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Effect of Pearl Millet and Sorghum Seed Quality on Stand Establishment in Botswana

II. On-station Millet Experiments

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II. On-station millet experiments.

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Abstract

The contribution of Serere 6A pearl millet [*Pennisetum glaucum* (L.) R. Br.] seed size and density in improving stand establishment in Botswana was examined. Large (>2.6 mm diameter), dense (>1.26 g cm^{-3} density), bold (large and dense), control, and washed control millet seed were grown at Sebele in a dryland planting on four dates and in an irrigated establishment trial. A dry/wet planting trial and an irrigated trial were planted at Etsha 8 with bold, large, and control seed.

Seedlings from bold and dense seed emerged faster and had a higher rate of establishment at 8 and 12 days after planting than those from control seed at Sebele. Yields were not affected by seed quality.

Under irrigation at Sebele, control seed had a higher rate of emergence than bold or dense seed. The ratio of plants at harvest to those emerged was higher from dense seed than from control seed. Seed quality did not affect yield.

A lower number of hills emerged under dry planting than wet at Etsha 6. At 2 days after emergence, large seed showed a higher rate of emergence than control. However, at 8 days after emergence, there were more hills emerged from control seed than from bold seed under dry planting, and no difference among seed sources for the wet planting. No yields were produced because of drought.

At Etsha 8 under irrigation, washed control seed established fewer hills than the other seed sources.

Introduction

Pearl millet [*Pennisetum americanum* (L). Leeke. syn *P. glaucum* (L.) R. Br.] has small seed with low vigor which results in poor stand establishment. Poor stands are a constraint to production in semiarid areas where sorghum and millet are grown (Peacock, 1982). Improved stand establishment from higher quality seed has been demonstrated by some authors (Gardner, 1980; Lawan et al., 1985; Okonkwo and Vanderlip, 1985), but results have not been consistent (Modiakgotla 1985; Freyenberger 1986). Verification of the contribution of seed quality (within a variety) to improvements in emergence were investigated in semi-arid Botswana. Improvements arising from the manipulation of seed within a genotype, by cultural production or physical separation methods, have potential for an immediate impact on the subsistence farmers' crop compared to the introduction and development of improved varieties through breeding programs.

Trials were undertaken in one season in Botswana as a complement to the studies on seed quality conducted under more controlled conditions (Mortlock, 1988). The main emphasis in Botswana was on-farm testing of bold (large and dense) millet seed and dense sorghum seed with their respective controls (Mortlock and Vanderlip, 1987). Trials, that were conducted at the research station and at two sites in Ngamiland, Botswana, to examine a broader range of millet seed characteristics than was feasible with the on-farm testing are discussed in this report.

Objectives

The objectives were to examine the effect of Serere 6A millet seed size and seed density on establishment and yield in many environments. Specific objectives of the four experiments were:

Expt. 1: To examine the effect of bold (large and dense), large, dense, dry and wet control seed on the establishment and yield of millet in four dryland plantings.

Expt. 2: To compare bold, large, dense, and dry control seed separations under two planting soil moistures in a trickle irrigated trial.

Expt. 3: To compare bold, large, and dry control seed under wet planted and dry planted seedbed conditions.

Expt.4: To compare establishment and yield of bold, large, wet and dry control seed under irrigation in a late planted trial.

Materials and Methods

Serere 6A millet seed was obtained from the Seed Multiplication Unit, Agricultural Research Station, Sebele. Seed was separated so that approximately 50% of the seed by weight was above the size or density category used. The criteria used were 2.58 mm diameter and 1.26 g cm^{-3} density (separated by flotation in a sucrose solution). Bold seed was both larger than 2.58 mm diameter and denser than 1.26 g cm^{-3}. The dry control was unseparated and unwashed, whereas the wet control was unseparated, washed, and air dried. All or some of these separations were used for the trials described below. Standard germination was determined by the seed testing laboratory at Sebele (Table 1). Two controls were included because of the possible effects of flotation in

sucrose solution and washing. The wet control is appropriate for dense and bold seed separations, whereas the dry control is appropriate for large seed.

Table 1. Germination of the seed used in the experiments.

Seed Quality	Germination - % -	±SE (n=2)
Bold (large and dense)	95.5	1.57
Large	92.0	1.19
Dense	98.0	0
Dry Control	92.0	1.19
Wet Control	92.0	1.68

Two experiments were planted at Content Farm, Sebele Agricultural Research Station (Expts. 1 and 2). In the millet growing district of Ngamiland, a dryland (Expt. 3) and an irrigated trial (Expt. 4) at Etsha 6 and Etsha 8, respectively, were conducted. Agricultural Development Ngamiland Project provided these latter two sites (ADNP, 1985).

Experiment 1. Establishment of Dryland Millet

Five separations of Serere 6A millet seed were compared in an experiment planted on four dates, as a randomized complete block with four replicates. Seed characteristics examined were bold, dense, large, and wet and dry controls. Plot size and planting details are given in Table 2.

Table 2. Planting dates and plot detail of multiple planting date experiment, Sebele.

Variable	Planting 1	2	3	4
Date Planted	4 Nov	25 Nov	2 Dec	13 Jan
Planting Method	Hand	Hand	Cone Planter	Hand
Plot Size (m)	5 x 4	10 x 4	8.5 x 4	9.5 x 4
Harvested area (m^2)	7.5	15	12.75	14.25

The trial was planted on Block B23 at Content Farm, Sebele. The site was at 24° 34' S and 25° 57' E, at an altitude of 994 m, with a medium textured, brown soil formed on intermediate igneous rock (Gaborone Granite) and was moderately well drained. FAO/UNESCO classification described it as a ferric luvisol (Anon, 1981). Approximate values for extractable water were 75-80 mm in 100 cm soil depth for a sorghum crop (DLFRS, 1982). Soil moistures in the planting zone were taken at planting.

Seasonal rainfall is presented in Fig 1. and that received for 21 days after planting by date in Table 3. Minimum and maximum air temperatures are shown in Table 4. Thermocouples were put into randomly assigned plots to monitor soil temperatures. Temperatures were recorded for all dates; however, data were only available from dates 2 and 3 because of technical difficulties (equipment was flooded on the first date and failed to dump data on the 4th date).

Measurements were taken on establishment and yield. An establishment index was calculated for plants established at 5, 8 and 12 days after planting: Index = ((12 DAP-8 DAP)/12) + ((8 DAP-5 DAP)/8) + (5 DAP/5). Analysis was carried out with the Statistical Analysis System (SAS).

Table 3. Rainfall for the first 21 days for each of the four dryland plantings, Sebele.

