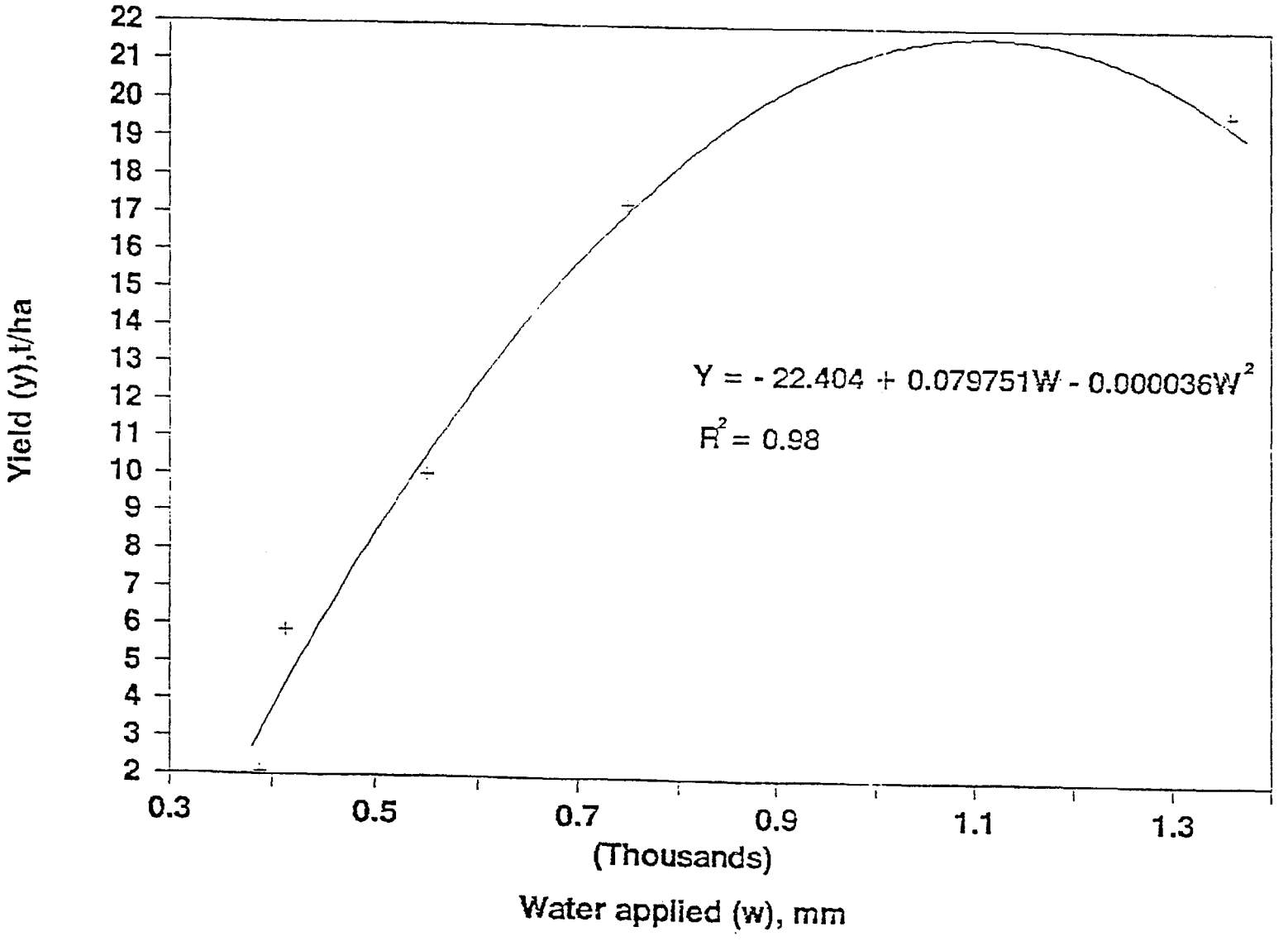

Fig.5. Relationship between water applied and marketable yield of green pepper.

5.8.4 Conclusions

The following conclusions can be drawn from three trials conducted at Boro and Etsha 6 experimental stations.

(i) scheduling irrigation at 20-25% soil moisture deficit was maximum for potential bulb yield of onion, but scheduling at 40-45% depletion proved beneficial for optimum yield and water economy.

(ii) irrigation scheduling at IW/E - R ratio of 0.8 was optimum for maximum yield and water economy of cabbage. Scheduling at IW/E - R ratio of 1.2 gave no yield improvement but increased the water expense by 45.6%.

(iii) scheduling irrigation at CPE 20-25 mm was appropriate for maximum yield and water economy of cabbage. Irrigation at CPE 8-12 mm decreased the yield due to excess soil moisture caused by frequent irrigation.

(iv) scheduling irrigation at CPE 20-25 mm was ideal for optimum yield and water economy of tomato and green pepper. Irrigation at CPE 8-12 mm increased yield by 4.2 and 14.2% for tomato and green pepper respectively, but increased water expense by 45%.

(v) the mean water applied and marketable yield of onion, cabbage,tomato and green pepper showed significant quadratic relationship. The mathematical equations developed in the present studies can be used to predict marketable yield and irrigation water neended in north-western region of Botswana.

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5.9 Tillage and Crop Effect on Residual Soil Water and Physical Properties.

5.9.1 Justification

In crop rotation systems, legume plants are often used mainly to incorporate nitrogen to the soil. Besides nutrients, there are other interactions that occur under tillage and cropping systems. A succeeding plant in a crop rotation may affect soil water content during the season depending on the leaf canopy, plant residue and water use.

Leguminous plants such as cowpea dry up when they reach maturity, greatly reducing or stopping soil water loss by transpiration. The water under this crop remains in the soil as residual moisture and may be used by the next crop in the following season.

Present knowledge on the interactions between tillage and cropping systems on soil physical properties is very little. Soil moisture is a limiting factor for crop production under semi-arid regions. Farming techniques that conserve soil moisture may improve crop yield and so they need to be investigated and under understood well.

Objective

To evaluate the effect of tillage and cropping systems on soil strength, bulk density and soil moisture content.

5.9.2 Materials and Methods

This experiment was carried out for the first season at Mmamashia on a farmer's field during the 1994/95 growing season. The soil type at the experimental site was a ferric luvisol with a textural class of sandy loam and was moderately well drained. The experimental plot was 40 m by 64 m and contained three blocks of 40 m by 20 m. Tillage treatments included ploughing once (single ploughing) and double ploughing (i.e. ploughing following the first rain and ploughing again after the second rain.). Four cropping systems were used as subplots. The trial was ploughed and planted on 6th of January, 1995.

Experimental Design

The two tillage treatments single ploughing (SP) and double ploughing (DP) were assigned to the main plots in a randomized complete block design. The main plots were split and four cropping systems were applied to the subplots. The following treatments were randomized within the tillage plots:-

1. Continuous Sorghum, 0 fertilizer (CSOF)

2. Continuous Sorghum, + fertilizer (CSF)

3. Sorghum after a legume (SL)

4. Legume after sorghum (LS)

In the CSOF "treatment", no fretilizer was applied and for CSF "treatment" 40 kg/ha N was applied into the seed bed. In all plots 30 kg/ha P was applied as a basal dressing. Segaolane and Tswana cowpeas or blackeye was planted in six row plots of 10 m length. The following measurements were made at the mid season ie during May and these are bulk density and shear strength. Soil moisture content was measured weekly throughout the season with use of the neutron probe. Soil physical measurements were made from two blocks only.

5.9.3 Results and Discussion

There was no yield data available because the farmer decided to harvest all the plots and let the cattle to graze the stover before we could harvest. Although there is no yield data to support these observations, it was found that plant establishment for both legume and sorghum was better under double ploughing than single ploughing treatment. Both sorghum and legume plants were taller at pre-flowering stage in the double ploughed soil and had bigger heads at harvest stage. Therefore higher yield was expected in the double ploughing treatment than in the single ploughed soil.

5.9.3.1 Bulk Density

Soil bulk density (Table 1) was not significantly different throughout the profile between the tillage treatments and among cropping systems (P = 0.05). Though the differences were none significant, bulk density values (1.51 g/cc) were higher in the double plough than in the single (1.50 g/cc) plough treatment. Probably the tillage and rooting systems of the two crops did not alter soil structure significantly in this layer. For depth range 15-30 cm (Fig. 1), bulk density was smaller under double ploughing (1.53 g/cc) than under single ploughing (1.56 g/cc). Bulk density values were persistently highest up to 22.5 cm of depth in the treatment of continuous sorghum with no fertilizer as compared to other crop systems (Table 1). The measurements for bulk density were taken during the mid season (3rd of March, 1995) about three months after ploughing and planting. Since sampling was done rather late on a sandy textured soil of which particles are held together by weak cohesion forces, the soil may have settled to a similar parking fraction. This would result in similar bulk density values and hence the lack of statistical differences between the two tillage system.

5.9.3.2 Soil Strength

Table 2 indicates that shear strength was significantly different (P = 0.05) for soil depth of 5 cm and the differences were none significant for ranges between 5 and 45 cm in the tillage treatments and throughout the profile in the cropping systems. In Fig. 2, the plot of shear strength versus depth shows that shear strength was higher in the double plough than in the single plough treatment for the depth range of 0-15 cm.

Since the differences in shear strength among treatments were not significant, the high values of shear vane in the double plough treatment may not be considered as a sign of compaction.

5.9.3.3 Soil Moisture Content Dynamics

Total rainfall at the experimental site for the months of January to May, 1995 was 203.8 mm. As indicated by fig. 6, more than 80% of this rain fell in March alone and the rest of the rain that fell was small and poorly distributed during the growing season. There was more water stored under double than under the single plough treatment as indicated by fig 3 for both 30 and 90 cm soil depth. This may be an indication that double ploughing the soil prepares the seedbed better than single ploughing. Soil moisture depletion was generally high under legume and low under sorghum for the double plough treatment (Fig. 4). A good plant establishment in the double plough treatment resulted in increased plant cover or canopy that probably cut down on soil water loss by evaporation from this treatment. Contrarily, the soil under legume plant in the same treatment did not have a cover as good as that under sorghum plant and therefore, it was exposed to more evaporative demands. As a result more water depletion was observed on soil with less cover, that is, under legume. The other factor for higher moisture content under sorghum in the double plough treatment is that the high plant cover prevented raindrops from destroying soil structure. Therefore it could be that more water infiltrated into the soil and increased water storage better than under legume. However, for the legume plant with less plant cover, raindrops destroyed soil structure resulting in decreased infiltration rates and water was lost through run-off instead of being stored in the soil. Table 3 and 4 indicates that there was no significant differences in soil moisture for 30 and 90 cm soil profiles between tillage treatments and among cropping systems.

