SUMMARY OF COMPOSITE AND VARIETY TRIALS ICRISAT PEARL MILLET BREEDING 1977-1986

Consultancy Report

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PREFACE

The pearl millet breeding program has a large data bank resulting from research conducted by several scientists over many years. A data bank such as this is a tremendous resource as reanalysis of data accumulated over years can provide conclusions of greater scope and significance than those obtained from analyses of individual trials. This report is intended to facilitate the exploitation of this data bank by providing 1) a descriptive summary of the purpose, methodology, and status of statistical analysis of these trials, 2) a data base that compiles information needed to find and analyze the data, and 3) recommendations of analyses to be made and analysis of the topic with highest priority. This report is divided into three sections that address each of these objectives.

Contents

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SECTION 1

DESCRIPTIVE SUMMARY OF PEARL MILLET COMPOSITE AND VARIETY TRIALS

INTRODUCTION

The purpose of this report is to provide information on the objectives, materials and methods, and status of statistical analysis of ICRISAT trials involving composites and varieties of pearl millet. The documentation of this information will aid interpretation and combined analyses of previous experiments.

The 56 trials summarized are presented in six groups according to the nature of the experiments. Trials examining the genetic nature of populations, alternative selection methods, and realized progress from selection form the first three groups. The remaining groups consist of Initial- and Advanced-Variety Trials, and Composite Progeny (Best Progenies) Trials.

The objectives, entries tested, and years and locations in which each trial was conducted are presented. A list of the locations used as experimental sites and their abbreviations is presented in Appendix 1. The method by which the genetic material was developed is also presented when available. This information, however, was very scarce, with only scant records being found in such sources as In-House Reviews. Improved documentation of both trials and recombination/progeny development plots could be achieved by routinely including pages in field books where information as suggested in Appendix 1 would be recorded.

The accuracy of trials and the status of statistical analyses of these trials is reviewed, with special focus on the Composite Bulk Trials. These assessments are reported at the end of this summary.

SUMMARY OF TRIALS

1.1 TRIALS ESTIMATING GENETIC PARAMETERS

Advanced Generation Trials

Objectives

The advanced generation trials assessed the level of inbreeding depression after random mating in experimental varieties and population progenies.

Genetic materials

The Syno entries were constituted by diallel mating of 5 to 9 progenies and bulking the resulting seed. The Syno was open pollinated in isolation with culling of about 5% of plants to produce the Syn1.

Trial		Year	Location
Advanced Generation Trial	(AGT)	1977	PHF HSR
Advanced Generation Trial-I	(AGT-I)	1978	PHF HSR PDN
Advanced Generation Trial-II	(AGT-II)	1978	PHF HSR PDN

Entries

1977 AGT		1978 AGT-I		1978 AGT-II	
WC-CX75	SYN0, SYN1	WC-C75	SYN0, SYN1, SYN2	SSC-H76	SYN0, SYN1
WC-5147	SYN0, SYN1	WC-5147	SYN0, SYN1, SYN2,	WC-B76	SYN0, SYN1,
WC-5346	SYN0, SYN1	WC-5346	SYN0, SYN1, SYN2,	MC-P76	SYN0, SYN1,
IVS-AX75	SYN0, SYN1	WC-5152	SYN0, SYN1, SYN2,	RF-A76	SYN0, SYN1,
IVS-5054	SYN0, SYN1	IVS-A75	SYN0, SYN1, SYN2,	WC-C75	SYN0, SYN1,
IVS-5427	SYN0, SYN1	IVS-5045	SYN0, SYN1, SYN2,	IVS-A75	SYN0, SYN1,
MC-CX75	SYN0, SYN1	SSC-C75	SYN0, SYN1, SYN2,	SSC-C75	SYN0, SYN1,
MC-5086	SYN0, SYN1	SC1-5026	SYN0, SYN1, SYN2,		
MC-5171	SYN0, SYN1	SC1-5106	SYN0, SYN1, SYN2,		
LC-CX75	SYN0, SYN1	SC2-5153	SYN0, SYN1, SYN2,		
LCL-5042	SYN0, SYN1	SC3-5048	SYN0, SYN1, SYN2,		
LC-5242	SYN0, SYN1	MC-C75	SYN0, SYN1, SYN2,		
SSC-CX75	SYN0, SYN1				
SSC-SC1-26	SYN0, SYN1				
SSC-SC2-153	SYN0, SYN1				

Diallel Trial of Composite Bulks 1985

The Diallel Trial was intended to identify heterotic combinations among composites currently undergoing population improvement at ICRISAT.