Days after planting	Date planted: Nov 4	Nov 25	Dec 2	Jan 13
	mm			
1	6.6	.1	T[1]	
2	6.8			6.9
3	31.3	15.5		
4		15.4	4.4	
5			8.2	
6			6.5	
7			1.2	2.5
8		T	5.8	
9				
10				
11		4.4		
12		8.2		
13		6.5	T	
14		1.2	5.8	
15	1.2	5.8		17.6
16	0.6			
17	11.3		19.9	
18			0.9	
19	1.5		5.3	
20		T		
21		5.8	4.6	T
Total	59.3	62.9	62.6	27
Pre-plant[2]	48.4	107.7	138.7	223.5

[1]T = trace only

[2]Rainfall from October to day of planting

Table 4. Maximum and minimum air temperature for the first 21 days after each of the four planting dates, Sebele.

	Date of Planting							
	Date 1		Date 2		Date 3		Date 4	
DAP	Nov 4		Nov 25		Dec 2		Jan 13	
	Min	Max	Min	Max	Min	Max	Min	Max
1	19.9	25.9	19.7	35.1	21.7	30.3	18.7	34.7
2	16.9	20.1	21.6	36.0	22.5	32.7	21.4	22.7
3	16.5	28.3	21.8	26.0	20.0	33.4	17.0	32.1
4	16.1	30.2	17.6	21.2	22.7	34.7	19.9	33.2
5	12.1	24.1	18.5	27.5	19.7	32.2	20.7	34.2
6	11.5	25.0	19.0	30.4	18.0	31.2	20.9	36.1
7	15.2	28.9	20.8	34.3	17.4	31.0	23.1	34.6
8	15.1	29.1	21.7	30.3	17.8	30.1	19.6	37.0
9	17.2	30.4	22.5	32.7	14.5	26.1	20.2	36.1
10	16.6	34.8	20.0	33.4	15.4	30.1	24.1	35.1
11	16.4	35.9	22.7	34.7	16.9	32.0	19.4	35.2
12	18.6	32.0	19.7	32.2	17.9	33.1	20.0	37.2
13	18.9	34.7	18.0	31.2	19.0	36.9	20.5	31.6
14	22.6	35.9	17.4	31.0	21.9	36.1	18.6	35.2
15	20.9	34.9	17.8	30.1	18.6	34.1	20.1	37.8
16	18.8	29.4	14.5	26.1	18.3	28.2	17.8	33.2
17	16.3	26.5	15.4	30.1	18.6	36.1	18.4	35.6
18	16.7	27.1	16.9	32.9	18.6	32.5	21.8	37.3
19	17.7	31.2	17.9	33.1	18.6	32.5	22.8	37.7
20	17.7	31.6	19.0	36.9	17.4	35.1	22.2	36.6
21	17.6	34.7	21.9	36.1	22.0	35.0	22.9	37.2
Mean	17.1	30.0	19.3	31.5	18.9	32.5	20.5	34.8

Experiment 2. Establishment of Irrigated Millet

The design was a split plot with main plots of irrigation at two levels and subplots of seed quality at four levels, replicated four times. Seed qualities were bold ,large, dense, and dry control, with the same criteria as above. Irrigations were on 16 February (40 mm and 10 mm for high and low irrigation treatments, respectively), 24 February (20 mm and 7.5 mm), 2 March (10 mm and 0 mm), and 10 March (30 mm and 0 mm). Irrigation treatments on 16 February prior to planting were to simulate 40 and 10 mm rainfalls, the latter often is considered the minimum for planting. Plot size was 5m by 3m (four rows on 75 cm spacing).

A two-row border (1.5 m) provided a barrier between irrigated plots. Borders were planted with a jab planter prior to the main planting and later removed prior to flowering to prevent shading of the plots. The main trial was planted on 16 February by hand, with 100 seeds

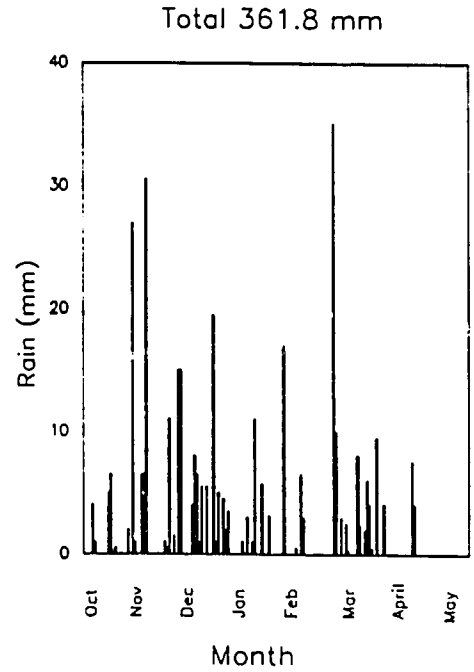

Figure 1. Rainfall received on Block 23, Sebele, 1986/87.

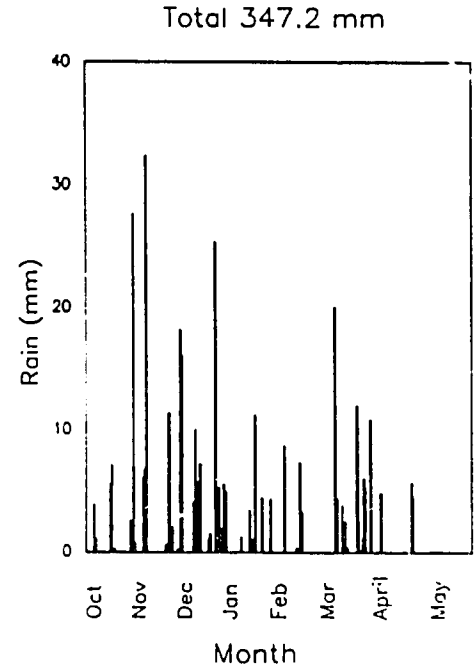

Figure 2. Rainfall received on Block 8, Sebele, 1986/87.

placed in each 5m row. Irrigation was by a low pressure drip system with dripper spacing at 75 cm by 30 cm and an output of 2.25 L hr^{-1}. Since each dripper served an area of 0.225 m^2, the application rate was 10 mm hr^{-1}.

Rainfall for the pre- and post-planting periods are shown in Fig. 2. Soil temperatures were monitored from

16 January through to early establishment at depths of 2, 5, and 10 cm. Soil moistures were taken at planting and 8 days after planting.