Fig. 5 indicates that in the single plough treatment, the legume depleted less water than the sorghum plant. Sorghum plant establishment was poor on this treatment and therefore there was no advantage of plant cover for either crop. Roder et. al., 1989 observed that legume used more water than sorghum plant when the tillage was uniform.

5.9.4 Conclusions

The effects of tillage and cropping systems did not cause statistical differences in bulk density within depth 30 cm. However, Bulk density was lower under double plough for layers deeper than 20 cm. Shear strength was significantly higher in double ploughed soil than in single ploughed soil for 5 cm depth but the differences were statistically not different for depth ranges between 20 and 45 cm. Soil moisture content was higher under sorghum than under legume plant in the double plough treatment. However, soil moisture was high under legume for single ploughed soil. Starting from mid (March) till end of season there was more soil moisture stored under double than under single ploughing treatment for both 30 and 90 cm soil profile.

Table 1: The effect of cropping systems, single, and double ploughing on soil bulk density (g/cc) variation

	Depth Range (cm)			
TRT#	0.0 - 7.5	7.5 - 15.0	15.0 - 22.5	22.5 - 30.0
SP	1.48	1.53	1.50	1.63
DP	1.48	1.50	1.46	1.60
CV %	4.21	4.88	1.22	3.19
SED (16)	0.02	0.03	0.01	0.02
P(>F)	0.82	0.53	0.12	0.35
CSOF	1.50	1.57	1.52	1.64
CSF	1.48	1.49	1.49	1.59
SL	1.47	1.47	1.45	1.57
LS	1.47	1.52	1.46	1.66
CV %	4.24	6.65	3.39	6.15
SED (8)	0.10	0.05	0.03	0.05
P(>F)	0.75	0.27	0.06	0.26
G/MEAN	1.48	1.51	1.48	1.62

TRT is treatment, G/meam is grand mean, SED is the standard error of the difference and the number besides SED refers to the number of observations.

Table 2: The effect of cropping systems, single, and double ploughing on soil shear strength (kPa).

	Soil Depth (cm)				
TRT#	5	10	20	30	40
SP	10.25	9.00	11.69	34.81	69.59
DP	13.66	11.38	8.31	33.88	61.13
CV %	3.56	6.94	77.78	8.75	90.72
SED (16)	0.15	0.25	2.75	1.06	20.96
P(>F)	0.03	0.07	0.44	0.54	0.76
CSOF	13.13	10.50	9.00	37.63	74.63
CSF	12.13	10.62	9.88	26.88	58.88
SL	11.50	9.50	9.25	37.25	60.93
LS	10.95	10.30	11.88	35.63	67.00
CV %	39.69	29.56	50.83	48.97	45.51
SED (8)	2.37	1.51	2.54	8.41	14.87
P(>F)	0.81	0.88	0.67	0.55	0.72
G/MEAN	11.93	10.19	10.00	34.34	65.36

TRT is treatment, G/meam is grand mean, SED is the standard error of the difference and the number besides SED refers to the number of observations.

Table 3: The effect of cropping systems, single, and double ploughing on soil moisture (cm) at 30 cm Depth.

	Dates between May and July, 1995						
TRT#	5/4	20/4	3/5	18/5	8/6	21/6	26/7
SP	2.62	1.38	2.60	1.59	1.15	1.02	0.91
DP	2.65	1.50	2.75	1.77	1.32	1.16	1.01
CV%	34.6	60.2	25.5	47.8	26.7	86.4	84.9
SED (16)	0.32	0.31	0.24	0.28	0.12	0.33	0.29
P(>F)	0.94	0.77	0.65	0.30	0.69	0.75	0.78
CSOF	2.73	1.53	2.79	1.81	1.26	1.10	0.95
CSF	2.43	1.25	2.55	1.47	1.12	1.02	0.89
SL	2.59	1.35	2.69	1.69	1.17	1.08	0.93
LS	2.78	1.63	2.68	1.75	1.39	1.15	1.07
CV %	13.0	22.1	18.7	21.8	24.4	28.1	24.4
SED (8)	0.17	0.16	0.25	0.18	0.15	0.15	0.12
P(>F)	0.19	0.11	0.82	0.30	0.33	0.86	0.45
G/mean	2.63	1.44	2.67	1.68	1.24	1.09	0.95

TRT is treatment, G/meam is grand mean, SED is the standard error of the difference and the number besides SED refers to the number of observations.

Table 4: The effect of cropping systems, single, and double ploughing on soil moisture (cm) at 90 cm depth.

	Dates between May and July, 1995						
TRT#	5/4	20/4	3/5	18/5	8/6	21/6	26/7
SP	10.72	7.47	7.96	6.60	5.81	5.71	5.48
DP	12.02	9.05	9.31	8.05	7.13	6.91	6.80
CV %	23.0	40.4	35.2	47.2	56.9	62.2	57.0
SED (16)	0.93	1.18	1.07	1.22	1.30	1.39	1.24
P(>F)	0.39	0.41	0.43	0.44	0.50	0.55	0.48
CSOF	11.81	8.92	9.14	7.67	6.72	6.44	6.24
CSF	10.89	7.41	8.10	6.81	6.07	5.90	5.82
SL	11.18	7.93	8.43	7.31	6.09	6.02	5.87
LS	11.59	8.81	8.88	7.69	7.02	6.88	6.62
CV %	11.1	16.8	17.15	17.9	17.5	20.7	18.9
SED (8)	0.63	0.69	0.74	0.66	0.57	0.65	0.58
P(>F)	0.48	0.12	0.52	0.48	0.27	0.45	0.50
G/MEAN	11.37	8.27	8.64	7.33	6.47	6.31	6.14

TRT is treatment, G/meam is grand mean, SED is the standard error of the difference and the number besides SED refers to the number of observations.

Fig.1: Variation of bulk density with depth under different cropping and cropping systems.

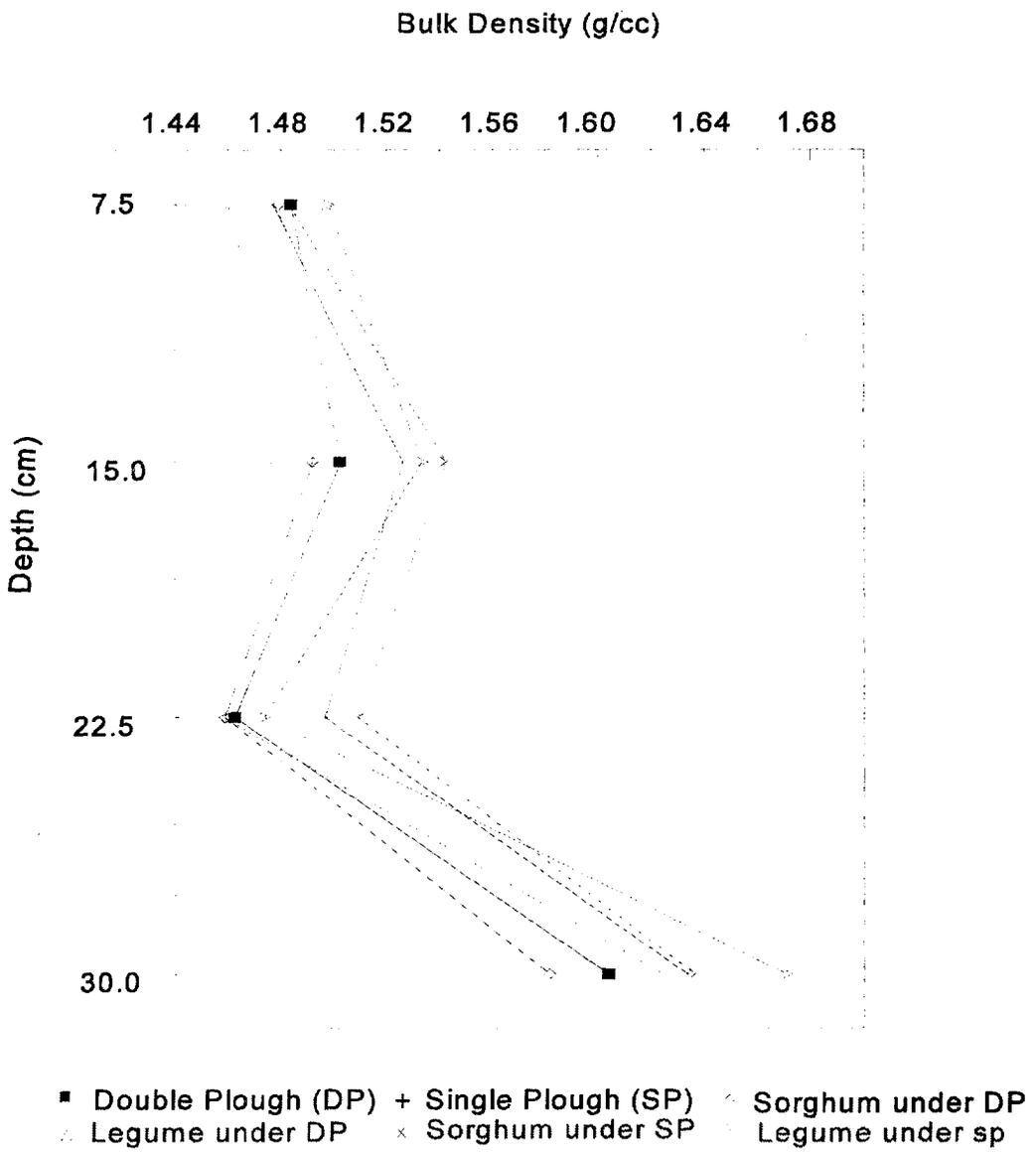


Fig. 2: Variation of soil shear strength with depth under different tillage and croppling.