Establishment was counted on 4, 8, 10, and 14 days after planting. At harvest (19 May), total plant number, productive plant number, head number, yield, and thousand seed weight were recorded. Analysis was carried out with the statistical package SPSS/PC+ (SPSS, 1985 Inc. Micro Software Products, Chicago.) using analysis of variance.

Experiment 3. Establishment of Millet in Wet and Dry Plantings, Etsha 6.

This two factor experiment examined the establishment and yield of three qualities of Serere 6A millet seed under dry and wet planting conditions. It was planted with four replicates as a randomized block. Seed qualities examined were dry control, bold, and large. Dry plots were planted on 11 November and the wet plots on 1 December, following a 12.1 mm rain on 30 November. Two border rows were planted at either side of the trial. Plots were 5m in length and hand planted on 75 cm rows with four seeds per hill at 50 cm hill spacing. Seed was weighed pre- and post- planting to give seed weight planted. Plant emergence was recorded on the center two rows, both as hill and plant number. Soil temperatures were monitored for both plantings; however. only data for the wet planting was retrieved, because of inadvertent overwriting of data. Gravimetric soil moisture was recorded on planting days. The seasonal rainfall pattern is shown in Fig 3.

Experiment 4. Establishment of Irrigation Millet, Etsha 8.

The design was a two-factor, randomized complete block design replicated four times. Seed quality was the first factor at four levels: bold, large, wet control, and dry control; the second factor was thinning to 1 plant hill^{-1} or no thinning. Thinned versus non-thinned comparisons allowed the seed qualities to be compared as yield plant^{-1} and yield hill^{-1}.

The trial was planted on 25 February 1987 on virgin land, which was cultivated with a small tractor following clearing and destumping. Plots were 5m by 3m (four rows on 75 cm spacing) with a 1.5m path between blocks. Two border rows were planted on either side of the trial.

A MASDAR Rotary Injection Planter (designed by G. Banbury and manufactured by L.P. Engineering Co,

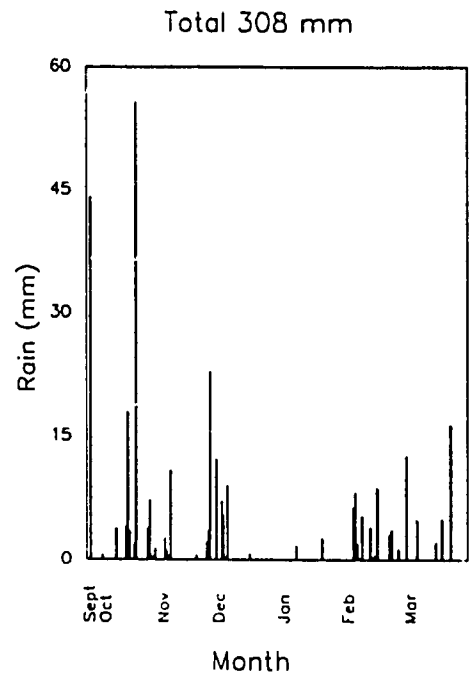

Figure 3. Rainfall received at Etsha 6, 1986/87.

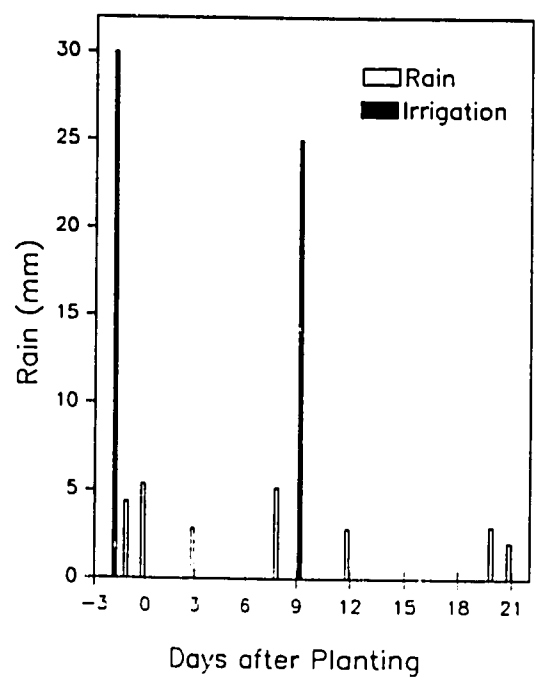

Figure 4. Rainfall and irrigation for Etsha 8, 1987.

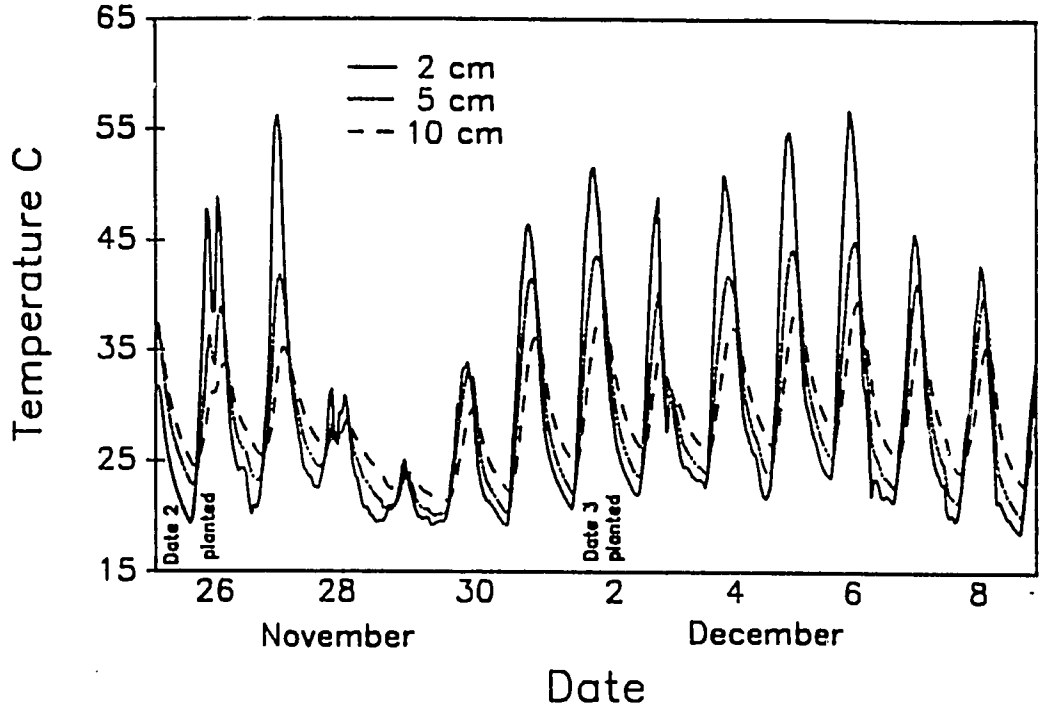

Figure 5. Soil temperature at 2, 5, and 10 cm depths on dryland seed quality trials, Sebele, 1986.