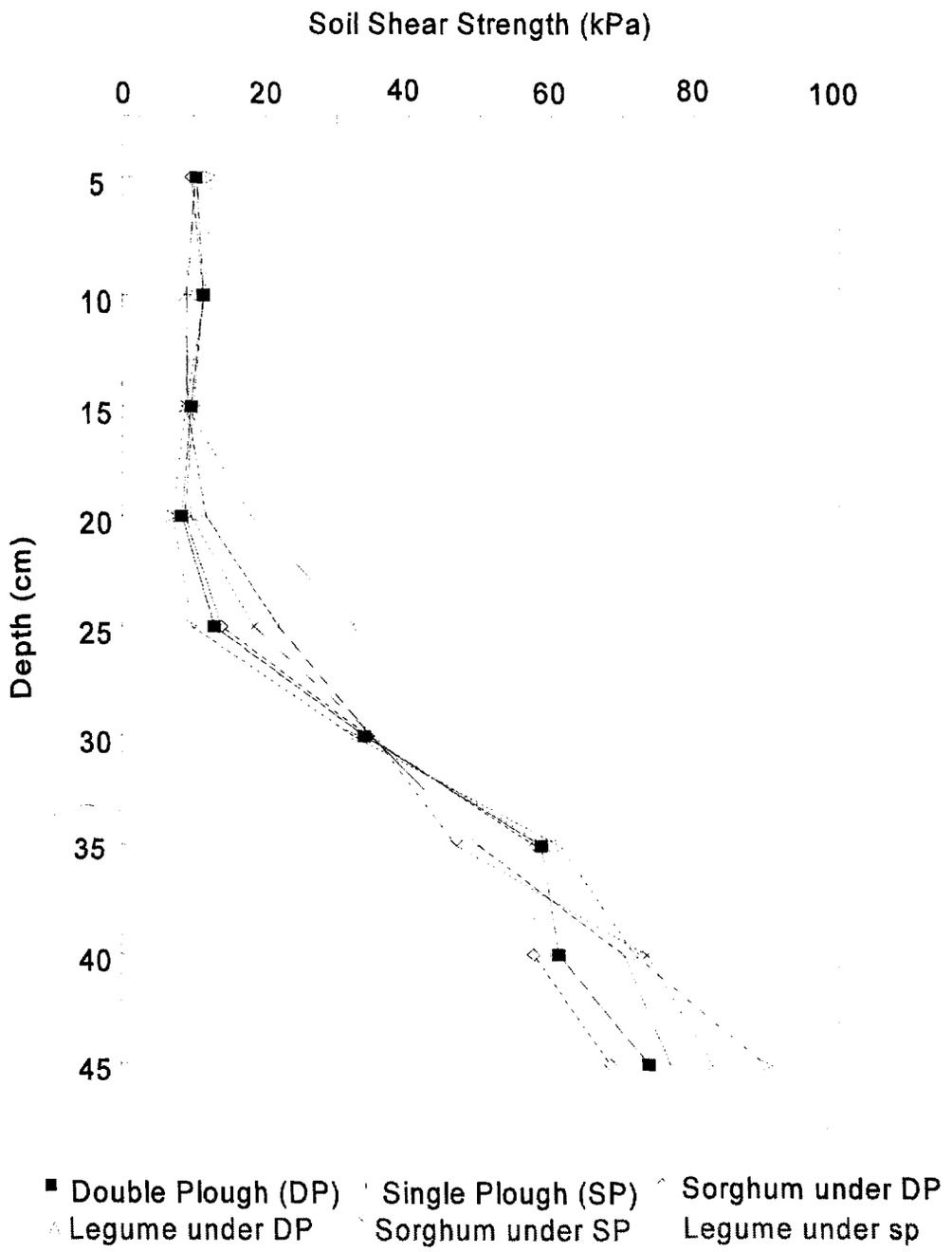


Fig.3: Variation of soil moisture content with time in different tillage systems.

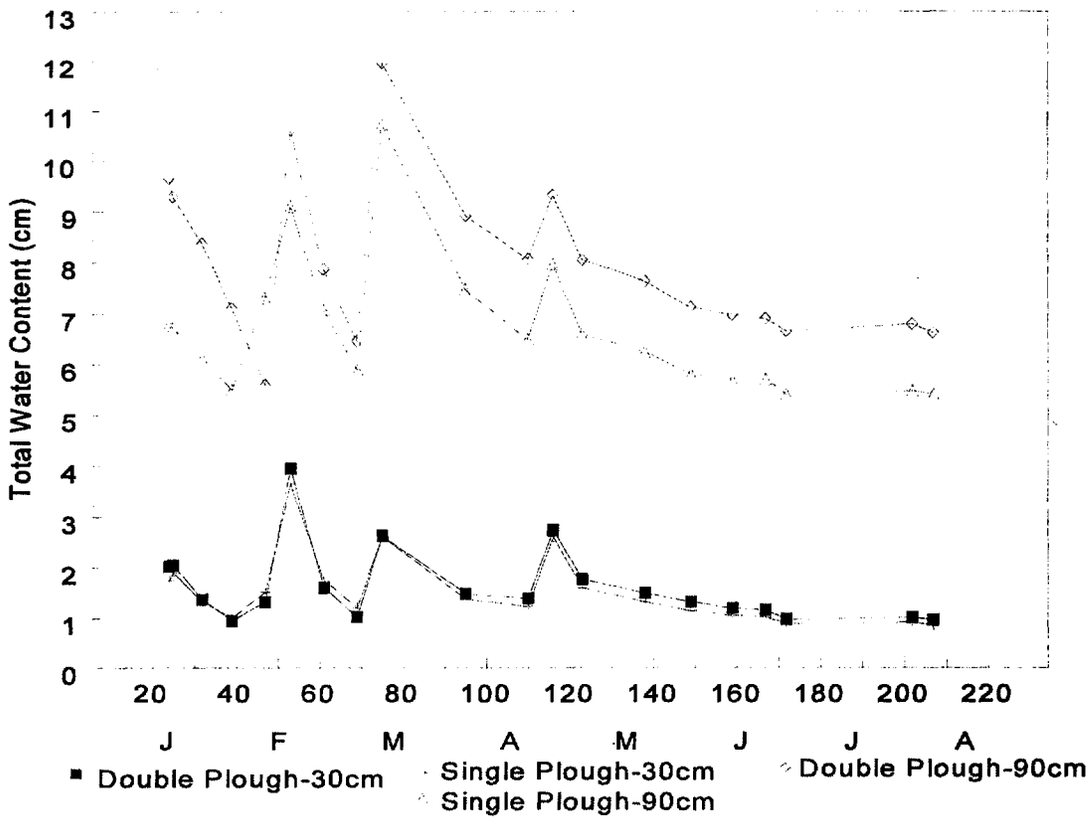


Fig. 4: Variation of soil moisture content with time under sorghum and legume in a double ploughed soil.

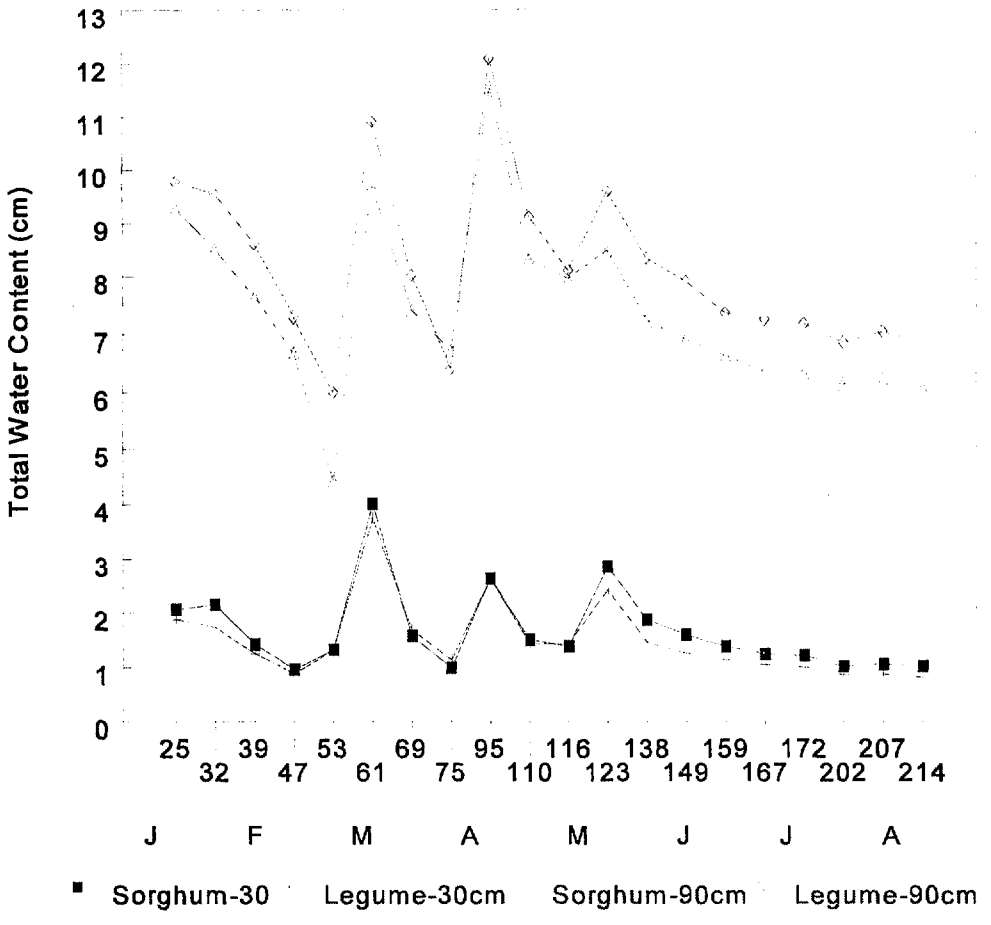


Fig.5: Variation of soil moisture content with time under sorghum and legume in a single ploughed soil.

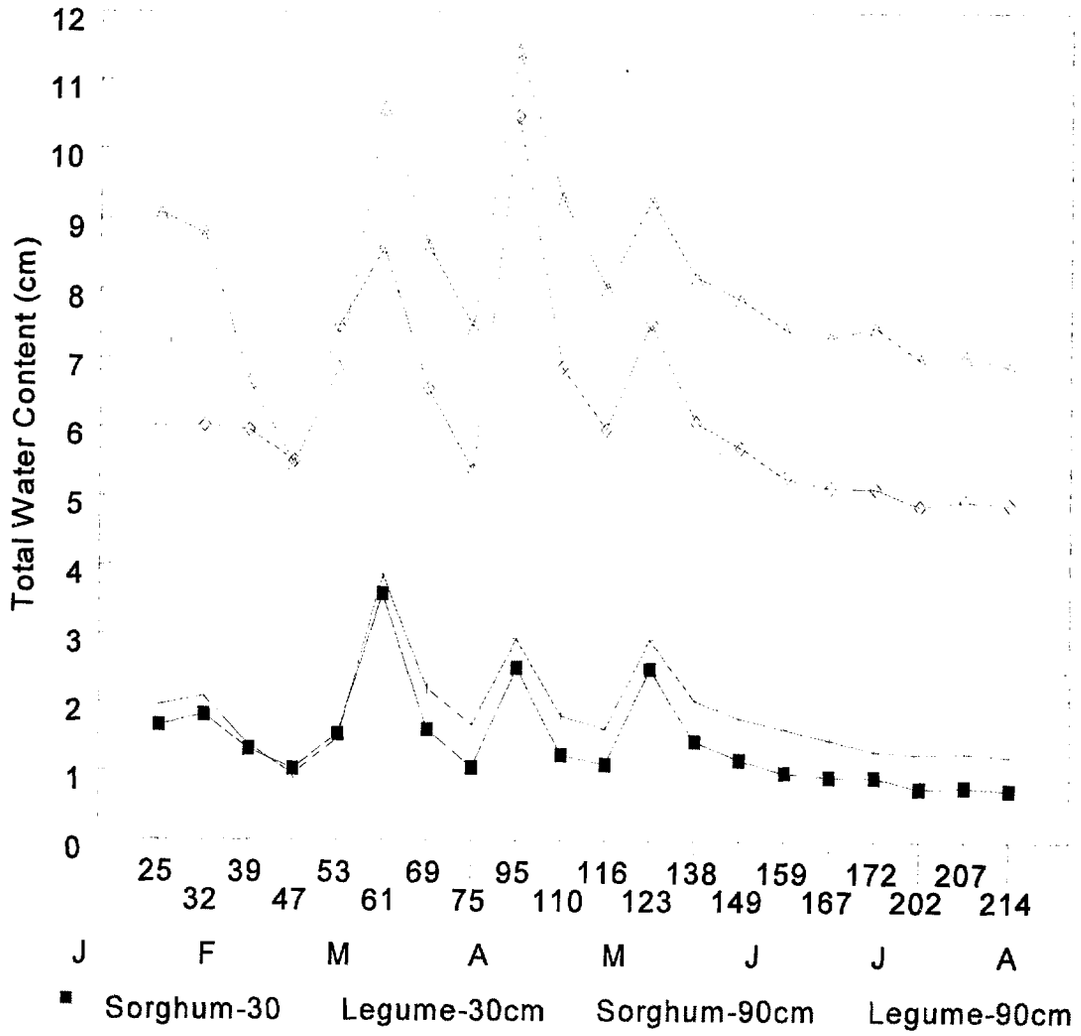
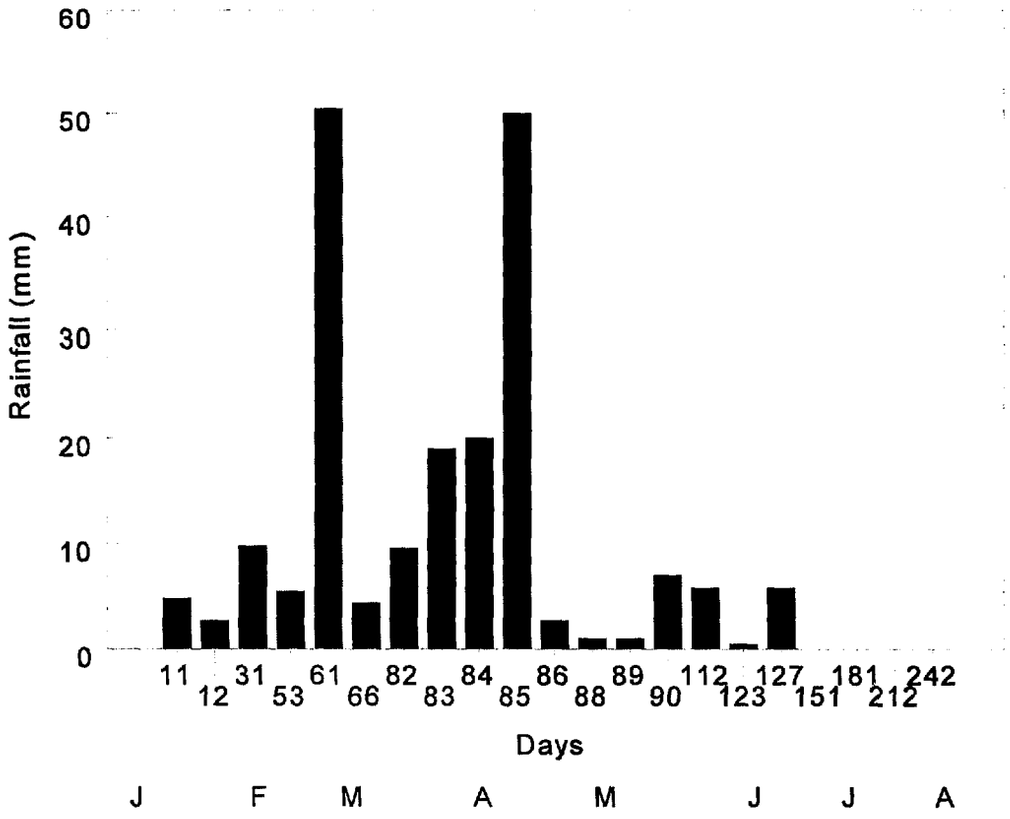


Fig.6: Dairy rainfall at Mmamashia experimental site for the period January to May, 1995



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5.10 Control of *Cynodon dactylon* in animal draught systems

5.10.1 Introduction

Cynodon dactylon is a highly competitive perennial weed which is important throughout the tropics and subtropics (Bryson and Wills, 1985). It is a major grass weed of the country. The weed is well adapted to the tillage method used in the low input extensive crop production systems in Botswana. Surveys conducted indicated that Cynodon occurs in most fields at high levels, particularly in the Southern, Ngamiland and Central agricultural regions (Phillips, 1992).

Elder (1951) observed that *Cynodon dactylon* root stocks were killed when exposed to winter freezing or to dry hot weather. Winter cultivation reduces the stand of *C. dactylon*. Long term field trials conducted over 8 years in Botswana demonstrated that *C. dactylon* can be controlled for 2-3 years using tractor (Bacon and Marsh, 1987, Riches, 1987 and Phillips, 1993).

On average winter and spring ploughing reduced grass regrowth during the season by 49% and double spring ploughing by 40% compared with single ploughing. Crop yield increases following these treatments were more than 100%. Use of cultivator was also tested for removal of rhizomes but it had no consistent effect on the control of *C. dactylon.* Double ploughing using tractor draught is now recommended for *C. dactylon* control and has been described (Agrifact, April 1992).

Use of animal draught power for ploughing is not easy in both winter and spring and not as effective as tractor draught for double ploughing. Thus, for resource poor farmers who cannot afford tractor draught, the recommendations of double ploughing is inappropriate.

Cynodon is mostly widespread in smallholder cropping systems where the mouldboard plough is commonly used. Infestations are particularly serious where tillage is limited to a single shallow plough pass each season.

The objective of the study is to determine the potential benefit of "double" ploughing with animal draught power.

5.10.2 Materials and Methods

A trial was established at two farmer's fields near Mmopane village, about 15km south-west of Sebele. Both sites have a serious infestation of *C. dactylon* an had never been ploughed with tractor. Treatments were applied in three consecutive seasons as indicated in Table 1.

Table 1: The sequence of the treatments of the two sites.

Year	Treatments			
1991/92	DS	W+S	ES+H	SP
1992/93	DS	DS	ES+H	SP
1993/94	SP	SP	SP	SP

DS = Double spring ploughing, W+S = Winter + spring ploughing, ES+H = Early spring plus harrow and SP = single ploughing (Control).

The trial design was a randomized complete block with four replications consisting of plots of size 6m x 20m. Fertilizer was applied at a rate of 200 Kg/ha, N:P:K (2:3:2). The ploughing treatments were done using a mouldboard plough pulled by a span of six or eight cattle.

In the first year, the average depth of ploughing was 21cm for first winter ploughing and 17cm for first spring ploughing. The depth of ploughing was measured at 10 random points along the furrow in the plots after each ploughing treatment.

Winter ploughing was done on 18 June 1991 at Dube's and 29 July at Mogae's after about 60mm of rainfall.

All the plots were row planted with maize on the 5 December 1991 and six days later at Mogae's field after about 16mm rain three days earlier. The crop suffered from severe drought stress and livestock damage. Ten 0.25m^2 quadrat were sampled to determine the weed burden by dry matter before ploughing at both sites.

A visual assessment of *C. dactylon* regrowth was made on 23 January 1992 at both sites. The level of regrowth was further measured by harvesting all the *C. dactylon* top growth on the 0.25m^2 quadrats laid systematically in each plot on the 03 March 1992.

In the second year (1992/93), Mogae's field was abandoned due to lack of draught power but the same tillage treatments were applied on the same plots at Dube's site. Winter ploughing and the first of the double spring ploughing were done at the same time on 24 December 1992. The second ploughing of the double ploughing treatment, harrowing and single spring ploughing were done on 16 February, 1993.

The initial infestation of *C.dactylon* was measured in each plot before ploughing to determine the residual treatment effects from the previous season in each plot. Another assessment was done at harvest, on the 21 May 1993.

In the third year, all plots were single ploughed and assesments of C.dactylon regrowth done as in previous seasons. The first assessment was done in January and the percentage cover in February 1994. Maize grain yield was also measured at the end of the season. Data for the percentage growth were transformed to a logarithmic scale before analysis.

5.10.3 Results and Discussion

The results indicated that the residual effect of double ploughing on *Cynodon* reduction is only evident after two seasons. Single ploughing plus harrowing had the highest *Cynodon* infestation even higher than the single ploughing. Results of the initial infestation of *C. dactylon* are presented in Table 2.

Table 2: Initial infestation (Dry weights) of *C. dactylon* before first winter and spring ploughing at Mogae and Dube sites, 1991/92 season.

Treatment	Dube's site	Mogae's site	mean
	----------	(g/m^2	----------
Winter ploughing	151 ± 45	112 ± 24	132
First Spring ploughing	72 ± 27	51 ± 19	61

Overall, there was much more infestation in plots at the time of winter ploughing compared to spring ploughing (Table 2). Mogae's site had less *C. dactylon* infestation at the time of the two ploughings compared to Dube's site. The reasons for the discrepancy are probably partly natural senenscence and grazing.