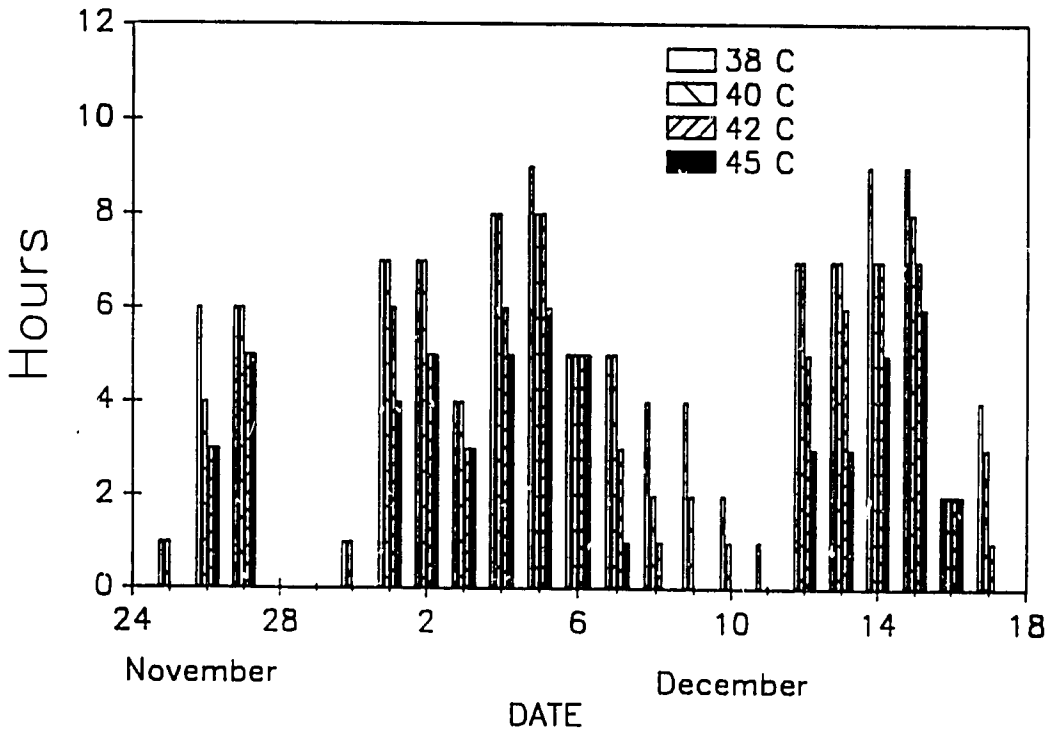

Figure 6. Hours that 2 cm soil temperatures were above 38, 40, 42, and 45 C on the dryland seed quality trial, Sebele, 1986.

Bishops Stortford, U.K) with a modified seed wheel for millet was used to plant the trial. Rainfall or irrigation from 5 days before to 20 days after planting was recorded (Fig. 4). Seed weight planted was not recorded, but it was assumed that a similar amount was planted from each seed source.

Establishment and yields were recorded. The number of hills with plants and total plant number of the middle two rows within each plot were counted. This was supposed to have been done immediately after first emergence, but was not done until 14 days after planting (DAP). Estabiishment data were examined by seed quality on eight replicates, since the thinning was done 21 days after planting. At harvest, the head number and yield from the middle two rows were recorded. Analysis was carried out with the statistical package SPSS/PC+ (SPSS.1985 Inc. Micro Software Products, Chicago) using analysis of variance.

RESULTS

Experiment 1. Establishment of Dryland Millet

In the first three weeks after the four planting dates, rainfall was 59.3, 62.9, 62.6, and 27.0 mm, respectively. Minimum and maximum air temperatures were slightly higher for each successive planting (Table 4). Evidence of runoff and the possible loss of seed on the first planting following the 7 November rainfall gave rise to doubts about the accuracy of establishment counts. Seed quality did not affect establishment, early growth, or yield when this planting was analyzed alone. Mean establishment was 24.3% and 28.5% at 5 and 10 days after planting, respectively. A population of 22,061 plant ha^{-1} was established producing 10,931 heads ha^{-1}, and the yield was 126 kg ha^{-1}. A severe attack of corn crickets (*Hetrodes papus*) and drought stress reduced grain yield.

Post-planting soil temperatures are given in Fig. 5 and the hours for which soil temperature was greater than 38, 40, 42, and 45 C at the 2 cm depths are shown in Fig. 6.

On a combined analysis on the three later dates, seed quality affected establishment at 5 and 8 days after planting. Establishment speed was determined by an establishment index and was affected by seed quality (Table A.1). At 5 days after planting, a date by seed quality interaction was significant for establishment percent. On the third date the dry control was significantly lower than the other seed qualities. Establishment on date 2 was low for all seed qualities (Table 5).

Stand establishment with bold and dense seed was higher than with the other seeds at 8 and 12 days after planting. Bold and dense seed also emerged faster (Table 6). Seed quality did not affect tiller production or plant weight on a combined analysis (Table A.1).

Although stand establishment and establishment index were lower at 8 days after planting for the second date, they did not affect tillering and plant weight (Table 7). These results suggest that the seed may have been planted deeper, so it was emerging slower but resulted in more vigorous early growth. Weather conditions also may have contributed to these differences.

Yield and population at harvest were not affected by seed quality (Table A.2). Thousand seed weights and seed number per head were not affected by either date or seed quality. The ratio of harvested plants to those established (at 14 DAP) and heads ha^{-1} varied with date (Table 8).

Table 5. Interaction of seed quality and planting date establishment 5 days after planting, Sebele.

Seed Quality	Date 2	Date 3	Date 4
	----------	%	----------
Bold	5.4	31.8	19.4
Dense	6.0	25.5	16.0
Large	2.8	24.8	10.6
Dry Control	4.9	9.8	9.3
Wet Control	3.9	20.8	13.5

LSD(P < 0.05) Seed quality within a date 6.8
LSD(P < 0.05) Dates within seed quality 11.4

Table 6. Effect of seed quality on establishment and early growth on dryland establishment, Sebele.

Seed Quality	Establishment 8 DAP	12 DAP	INDEX[1]
	------	%	------
Bold	21.8a	23.3a	4.23a
Dense	22.4a	24.5a	4.16a
Large	17.0b	19.4b	3.27b
Dry Control	13.6b	17.2b	2.60b
Wet Control	15.6b	17.1b	3.03b
LSD (P < .05)	3.9	3.7	0.70

[1]Index = plants established at 5, 8 and 12 DAP:
((12 DAP-8 DAP)/12) + ((8 DAP-5 DAP)/8) + (5 DAP/5)

Table A1. Analysis of variance for establishment and early growth on the seed quality, dryland planting, Sebele.

Source	df	Mean Squares					
		Establishment				Tillers plant^{-1}	Plant weight
		5 DAP	8 DAP	12 DAP	Index		
		---------- % ----------					g
Date (D)	2	1606.8**	1224.9**	332.2	35.6*	4.7*	130.7**
Error a	9	183.6	143.9	127.5	5.7	1.0	9.0
Seed Quality (S)	4	197.4***	175.4***	142.8***	6.3***	0.5	3.4
D * S	8	70.6**	38.1	31.1	1.4+	0.4	1.8
Error b	36	22.3	22.0	20.3	0.7	0.4	3.2
CV (b)		34.7	25.9	22.2	24.4	24.6	66.6

Table A.2. Analysis of variance for yield components of the seed quality, dryland planting, Sebele.

Source	df	Mean Squares					
		Ratio of plants harvest: emerged	Heads ha^{-1} (thousands)	Heads plant^{-1}	Yield[1] (kg ha^{-1})	Seed weight (g/1000)	Seed number head^{-1}
Date (D)	2	0.639***	6149751*	3.85	2614457***	2.366	4.796
Error a	9	0.014	834448	2.91	126846	4.568	0.390
Seed Quality (S)	4	0.017	41567	0.60	19643	1.009	0.227
D * B	8	0.009	114893	1.17	46229*	3.082	0.223
Error b	36	0.009	99141	0.63	23569	1.642	0.143
CV (b)		15.7	27.9	35.6	37.9	14.1	35.6

[1]For Yield 4 missing values (Error b df = 32)
[2]For thousand seed weight, and seed/head, 6 missing values (Error b df = 30)

Table 7. Effect of planting date on establishment and early growth of the seed quality dryland trial, Sebele.

Date	Establishment			Tillers plant^{-1}	Plant Weight (g)
	8 DAP	12 DAP	INDEX[1]		
	------- % -------				
Date 2	9.5a	16.2	2.09a	2.5ab	5.6a
Date 3	24.9b	24.4	4.75b	3.2a	1.9b
Date 4	19.9b	20.4	3.55b	2.3b	0.7b
LSD(P<0.05)	8.6	NS	1.71	0.7	2.1

NS = not statistically significant.

Table 8. Means of yield parameters by date for seed quality dryland trial, Sebele.

Date	Ratio of plants harvest: emerged	Heads ha^{-1}	Yield (kg ha^{-1})
Date 2	0.61	23,000	154
Date 3	0.40	28,000	194
Date 4	0.75	56,000	816
LSD(P<0.05)	0.06	15,000	254

Table 9. Effect of date by seed quality interaction on yield.

Seed Quality	Date 2	3	4
	-------kg ha^{-1}-------		
Dry Control	210	84	943
Wet Control	215	219	718
Bold	156	244	747
Large	95	217	1012
Dense	96	211	664
LSD (P < 0.10) within dates 184			
LSD (P < 0.10) among dates 187			

Yield was higher for date 4 compared to the other dates because of more heads ha^{-1}. Seed quality by date interaction was significant for yields (P < 0.10) (Table 9).

Experiment 2. Establishment of Irrigated Millet

Soil temperatures for the 2, 5, and 10 cm depths are presented in Figs. 7 and 8. Irrigation at planting ameliorated soil temperatures for the high compared to the low irrigation treatment (Fig. 7). High- irrigation plots had a mean of 1 hour over 45 C, whereas the low-irrigation plots had 6 hours over 45 C (Fig. 8).

Soil gravimetric moisture was 5.1%, 6.3%, and 7.6% at 0-10, 10-30, and 30-50 cm depths, respectively, on 16 January when the borders were planted. On 16 February, gravimetric soil moistures were 9.7% for the high and 7.1% for the low irrigation treatments [LSD (P < 0.05) = 1.0%]. At 8 days after planting, the levels were 8.6% and 7.8% for these treatments, respectively, [LSD (P < 0.05) = 0.6%].

Table A.3 Analysis of variance for percent establishment of irrigated establishment trial, Sebele.

Source	df	Mean Squares Establishment 4 DAP	8 DAP	10 DAP	14 DAP
		----------%	----------		
Block	3	137.9	360.0	364.4	457.7
Irrigation(I)	1	164.3	416.8	264.5	140.9
Error a	3	94.1	90.0	95.7	164.1
Seed Quality(S)	3	62.0	136.5	131.9	279.8+
SI	3	26.2	46.9	45.8	27.3
Error b	18	56.4	88.1	91.1	97.2
CV (b)		43.5	48.4	51.3	49.9

Table 10. Establishment percentages by seed quality for irrigated establishment trial, Sebele.

Seed Quality	Days after Planting 4	8	10	14
	----------%	----------		
Bold	16.5	18.8	17.7	17.8
Large	16.1	19.8	18.5	19.5
Dense	15.1	14.5	14.2	13.9
Dry Control	21.3	24.6	24.0	28.0
LSD (P < 0.10)	NS	NS	NS	8.5

Emerged populations on 4, 8, and 10 days after planting showed no significant effect of seed quality or irrigation or any interaction (Table A.3), except at 14 days after planting, when seed quality was significant (P < 0.10). Means are shown in Table 10. Populations established by 14 days after planting ranged from 37,000 (dense seed) to 75,000 (dry control) plants ha^{-1}. At 14 days after planting, the dry control had a higher percentage of established plants (P < 0.10) than the other three seed sources. Since there was no interaction with irrigation, the control gave higher percentages of established plants regardless of the moisture at planting.

Establishment was similar for the two irrigation treatments. Percentages were 19.5% and 15.0% at 4 DAP, and 21.9% and 17.8% at 14 DAP for high and low irrigation treatments, respectively.

Analysis of the populations and yield showed few treatment effects and no interactions (Table A.4). Mean population at harvest was 34,000 plants ha^{-1}, with no significant differences among treatments. The ratio of the population at harvest to that at 14 days after planting was significantly higher for dense seed than for the control. Bold seed was not different from any other seed. This indicates less plant mortality from a good quality seed (Table 11).

Seed head^{-1} was the only yield component affected by seed quality, and there was an interaction with moisture (P < 0.10) (Table 12).