The first season results indicated that there was no significant difference between winter + spring ploughing versus single ploughing, and double spring ploughing versus single ploughing at Dube's site (Table 2). At Mogae's site both double ploughings did better than the control (single ploughing). The two double ploughings were slightly different at Dube's site (P = 0.05) but not at Mogae's site. Winter + spring ploughing was more effective in *C.dactylon* reduction than double spring ploughing at Dube's site.

Table 3: Effect of ploughing treatments on *C. dactylon* percentage cover, for the 1991/92 season.

Treatment	Dube's site	Mogae's site
	---------- % cover ----------	
Winter and Spring ploughing	23.8	27.5
Double Spring ploughing	33.8	26.2
Early Spring ploughing and Cultivate	76.2	85.0
Single ploughing	31.2	71.2
SED (9 df)	3.436	7.817
C.V (%)	11.8	21.1

Early spring ploughing and harrowing later in the season had the highest *C. dactylon* infestation compared to other treatments at both trial sites. At Mogae's site early spring plough and harrow had the same level of infestation as the control but Dube's site had significantly more *C. dactylon* top growth cover. It appears the zigzag harrow created a favourable seedbed for the rhizomes to grow even though large quantities of rhizomes were removed during harrowing.

The results of the final growth assessment for the two sites are given in Table 4 and data were transformed to a logarithmic scale for analysis.

Table 4: *Cynodon dactylon* top growth dry matter, harvested on the 3 March, 1992 at both sites.

Treatment	Dube,s site	Mogae's site
	---------- (log g/m^2) ----------	
Winter and Spring ploughing	4.179 (67.1)*	3.956 (54.5)
Double Spring ploughing	4.079 (63.0)	4.022 (58.3)
Early Spring ploughing and harrow	4.696 (114.3)	4.755 (117.0)
Single ploughing	3.737 (45.0)	4.384 (81.26)
SED (9 df)	0.2103	0.1513
C.V (%)	7.1	5.0

* Values in brackets are the untransformed values.

At Mogae's site winter + spring ploughing and double spring ploughing treatments had similar levels of infestation at harvest. The two treatments significantly reduced *C. dactylon* top growth ($p<0.05$) by about 33% and 28% of the infestation compared to single ploughing respectively. At Dube's site the two double ploughings were not significantly different ($p>0.05$) from the control. Early spring ploughing and harrowing had significantly higher ($p<0.05$) dry weight of *C. dactylon* top growth than the other treatments.

The early spring ploughing + harrowing appeared to enhance *C. dactylon* growth. The grass growth on the single ploughed plots senesced earlier than on other plots and seem to have been suffering greater moisture stress.

In tractor draught systems *C. dactylon* top growth was reduced by 60% and 33% in winter +spring and double spring ploughing respectively (Bacon and Marsh, 1987). The poor results from animal draught power might be due to the shallower penetration of the mouldboard plough resulting in poor quality ploughing and missed strips. Bacon and Marsh (1987) observed that animal draught was less effective method of tillage to control *C. dactylon* than tractor draught. They also observed that initial weed density affected weed control.

The results of the second season (1992/93) are given in table 5. Early spring ploughing + harrowing treatment had significantly ($p<0.05$) more *C. dactylon* top growth dry matter than other treatments. The residual effect of previous treatments was not apparent.

Table 5: The initial *C. dactylon* infestation before ploughing on 24 December 1992, at Site 1.

Treatment	Weight (g/m^2)
Winter and spring ploughing	16.9
Double spring ploughing	21.0
Early spring ploughing and harrowing	29.8
Single spring ploughing	19.9
SED	4.376
C.V (%)	28.0

Cynodon was generally low in all the plots because of cattle grazing. The assessment of top growth of *C. dactylon* resulting from different treatments for 1992/93 season are presented in table 6. Winter + spring ploughing and Double spring ploughing had similar levels of infestation which were significantly lower than the other two treatments. Percentage reduction of *C. dactylon* top growth achieved by these treatments was more than 95% compared to the control. Early spring ploughing + harrowin tripled *C. dactylon* top growth compared to the control.

Table 6: C. dactylon top growth dry weight, harvested on the 21 may 1993 and the yield of stover harvested at Dube's site.

Treatment	Cynodon top dry matter	Yield of stover
	(g/m_2	(Kg/ha.)
Winter + spring ploughing	1.3	1199
Double spring ploughing	1.1	968
Early spring ploughing + harrowing	81.6	338
Single ploughing	26.8	403
SED	4.502	201.6
CV (%)	9.0	39.0

The double ploughings were similar and significantly ($p<0.05$) different from early spring ploughing + harrowing and the control for stover yield (Table 6). The latter were not significantly different. The results for the third season are shown in table 7.

Table 7: The effect of tillage treatments on *Cynodon* dry weight in January 1994 and % cover in February 1994 at Dube's site.

Time of ploughing			Dry weight	% cover
1991/92	1992/93	1993/94	$g\ m^{-2}$	%
Single	Single	Single	12.4	30.5
Early spring & Harrow	Early spring & Harrow	Single	71	46.5
Winter + spring	Double spring	Single	1.2	7
Double spring	Double spring	Single	1.2	9
		S E (9 df)	1.9	3.4

There was a high significant difference ($p<0.001$) among the tillage treatments with double ploughings giving very low *Cynodon* infestation and percentage cover compared to single ploughing and single ploughing plus harrow. It seems the early spring and harrow created a favourable seedbed for both rhizomes and stolons to grow dispite having removed the propagating units.

The results of the assessment of top growth of *Cynodon* at harvest are presented in table 8. The results indicate that there was a significant ($p<0.001$) residual treatment effect on regrowth. Double ploughing gave the largest residual effect of about 95%, followed by winter + spring double ploughing with 33% compared to the control. The single plough + harrow and continous single ploughing significantly higher ($p<0.001$) *Cynodon* infestations.

Table 8: Residual effect of tillage treatments on *Cynodon* dry weight at harves after 3 seasons.

Time of ploughing			Dry weight
1991/92	1992/93	1993/94	g m^{-2}
Single	Single	Single	171
Early spring & Harrow	Early spring & Harrow	Single	275
Winter + spring	Winter + spring	Single	114
Double spring	Double spring	Single	9
		S E (9 df)	27***

The maize stover yield was also measured at the end of the season and results are presented in Table 9.

Table 9: Residual effect tillage treatments on maize stover yield after three seasons.

Time of ploughing			Stover yield
1991/92	1992/93	1993/94	kg ha^{-1}
Single	Single	Single	994
Early spring & Harrow	Early spring & Harrow	Single	818
Winter + spring	Winter + spring	Single	1547
Double spring	Double spring	Single	2155
		S E (9 df)	460

The double ploughings treatment increased stover yield. Statistics at analysis showed no significant difference (p.0.05) among the treatments. The double spring ploughing for two seasons followed by single ploughing in the third season yielded significantly higher ($p<0.05$) than continous single ploughing and early spring plough + harrowing for two seasons by 117% and 163% respectively.

5.10.4 Conclusions

The three year results have shown that double spring ploughing reduced Cynodon by 28% and 95% in the first and second year respectively and the residual effect of 95% control was observed in the third year. This is an indication that double ploughing needs to be repeated for at least two seasons to obtain effective control of Cynodon. However, the study will be continued to determine how long the residual effect last.

6.0 PRODUCTION SYSTEM PROGRAMME

6.1 Millet Variety Trial

6.1.1 Introduction

Millet(*pennisetum typhoides)*, is a popular crop in the Central, Francistown and Ngamiland regions. In Francistown region the crop is a staple food. The flour is used to prepare porridge while stover is fed to livestock. In the Ngamiland region, the flour is used for porridge or fermented to make alcoholic beverages (beer). Millet is also drought tolerant due to physiological characteristics such as a deep root system.

A comparison of millet to sorghum in terms of cash value shows that millet supersedes sorghum in the Francistown area. The prices of five kilogram pockets of millet and sorghum flour are P9.67 and P6.25 respectively(unpublished report). Observations are that, there is generally a gradual increase in the area planted under millet every year. Mostly farmers grow Serere 6A though some landraces can also be found.

Objective

To verify the performance of promising pearl millet varieties under on-farm conditions.

6.1.2 Materials and Method

Two millet lines (SDMV 89004, ICMV 88908) were included under on-farm research with Serere 6A as a control. Seeds were given to established research oriented farmers in the Central and Francistown regions. Farmers were allocated 200g of seed of each line to plant in adjacent plots of 500m^2 area. The trials were implemented and managed by the farmers. Due to large variability among the data values, the yield data were logarithmical transformed before the analysis of variance was done.

6.1.3 Results and Discussion

The results are presented in Table 1.

Table 1: Millet grain yield during 1994\95 Cropping Season

Name of variety	Yield (log)	Actual yield (kg\ha)
Serere 6A (29)	5.52	398
SDMV 89004 (28)	5.40	435
ICMV 88908 (30)	5.53	402
CV%	10	26
MEAN	5.48	411 ns

There was no significant yield difference between the means of the three varieties ($p > .05$).

6.2 Groundnut Variety Trial

6.2.1 Introduction

Groundnuts, (*Arachis hypogea*) have been grown for years in Botswana. However, the crop is grown mostly at subsistence level, especially in the Bobirwa and North East districts. Few cases of commercial production are found in the Barolong and Tuli block farms. Most households consume groundnuts as a snack.Its high protein content, provides a nutritious diet. The hulls can be fed to livestock. Groundnuts have a high oil content, thus there is potential for extracting the oil on commercial basis, which has not been tried in the country. The common variety grown locally is Sellie, an improved variety from South Africa. However, some landraces are also found. Sources of seed include previous harvests, traders and other farmers.

Objective

To determine whether the introduction of a new variety can increase the level of groundnut production at household level.

6.2.2 Materials and Method

Groundnut varieties(ie., Flower-11 and 55-437) were compared to Sellie, a popularly grown variety, under on-farm management conditions. Fifteen farmers were selected to implement and manage the trial in Mahalapye, Pelotshetlha and Francistown areas. Each farmer was given 500g seed of each variety to plant in adjacent plots of 500 m^2. The yield data were transformed using log-transformation because of large variation among the values.

6.2.3 Results and Discussions

The yield results are shown un Table 2 below.