Experiment 3. Establishment of Millet in Wet and Dry Plantings, Etsha 6.

Rainfall at Etsha 6 was negligible following the dry planting (Fig 3). Emergence of both plantings occurred in December because of the dry conditions following the

Table A.4. Analysis of variance of yield parameters for the seed quality, irrigated establishment trial, Sebele.

Source	df	Mean Squares					
		Population at harvest (thousands)	Head ha^{-1} (thousands)	Ratio harvested: emerged plants	Seed weight (g/1000)	Seed number $head^{-1}$ (thousands)	Yield (kg/ha)
Block	3	934.7	25811842	.157	6.00	0.491	664860
Irrigation (I)	1	93.4	19866938	.056	7.92	0.804 +	705196
Error a	3	295.4	6550164	.026	3.96	0.136	509631
Seed Quality (S)	3	297.8	1476374	.119**	3.79	0.736*	335090
ST	3	61.8	7408241	.009	0.45	0.506 +	81204
Error b	18	226.5	3989170	.034	1.87	0..208	357936
CV (b)		43.9	30.0	25.0	11.2	36.1	40.4

Table 11. Population at harvest, ratio of plants surviving and yield components for irrigated establishment trial, Sebele.

Seed Quality	Population at harvest	Heads ha^{-1}	Ratio harvested: emerged plants	Seed weight (g)	Seed number $head^{-1}$ (Thousands)	Yield (kg/ha)
Bold	34,000	215,000	0.81ab	12.7	1.33ab	1517
Large	31,000	199,000	0.65b	12.2	1.66a	1770
Dense	29,000	200,000	0.87a	12.7	0.98b	1553
Dry Control	43,000	227,000	0.62b	11.2	1.09b	1081
LSD ($P < 0.05$)	NS	NS	0.19	NS	.48	NS

November planting. Soil temperatures for the wet planted treatment at 2, 5, and 10 cm depths are given in Figs. 9 and 10. Plants in dry planted plots first emerged on 29 November (18 DAP), and those in wet planted plots on 4 December (3 DAP). These data were analyzed on days after emergence (DAE). At 2, 4, 6, and 8 DAE, planting method and seed quality affected number of hills with emerged plants (Table A.5). A lower number of hills had emerged plants in the dry planting. Large seed gave a higher number of hills with plants established 2 DAE (Table 13).

By 8 DAE, seed quality and planting method interaction showed that control seed gave a higher population of hills with plants emerged than bold seed under dry planting. There were no differences among seed quality for the wet planting (Table 14).

Table 12. Interaction of seed quality and moisture on seed number.

Seed Quality	Soil Moisture at Planting: High	Low	Means
	Thousand Seed $Head^{-1}$		
Bold	1.49	1.18	1.33
Large	0.97	0.98	0.98
Dense	2.17	1.14	1.66
Dry Control	1.05	1.12	1.09
LSD ($P < .05$)			0.48
Means	1.42	1.11	

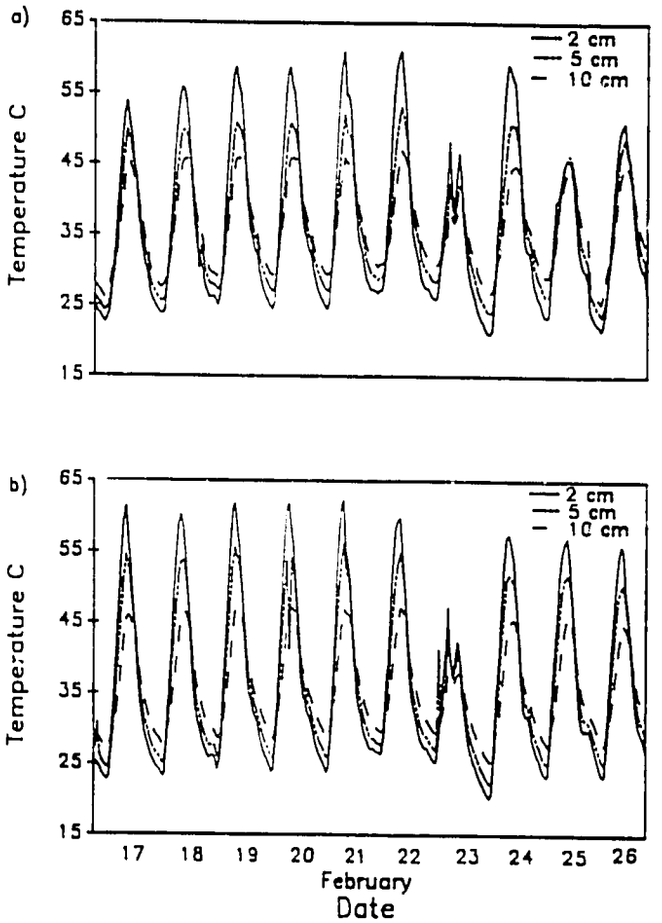

Figure 7. Soil temperature at 2, 5, and 10 cm depths on irrigated seed quality trial, Sebele, 1987, (a) high irrigation and (b) low irrigation.

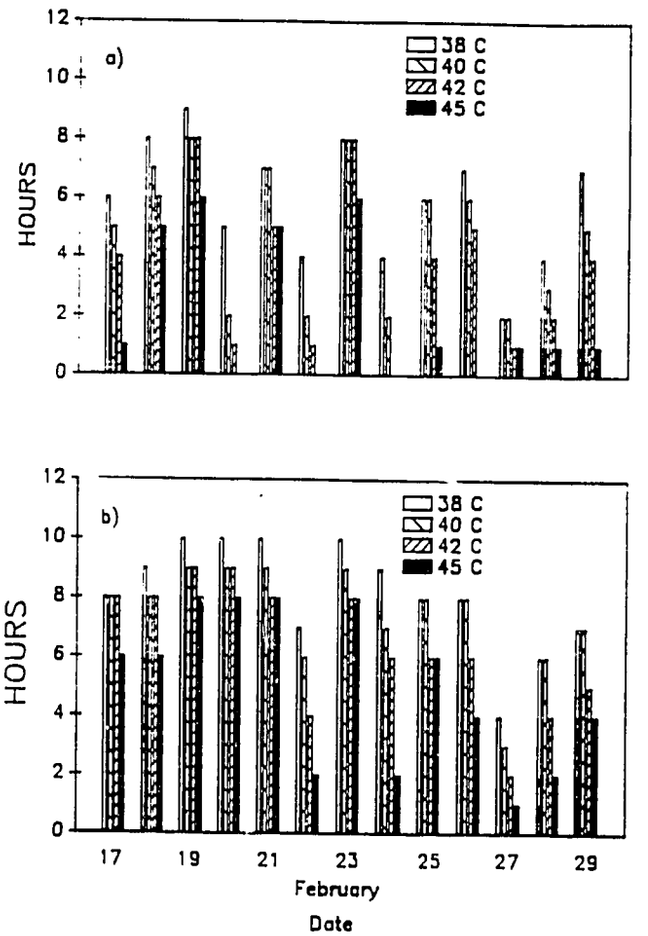

Figure 8. Hours that 2 cm soil temperature was above 38, 40, 42, and 45 C on the irrigated establishment trial, Sebele, 1987, (a) high irrigation and (b) low irrigation.