Table 2: Groundnuts grain yield across sites during 1994\95 Cropping Season

Variety	Yield (log)	Actual yield (Kg\ha)
SELLIE	3.76	92
FLOWER 11	4.24	104
55 - 437	3.86	96
CV%	22	70
MEAN	3.95	97

6.3 Jugobean Variety Trial

6.3.1 Introduction

A review of previous reports on jugobean production by Doku Karikari (1971) suggested that the jugobean (*Vigna Subteranea*) is indigenous to Africa. It is adapted to a wide range of soils, is drought tolerant and thrives under conditions of high temperature and low rainfall where other pulses fail (Doku, 1969).

Although the jugobean has been cultivated in Africa for a long time, very little agronomic work has been done on the crop in Botswana. Jugobeans fetch very high prices in the market in the country. A Kilogram of dry threshed beans sells for P3.00 which comes to P210.00 for a 70Kg bag. They are eaten fresh and dry. Low acreage of the crop is planted due to lack of seed and high yielding varieties.

Objectives

The objective of the trial on-station was to assess the yield potential of locally available lines of jugobeans.

6.3.2 Materials and Methods

Five jugobean lines were obtained from farmers in the North East District to be evaluated at Pelotshetlha experimental site. The lines used were MA-15A dark cream with V-shaped purple colour surrounding a white eye, N-100 completely purple with a white eye, 0-15A dark cream with a white eye, 0-34F light cream with a light purple ring around a white eye and 0-17C cream with a dark purple ring around a white eye. The experiment was laid out in a randomised complete block design with four replications. Plot sizes were 10m x 5m with an inter-row spacing of 50cm between rows and intra-row spacing of 30cm. Days to maturity and yield were measured.

6.3.3 Results and Discussion

Table 1 shows the mean yield results of the five lines. There were no significant yield difference among the lines. However, MA-15A with an average yield of 350kg per hectare and O-34F with an average yield of 303kg per hectare, showed some potential for high yielding.

Some of the major problems encountered were late and low rainfall. Termites also did some damage at pod-setting. All lines were harvested at 150 days after planting.

Table 3: Mean Yield for 5 Jugobean Lines 1994/95 Season:

Variety	Mean yield (kg/ha)
0-17C	231.0
0-15A	170.0
MA-15A	350.0
N-100	259.0
0-34F	303.0
CV	44.36
LSD.O5	443.8
LSD.01	622.3
MEAN	263.0

References

Doku, E.V. 1969: **Growth habit and pod production in bambara groundnuts. Ghana Journal of Agricultural Science(2: P 91-95).**
Doku, E.V. and S.K. Karikari. 1971: **Babara groundnut Economic Botany, 25 (P. 255-262):**

6.4 Sorghum Variety Trial

Objectives

The objectives of this study were:

i) To test the performance of the four released varieties with and without Kraal Manure.

ii) To demonstrate to both farmers and extension personnel the performance of four released varieties of sorghum during field days.

6.4.1 Justification

The Department of Agricultural Research has recently released four new varieties of sorghum ie One hybrid, two food types and one malting type. Though these new lines were previously evaluated on-farm and ranked by farmers as being superior in terms of food and malting qualities, the fertility issues were never addressed. It is hypothesized that improving the fertility status of the soil will improve yields of these varieties.

6.4.2 Materials and Methods

The four varieties namely Phofu, Mmabaitse, Mahube and BSH1 were compared against Segaolane and were evaluated with or without 10 tonnes/ha. The area per plot per variety was 250 m2. The trial layout was a split plot in a randomised complete block design with Manure as main plot and varieties as subplots. In this trial the farmer was treated as a replication, with seven (7) farmers in Francistown region and five (5) in Pelotshetlha. The data was analyzed using a SAS programme.

6.4.3 Results and Discussion

Table 4 shows the results of the varieties as they performed with and without Kraal Manure and at two regions. The results indicates that varieties were significantly different, but the effect of kraal manure and the interaction were not for both Francistown and Southern regions. The lack of effects of manure may be explained by the fact that, though kraal manure improves the structure and moisture retention of the soil, sometimes there is little or no nutrients in it to support plant growth and development. This is particularly true when kraal manure is left on soil surface after spreading or uncovered during spreading as nitrogen is lost through volatilisation. In the table above, the mean yields are much higher for the southern Region than for Francistown due to the differences in rainfall obtained at these regions.

Table 4: Effect of kraal manure on yield of sorghum varieties in Francistown and Southern region - 1994/95

Treatment	Yield(kg/ha.) Fransistown	Southern
Segaolane + NoKM	371	260
Segaolane + KM	403	423
Mmabaitse + NoKM	195	565
Mmabaitse + KM	372	812
Phofu + NoKM	202	540
Phofu + KM	269	566
BSH1 + NoKM	302	440
BSH1 + KM	586	688
Mahube + NoKM	235	180
Mahube + KM	279	464
Grand Mean	321	492
CV (i) Main plot KM	70	76
(ii) Sub plot variety	47	60
Main effect of Manure		
SED	35.847	83.03
$LSD_{0.05}$	72.448	170.04
Main effect of variety		
SED	56.679	131.281

NOTE: +NoKM = No Kraal Manure Applied and +KM = Kraal Manure Applied.

6.5 *Cynodon dactylon* Survey

6.5.1 Introduction

The Weeds Section of the Department of Agricultural Research has for many years taken keen interest in the control of *cynodon dactylon*. However, in some regions, the extent of infestation has not yet been established. Also, the magnitude of Cynodon as a constraint to crop production from the farmers point of view has not been ascertained. Current control practices are also not known. Hence it was found necessary to make a formal survey so as to address some of these issues.

Objectives

The objectives of the survey were to:

(a) establish if *cynodon dactylon* was a problem in crop production within specified regions

(b) Ascertain current practices farmers are using in an effort to control *cynodon dactylon*

6.5.2 Methodology

The survey was conducted on farmers in the Gaborone and Southern Agricultural regions. The villages in the Gaborone Region were; Bokaa, Monwane, Gatshephe, Matswi, Mmopane and Kopong and in the Southern Region were Motsentshe, Borobadilepe, Dipotsana, Tswidi Diabo, Mmathethe and Lotlhakane. A one to one interviewee to interviewer approach was used in conducting the interview. Most questionnaires were closed ended.

6.5.3 Results

The survey was administered on 114 households chosen at random. Of these, only 77 farmers had cynodon infected fields and are the ones which are used in Section 4.0.

(i) **Relationship between years of using a given field and Cynodon incidence**

In order to address this issue, farmers were asked to state the number of years they have been cropping their fields and to also state whether their fields were infested with Cynodon. The results are shown in Table 5 below. Figures in parenthesis are actual number of farmers for each respective category.

The results show that 74% of the fields have been under cropping for over 10 years. The relationship between years of cropping and cynodon infestation is shown in Table 5b. The expected values(E_{ij}) were derived from Table 5a. The calculated Chi-square for these values is 23.7 with a tabular value of 5.99 at 5% level of significance and 9.21 at 1% level. These show that there is a dependence relationship between years of cropping and cynodon infestation.

Table 5a: Cynodon infestation relative to number of years of cropping same field

Years of Cropping Same Field	Cynodon Infestation (Percentage of Farmers) Yes	No	Total Number of farmers
1-5	23.53(4)	76.4(13)	17
6-10	46.15(6)	53.85(7)	13
>10	79.76(67)	20.24(17)	84
Totals	77	37	114

Note: For each year category, values in brackets indicate number of respondents.

Table 5b: Expected values under the hypothesis of independence

Years of Cropping	Response(No. Of Farmers) Infestation	No Infestation	Chi-Square
1-5	11.5	5.5	
6-10	8.8	4.2	
>10	56.7	27.3	
Calculated			23.7
Tabular: @ (5%)			5.99
@ (1%)			9.21

(ii) Approximate area infested with Cynodon

Table 6 shows the extent of cynodon infestation within fields using percentage of respondents as an indicator. Indications are that, 60% of infestations are in slight to heavy patches with only 22% in more than half or the whole field.

(iii) Spread of Cynodon to other areas within fields and fields abandoned due to Cynodon infestation

Table 7 shows percentage of farmers who perceives that cynodon infestation is spreading and those who have abandoned cynodon infested fields/plots. It shows that 92.2% of the farmers indicated that once a field has been infested with Cynodon, it keeps on spreading. The table also indicates that 17% of the respondents abandoned Cynodon infested fields.

Table 6: Percentage of farmers per approximate area Of cropping land infested with *cynodon: dactylon*(n=77)

Area Infested	Percentage of Farmers
Whole Field	11.69
Over Half of the Field	10.39
Less Than Half of Field	18.18
Patches Heavily Infested	25.97
Patches Slightly Infested	33.77

Table 7: Percentage of Farmers who perceives that Cynodon is spreading to other parts of the field and those who have abandoned Cynodon infested fields(n=77):

Item		Percentage of Farmers
Spread of Cynodon:	Yes	92.2
	No	5.2
	Don't Know	2.6
Abandoned Infested Field:	Yes(Patches)	12.98
	Yes(Whole Field)	3.90
	No	83.12

(iv) **Current measures taken to control Cynodon by farmers**

Farmers were asked to indicate current methods used to control Cynodon. Responses are shown in Table 8.

The results are that, (i) 61 of the farmers do not control Cynodon and (ii) 18% use hand operations which include pulling of Cynodon stolons. However, it is interesting to note that about 12 percent of the farmers use improved techniques such as double ploughing(DP) and that none of the respondents use chemical control measures.

Table 8: Percentage of farmers using certain Cynodon control measures (n = 77):

Control Measure	Percentage of Farmers Using Measure
DP(winter + spring)	9.09
DP(SPRING + spring)	2.6
Herbicides	0.00
Fallow	3.9
Plough + Harrow	5.2
Hand Removal	18.18
Do Nothing	61.03

Note: DP = Double Ploughing

Conclusions

(i) Based on the percentage of fields with Cynodon infestation, Cynodo is indeed a problem in crop production.

(ii) Fields which have been cultivated for more than 10 years, are more likely to be infested than those which have been cultivated for fewer years.

(iii) There is a likelihood of Cynodon spread to other parts of the field with time through cultivation.

(iv) Very few farmers use improved methods of control and none of the interviewees used chemical control.

6.6 Sebele standard row planter adoption study

6.6.1 Introduction

Adoption studies are effective ways of monitoring and evaluating progress in technology transfer. Also, information obtained can be used to the efficiency of adaptive research. However, as it is a relative term, there is no single definition of adoption. In each given case, measurable indicators can be used to define intended adoption study(ies).