Table A.5 Analysis of variance of hill number for the wet/dry planting at Etsha 6.

		Mean Squares			
		Hill number			
Source	df	2 DAE	4 DAE	6 DAE	8 DAE
Block	3	57.9**	5.0	7.1	7.1
Planting Method (P)	1	287.0***	57.0***	63.4***	40.0***
Seed(S)	2	28.8*	17.0**	9.9*	7.5*
PS	2	12.7	4.5	4.6	7.3*
Error	15	7.6	2.5	1.9	1.7
CV		18.1	7.9	6.7	6.3

Nb. ANOVA on hill/ 7.5 m^{-2}

Table A.6 Analysis of variance for hill and plant number at 14 and 20 DAP for the irrigated seed quality trial at Etsha 8.

		Mean Squares			
		Hill number		Plant Number	
Source	df	14 DAP	20 DAP	14 DAP	20 DAP
		--hills/ 7.5 m^2--		--plants/ 7.5 m^2--	
Block	7	10.9	14.1	85	96
Seed(S)	3	29.8+	43.6*	239	296
Error	21	9.8	10.2	2650	115
CV		21.0	21.7	37.6	38.1

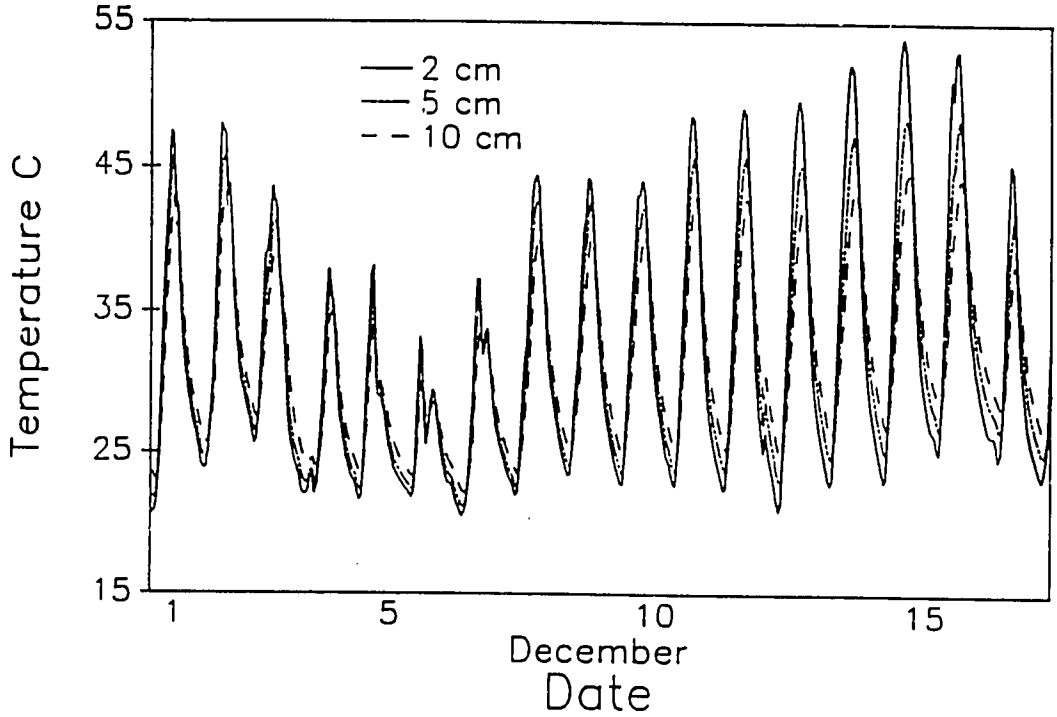

Figure 9. Soil temperature at 2, 5, and 10 cm depths on Etsha 6, 1986.

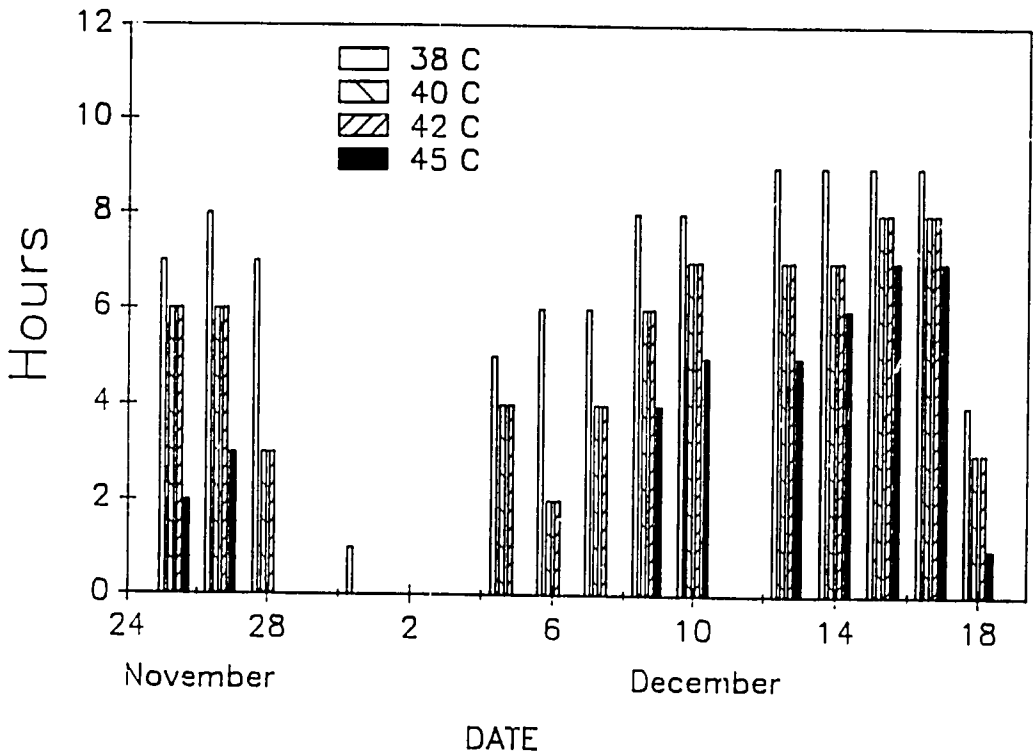

Figure 10. Hours that 2 cm soil temperature was above 38, 40, 42, and 45 C, Etsha 6, 1986.