Development and nation-wide testing of this planter by the Evaluation of Farming Systems and Agricultural Implement Project (EFSAIP), started during the late 70's with an objective of developing an alternative to the Safim planter. Further on-farm evaluation was also carried by the Agricultural Technology Improvement Project (ATIP) during the early 80's. In 1984, the planter was recommended to the Department of Crop Production and Forestry (DCP&F) as an alternative to the Safim planter.

Since then, more effort has been put into it's promotion and dissemination. Up to December 1993 the DCP & F, had distributed a total of 2584 Sebele Standard planters nation wide. At current prices each planter costs about P360(ie., OSCA prices for 1995), of which through the ALDEP scheme farmers are required to pay only 15%. Implications are that, the government has since December 1993 used about P930,240 on this planter alone.

Despite of the development and promotional effort by different organisations, little is known about the adoption of this planter.

Objectives

The main objective of this study was to assess the adoption of the Sebele Standard Planter by farmers as indicated by the proportion of farmers owning this planter type and the extent of its use.

6.6.2 Methodology

A questionnaire was to be administered in the Southern and Central Agricultural region. These regions were chosen based on their history with the use of row planters.

The target group was only those farmers with animal drawn single row planters. A sample size of not more than 20 farmers per extension area was used.

Verifiable indicators used in the analysis include the following: (i) planter ownership by type, (ii) extent of use as indicated by current cropping area row planted using this planter type and (iii) index of acceptability.

6.6.3 Results and Discussion

In the Southern Region, the questionnaire was administered to 142 farmers in 8 extension areas covering 4 of the 5 districts and in the Central region, the same questionnaire was administered in 54 farmers covering 8 extension areas within two agricultural districts. Of these farmers, 30 farmers in the Southern and 23 in the Central region owned the Sebele Standard planter.

(i) Planter ownership by type as an indicator of adoption

Table 9 shows planter ownership by type. Overall indications, are that, the Sebele planter can be found in only 31% of the respondents as compared to 60% for the Safim planter. In Borolong, Ngwaketse Central and South, 29% of farmers own the Sebele planters. These are districts with a long history with planters and by then, the Safim planter was the only one in offer. Hence as you move towards the northern part of the country(ie., Ngwaketse North, Mahalapye and Bobonong districts), there are more Sebele planters than Safim planters in circulation.

The implication of this is that, there are higher chances of the Sebele planter being adopted as you move from South to North.

Table 9: Percentage planter owners) by type per extension area

District	Total Number Of Planters	Percentage by Planter Type Sebele	Safim	Others
Borolong	40	12.5	80.0	7.5
N/South	3 5	8.6	88.6	2.8
N/North	41	61	29.2	9.8
N/Central	26	7.7	92.3	0.0
Mahalapye	13	53.9	30.8	15.4
Bobonong	20	75.0	20.0	5.0
S/Phikwe	20	20.0	50.0	30.0
Total	195	31.3	60.00	8.70

Note: N= Ngwaketse

(ii) Area planted by planter type as an indicator of adoption

Table 10 shows percentage area row planted for each planter type using area row planted for the base year 1994/95 cropping season. The implication of this table is that of the 814 hectares row planted during 1994/95 cropping season, the Sebele standard planter was used in only 23% of it as compared to 66% for the Safim planter.

Table 10: Percentage Area Row Planted by Planter Type Per Extension Area

Extension Area	Total Area Row Planted (ha)	Percentage Area Row Planted By Planter Type Sebele	Safim	Others
Borolong	220	16.8	49.9	33.3
N/ South	294.9	5.7	91.2	3.11
N/North	219	54.8	36.1	9.1
N/Central	80	11.9	88.1	0.0
Bobonong	110	50.0	26.4	23.6
Mahalapye	31	100.0	0.0	0.0
Selibe Phikwe	49	24.5	62.3	13.3
Totals	1003.9	28.0	62.3	13.5

Note: N = Ngwaketse

(iii) Age of planter type as an indicator of adoption

As additional information to area and planter ownership, the age of planter by type is presented in Table 11. It shows that the probability of finding farmers with a new Safim planter type is less than that for the Sebele standard(0.01 compared to 0.03). Also, while there has been fluctuations with time in the probability of finding farmers with Sebele standard planter, for the Safim planter type, there are less chances of finding farmers with new ones with time.

Table 11: Frequency distribution of planter type by age(n=142):

Planter Type	Age Category		
	<1	1-5	>6
Sebele Standard	.03	.18	.04
Safim	.01	.26	.37
Others	.01	.02	.08

(iv) Adoption rates

Given that the Sebele standard planter has been in circulation for 11 years (ie.,since 1984) and using area as an indicator of adoption, the adoption rate can be estimated at 2.65 % per year(ie., at estimated 28% of row planted area in 1995. Also, using planter ownership, the rate of adoption can be estimated at 2.8% per year given a 31% Sebele standard planter type ownership over 11 years.

Thus, the two indicators give similar adoption rates. However, as there is no standard adoption rate for any given technology, it is up to the developers to decide whether these rates are high enough/acceptable.

(v) Index of acceptability

To determine the index of acceptability, farmers who own the Sebele Standard planter were asked if there were using it, and if so, on what proportion of the cropping land. The index of acceptability was then calculated as follows;

$$I_a = (C + A) / 100$$

I_a =Index of acceptability

Where: C =The percentage of the farmers interviewed who own Sebele standard planter and who used the planter during 1993/95 cropping season on at least part of their crop land

A =(average area row planted using the sebele standard planter) / average area ploughed by farmers who row planted using the sebele standard planter)

(va) Southern Agricultural region: Of the 30 interviewed farmers who own the sebele planter, all of them were using it in at least part of their cropping area. The average area row planted by the 30 farmers using the sebele planter was 5.38 hectares. The average area ploughed by the same farmers was 5.38 hectares.

Thus: **C = (30 / 30) * 100 = 100%**
A = (5.4/5.4) * 100 = 100%
Then: **I = (100 *100) / 100 =100**

(vb) Central Agricultural Region: Of the 23 interviewed farmers who own the sebele planter, 17 of them were using it in at least part of their cropping land. The average area row planted by the 17 farmers using the sebele planter was 5.8 hectares. The average area ploughed by the same farmers was 8.29 hectares.

Thus: **C= (17 / 23) * 100= 74%**
A= (5.8 / 8.29) * 100= 70%
Then: **I_a= (74 * 70) / 100= 51.8**

A rule of thumb for interpreting the index of acceptability is that, a technology has a good chance of being adopted if I_a exceeds 25 and "C" is equal to or greater than 50(Hildebrand and Poey, 1985). These conditions are met in both regions indicating that there is a very high chance for the planter to be adopted in both regions.

6.6.4 Conclusions

There is strong evidence as indicated by the index of acceptability that the sebele standard planter will be adopted by farmers. Indications are that, a large number of those farmers who own the planter are using it in a large proportion of their land(ie., hence large "C" and "A" for both regions). There are also indications that, farmers in the Central region are more likely to adopt the Sebele planter than those in the Southern region.

References

Hildebrand, P. and F. Poey, 1985. **On-Farm Agronomic Trials in Farming Systems Research and Extension.** Boulder Colorado, USA: Lynne Rienner.

7.0 SUPPORT SERVICES

7.1 Seed Multiplication Unit

Seed processing commenced on June 3, 1994 and continued until January 13, 1995. Initially, seed was purchased from contract seed growers, but as the season progressed, grain was purchased from non-seed growers to be used as seed on the basis of germination and purity analysis only. In order to meet the national requirements for maize and millet seed, 802 MT and 36 MT had to be obtained from Zimbabwe and Namibia respectively.

The seed processing machinery breakdowns were minimal as compared to the previous seasons. This led to the relatively smooth running of the seed processing activities. Only two processing shifts were engaged with a total target seed output of 40 MT per day. Initially, the shifts were only engaged during weekdays, but as the season progressed, it became necessary to even engage them over the weekend.

Seed distribution began in early October throughout the whole country. All the districts were initially supplied with 50% of their seed requirements, then steady increases effeacte until 100% of each district was met. By mid-December all the districts had been supplied with 100% of their seed requirements.

For the first time in the history of the Seed Multiplication Unit (SMU), seed was sold to contract seed growers at a nominal price. The idea of selling seed to contract seed growers was adopted to minimise, though to a very limited extent, the production costs of basic seed.

Data on seed purchased, handled, processed, distributed and sold to contract seed growers by SMU is presented in Tables 1 - 5.

Table 1: Total Quantities of Seed Purchased by the Seed Multiplication Unit during 1994/95

Crop	Local Purchase	Foreign Purchase	Total
	(Metric	Tonnes)	
Sorghum			
Segaolane	3473.40	-	3473.40
Marupantse	119.49	-	119.49
Town	3.29	-	3.29
Total	3597.18		3597.18
Millet			
Serere 6A	13.23	-	13.23
Okashanal	0.07	35.00	35.07
Total	13.30	35.00	48.30
Maize			
Kgalagadi	1031.10	802.00	1833.10
Early Pearl			
Total	1031.10	802.00	1833.10
Cowpeas			
Blackeye	8.96	-	8.96
Tswana	34.37	-	34.37
ER 7	2.24	-	45.57
Total	45.57		45.57
Groundnuts			
Sellie	41.80	-	41.80
Total	41.80	-	41.80
Sunflower			
Russian No.4	7.98	-	7.98
Total	7.98		7.98

Table 2: Total Seed Handled by SMU during 1994/95

Crop	Carry over Seed	Purchases	Total
	Metric Tonnes		
Sorghum	633.44	3597.18	4230.62
Millet	6.66	48.30	54.96
Maize	214.75	1833.10	2047.85
Cowpeas	12.15	45.57	57.72
Groundnuts	6.54	41.80	48.34
Sunflower	12.9	7.98	20.88

Table 3: Total Seed Processed by SMU during 1994/95

Crop	Variety	Total (TM)
Sorghum	Segaolane	2328.23
	Marupantse	240.17
	Town	11.48
	8D	0.75
	Phofu	1.22
	Mmabaitse	1.00
Total		2582.85
Maize	KEP	1504.05
	Potch. Pearl	0.99
	PNR 6663	1.91
Total		1506.95
Millet	Serere 6A	24.05
	Okashana 1	38.02
Total		62.07
Cowpeas	Blackeye	10.08
	Tswana	29.93
	ER 7	2.11
Total		42.12
Groundnuts	Sellie	12.49
	55-437	0.28
Total		12.77
Sunflower	Russian No.4	13.73
Total		13.73
Mungbeans	Mmelegi	1.05
Total		1.05