Table 13. Effect of planting method and seed quality on emerged hill population, Etsha 6.

Planting Method	Date after emergence		
	2 DAE	4 DAE	6 DAE
	Thousand Hills ha^{-1}		
Wet	24.9	28.7	29.3
Dry	15.2	24.5	25.0
LSD (P .05)	3.2	1.9	1.6
Seed Quality			
Bold	18.8	24.5	25.5
Large	23.2	27.1	27.7
Dry Control	18.8	28.4	28.4
LSD (P < 0.05)	3.9	2.3	2.0

Table 14. Interaction of planting method and seed quality 8 days after emergence.

Seed Quality	Planting Method	
	Wet	Dry
	Thousand Hills ha^{-1}	
Bold	28.7a	23.0 c
Large	29.7a	25.7 b
Control	28.7a	28.0 ab
LSD (P < .05)		2.6

Table 15. Emerged hill population at the irrigated trial, Etsha 8.

Seed Quality	Emerged Hill Population	
	14 DAP	20 DAP
	Thousand Hills ha^{-1}	
Bold	22.8a	22.7a
Large	21.3ab	21.5a
Dry Control	19.7b	18.8ab
Wet Control	16.8c	15.7b
LSD (P < .10)	3.6	-
LSD (P < .05)	-	4.4

Severe drought late in the season at this site caused complete crop failure. Percent mortality of hills with emerged plants showed no treatment effects. Mean mortality on 27 January was 72 %. No yields were recorded.

Experiment 4. Establishment of Irrigated Millet, Etsha 8.

This trial examining establishment with favorable moisture conditions at planting complemented the wet/dry planting trial on the dryland plot at Etsha 6. Hills with plants established on 14 and 20 DAP varied with seed quality; however, total number of plants established was not affected by seed quality (Table A.6). Speed of establishment was not determined because early plant counts were not made. Mean number of plants hill^{-1} ranged from 1.6 to 2.0. At 20 DAP, following a small shower (Fig 4), the dry control had fewer hills with plants established than the wet control, but the latter was not different from the bold and large seed (Table 15).

Records of yield following the thinning to a single plant hill^{-1} were requested; however, data have not been received for inclusion in this report.

Discussion

Jones (1987) discussed the physical conditions for arable cropping in Botswana. The rainfall distribution often gives rise to 20 to 30-day drought periods in the middle of the growing season. In the 1986/87 season, the Etsha rainfall exemplified this (Fig. 3). The crop did not produce grain on the dryland trial and mortality was over 70%. Since this study was concerned predominantly with establishment, the lack of yield data did not detract from the study. Establishment at Sebele was low, and planting date had a major effect on the dryland study. However the dry control had poorer establishment than the other seed qualities at date 3. Bold and dense seed did emerge faster as determined by an index; seed quality did not affect plant size. On the irrigated experiment at Sebele, there was no soil moisture by seed quality effect. The dry control had higher establishment at 14 DAP, although overall establishment was low. Dense seed had better survival than control seed. Yield was not affected by seed quality.

At Etsha, large seed had a higher establishment at 2 days after first emergence, however, this advantage did not last. Up through 6 DAE, there was no planting method by seed quality interaction. At 8 DAE the dry planting, bold seed had a lower emergence than large or control seed. Under irrigation at Etsha, more hills had established plants from bold seed at 14 and 20 DAP. At 14 DAP, the wet control had lower establishment than the other seed sources.

Seed quality did not show consistent differences across the trials. Since there was no moisture by seed quality interaction (Experiment 2), the effects of seed should be apparent at any moisture level. Dry and wet controls did not always behave similarly. This could have been due to the fungicide seed dressing that had been removed. Fungicides may have direct (protection from pathogens) and/or indirect effects. The latter could affect water imbibition and subsequent germination of seed. Results are conflicting at Sebele, where dry seed had lower establishment than the other seed qualities, whereas at Etsha under irrigation, the dry control had higher establishment than the wet control.

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References

ADNP. 1985. Agricultural development Ngamiland Phase 2 report. Agricultural Research Station, Botswana, Government Printer.

Anon. 1981. Soils of the agricultural research station, Content farm, Gaborone. Agricultural Research Station, Botswana, Government Printer.

DLFRS, 1982. Dryland farming research scheme , Phase III. Third Annual Report. Agricultural Research Station, Botswana, Government Printer.

Freyenberger, S.G. 1986. Emergence, yield and yield components responses to size and density separations of pearl millet seed produced by three management practices. Master's Thesis, Kansas State Univ., Manhattan.

Gardner, J.C. 1980. The effects of seed size and density on field emergence of pearl millet [*Pennisetum americanum* (L.) K. Schum.]. Master's Thesis, Kansas State Univ., Manhattan.

Jones, M.J. 1987. Soil water and crop production in Botswana. Soil Use Man. 3:74-79.

Lawan, M., F.L. Barnett, B. Khaleeq, and R.L. Vanderlip. 1985. Seed density and seed size of pearl millet as related to field emergence and several seed and seedling traits. Agron. J. 77:567-571.

Modiakgotla, E.E. 1985. Pearl millet [*Pennisetum americanum* (L.) Leeke] emergence, yield and yield component response to seed quality and soil temperature. Master's Thesis, Kansas State Univ., Manhattan.

Mortlock, M.Y., and R.L. Vanderlip. 1987. Effect pearl millet and sorghum seed quality on stand establishment in Botswana. I. Farmer field experiments. Technical Series Report 1. INTSORMIL, Lincoln, Nebraska.

Mortlock, M.Y. 1988. Germination and Stand Establishment of Pearl Millet and Sorghum of Different Seed Qualities under Field Conditions in Botswana and Controlled High Temperature Environments. Ph.D Dissertation, Kansas State Univ., Manhattan. Okonkwo, J.C., and R.L. Vanderlip. 1985. Effect of cultural treatment on quality and subsequent performance of pearl millet. Field Crops Res. 11:161-170.

Peacock, J.M. 1982. Response and tolerance of sorghum to temperature stress p.143-160. In Sorghum in the Eighties. Proc. Int. Symp. on Sorghum. ICRISAT, India 1981, Patancheru, A.P., India, ICRISAT.