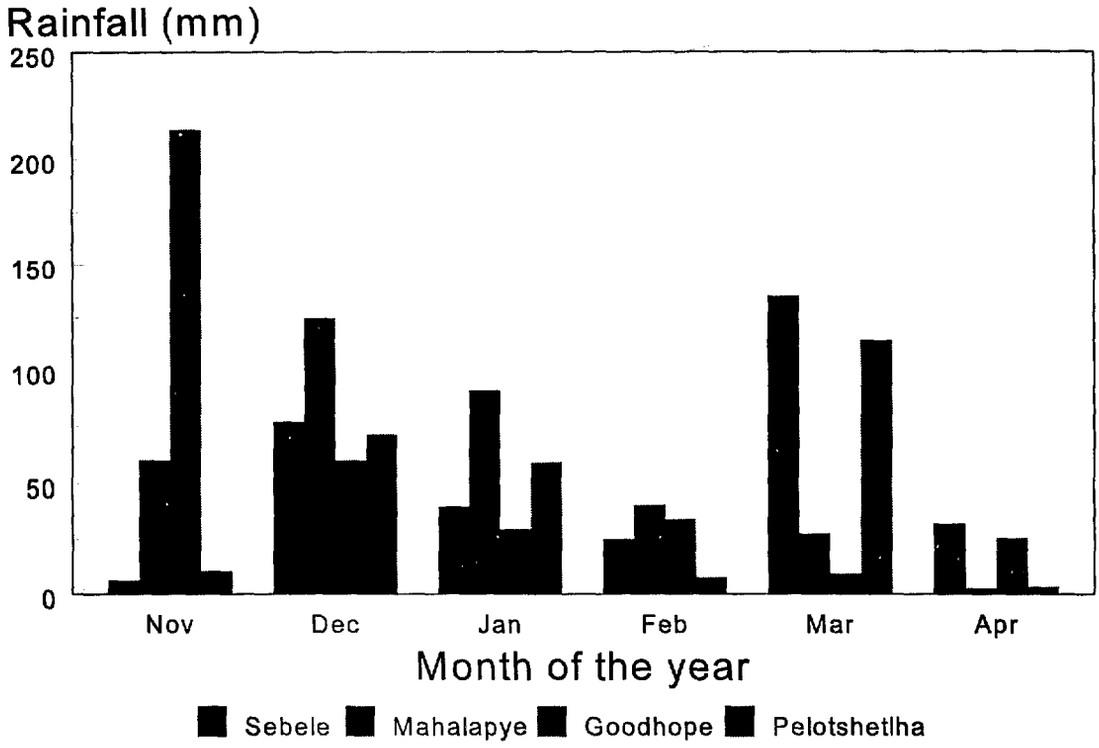
Table 4: Seed Distribution

Organisation	Sorghum	Millet	Maize	Cowpeas	Sunflower	Groundnuts
			(Metric	Tonnes)		
DCPF	2301.60	32.15	1346.01	3.96	-	-
BAMB	216.34	7.50	139.98	25.78	15.54	4.42
COOPS	4.80	-	16.60	2.45	-	0.08
OSSCA	2.00	-	4.00	-	0.70	-
BALBIR (PTY)	4.30	-	8.00	1.7	O.35	0.20
RESEARCH & OTHERS	2.74	0.41	1.48	2.45	0.32	0.90
Total	2531.78	40.06	1516.07	36.34	16.91	5.60

Table 5: Seed Sold to Contract Seed Growers

Crop	Variety	Total (MT)
Sorghum	Segaolane	8.23
	Marupantse	0.15
	8D	0.47
	Phofu	0.80
	Mmabaitse	0.30
Total		9.95
Maize	KEP	13.56
Total		13.56
Millet	Serere 6A	0.25
Total		0.25
Cowpeas	Blackeye	1.03
	Tswana	1.19
	ER7	0.15
Total		2.37
Groundnuts	Sellie	1.80
Total		1.80
Sunflower	Russian No.4	0.46
Total		0.46
Mungbean	Mmelegi	0.34
Total		0.34

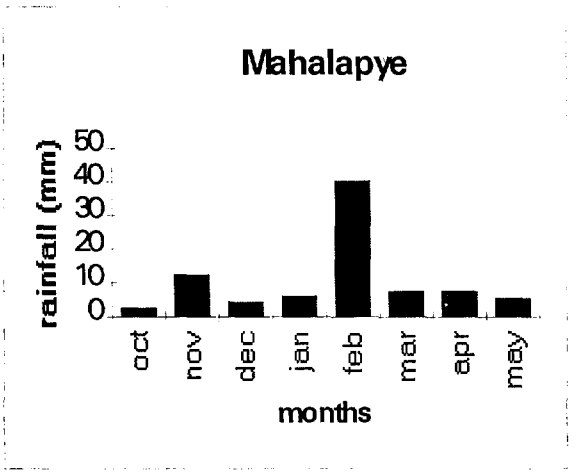
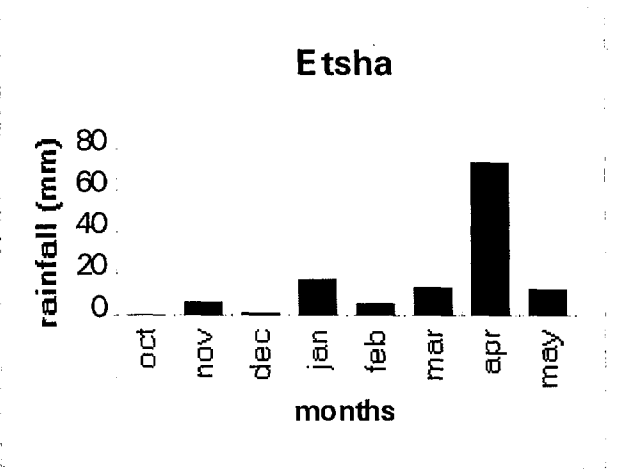
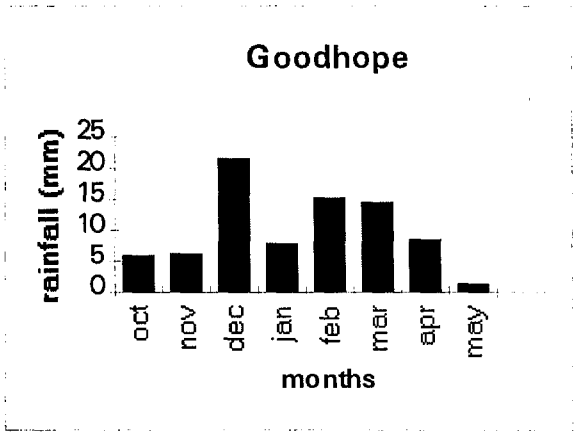
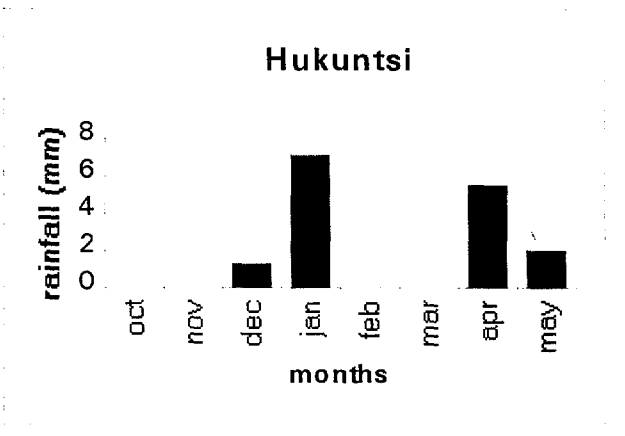
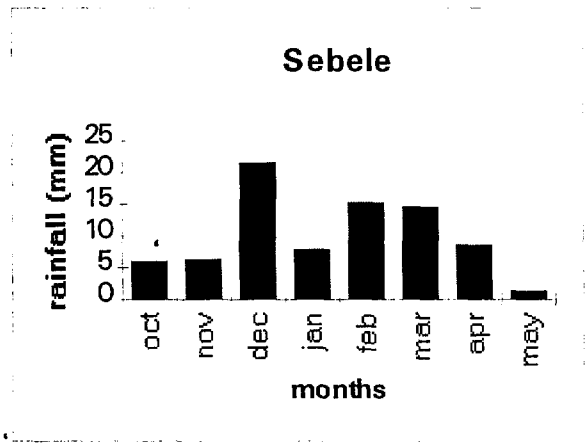
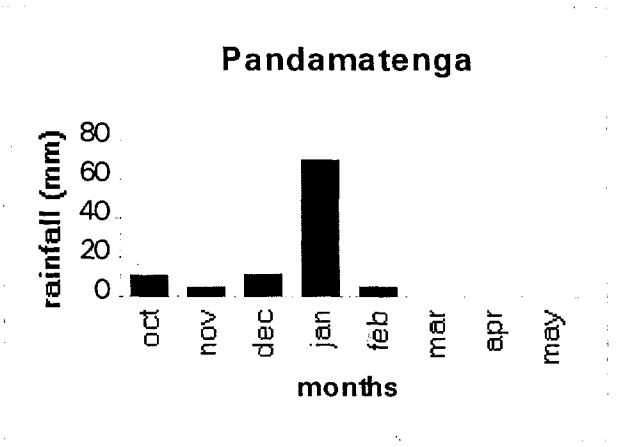
APPENDIX 1 : RAINFALL



APPENDIX: 2

Rainfall and Temperature at Sebele during the 1994/95 Cropping Season.

DATE	RAINFALL (mm)	MAXIMUM TEMPERATURE (°C)	MINIMUM TEMPERATURE (°C)
1994			
Oct 1-15	7.2	28.9	12.5
16-31	47.6	32.5	16.3
Nov 1-15	6.3	32.6	19.0
16-31	0.0	33.2	18.9
Dec 1-15	3.5	33.9	18.7
16-31	73.3[1]	35.4	19.5
1995			
Jan 1-15	25.7	33.1	19.5
16-31	14.0	34.0	20.2
Feb 1-15	4.6	34.6	19.5
16-28	20.4	31.3	19.3
March 1-15	14.8	30.9	18.2
16-31	93.5[2]	28.9	17.2
April 1-15	0.0	27.5	12.8
16-30	31.8	28.1	13.0
May 1-15	3.7	23.5	11.3
16-31	0.0	22.3	8.5
June 1-15	0.0	21.9	3.5
16-31	0.0	22.9	3.5

1. 69 mm fell on one day
2. 50 mm fell on one day

Appendix 3: Average Rainfall For All Research Sites - 1994/95