Trial	Year	Location
Diallel Trial of Composite Bulks (DTCB)	1985	PHF BSR

Entries

NELC-C4 X IVC-C5
NELC-C4 X MC-C7
NELC-C4 X SRC-C2
NELC-C4 X EGP-C0
IVC-C5 X MC-C7
IVC-C5 X SRC-C2
IVC-C5 X EGP-C0
MC-C7 X SRC-C2
MC-C7 X EGP-C0
SRC-C2 X EGP-C0
NELC-C4
IVC-C5
MC-C7
SRC-C2
EGP-C0

1.2 TRIALS ASSESSING ALTERNATIVE SELECTION METHODS

Objectives and trials

These trials (listed below) investigated differences among alternative methods for selecting superior varieties, or for conducting population improvement. The NPEV experiment studied the association between number of parental lines used in forming varieties with the performance of those varieties. The feasibility of improving varieties by evaluating progenies derived from selfing, sibbing, and test-crossing was examined in IXVT. The feasibility and effectiveness of using gridded mass selection (GMS), restricted recurrent phenotypic selection (RRPS), full-sib (FS), and S2-progeny selection for improving population performance, *per se* and/or testcross, was evaluated in PCT-I and WCSMBT. The AMMS trial focused solely on the feasibility of mass selecting for improved performance *per se* of populations. This trial compared several intuitive and biometrically derived selection indices. The effect of GMS, RRPS, FS-, and S2-selection on the genetic variability and level of inbreeding in the selected populations was tested in PCT-II.

Trial	Year	Location
No. Progeny to Produce Expt. Varieties (NPEV)	1979	PHF PLF
Improved Expt. Varieties Trial (IXVT)	1979	PHF PLF HSR KAM WAD SAM
Seln. Intensity in New Early Composite (SINEC)	1979	PHF
Population Comparison Trial-I (PCT-I)	1979	PHF
Population Comparison Trial-II (PCT-II)	1979	PHF
World Composite Seln Method Bulk Trial (WCSMBT)	1982	PHF
Alternative Methods of Mass Selection (AMMS)	1986	PHF HSR BSR

Genetic Materials

- NPEV-1979

  20 entries. No information was found describing the nature of these entries, so the data are unanalysable.

- IXVT

	Method of Selection				
Variety	Bulk[a]	Selfed	Sib	Testcross	Overall[b]
WC-C75	X	X	X	X	X
IVS-A75	X	X	X	X	X
MC-P76	X				X
SSC-H76	X				X
RF-A76	X				X
WC-B76	X				X
SSC-C75	X				X

[a] unselected variety
[b] multistage selection, eg. upon selfed and test-cross performance

- **SINEC**

Composite	Number selected	Selection intensity
New Early	252	15%
"	252	5%
"	90	15%
"	90	5%

- **PCT-I**

Populations
WC CO
WC GMS-C2
WC RRPS-C2
WC FS-C2
WC S2-C1

Each population was tested and random mated bulk, selfs, and topcrosses with WC-CO, IVS, and 5141A

- **PCT-II**

351 S1 progenies in total, with S1s derived from WC-CO, WC-GMS, WC-RRPS, WC-FS, and WC-S2.

- **WCSMBT**

Methods
RRPS, GMS, and FS evaluations were conducted each kharif at Patancheru. S2-progeny evaluation was done every other Kharif. 222 progenies were tested and 22 selected in each method (Pearl Millet Breeding publication PMB 1.5).

Size of population subjected to RRPS and GMS selection was 2000 hills according to PMB 1.10.

Selection criteria in S2 and FS selection were days to bloom, plant height, and head weight. RRPS and GMS were based on visual assessment of the same characters, with 2000 hills divided into grids of 100 plants from which 10 plants were selected. Selection in GMS was at harvest whereas that of RRPS was before flowering. RRPS was modified in Cycles 5 and 6, with 15 plants selected per grid before flowering and 10 of these retained at the time of harvest (PMB 1.12).

Entries
WC CO bulk (twice)
WC S2 (cycles 1 to 3)
WC FS (cycles 1 to 6)
WC GMS (cycles 1 to 6)
WC RRPS (cycles 1 to 6)
WC RRPS-modified (cyles 5 to 6)

- **AMMS**

46 experimental populations were derived by selection for increased or decreased yield potential in the Dwarf, New Early, and New Elite composites. Detailed description of the selection indices employed and the methods for developing the

experimental populations can be found in "Mass-selection strategies for pearl millet improvement" (Ph.D. dissertation, H. F. Rattunde).

1.3. TRIALS EVALUATING PROGRESS FROM SELECTION

Objectives and trials

The purpose of these trials (listed below) is to determine what progress has been achieved by the variety and population breeding of the Pearl Millet Improvement Program at ICRISAT. The performance of experimental varieties derived from initial and advanced cycles of composites were compared in CXVT. Seed stocks from the many reselection within WC-C75 were compared in WCC75CT. The effects of recurrent selection on yield potential, agronomic traits, and disease resistance of pearl millet populations were assessed in a series of composite bulks trials.

Trial	Year	Location
Comparison of Experimental Varieties (CXVT)	1979	PHF PLF HSR BSR
WC-C75 Comparison Trial (WCC75CT)	1983	PHF BSR
Composite Bulk Trial (CBT)	1976	PHF PLF HSR BSR
Composite Bulk Trial (CBT)	1977	PHF PLF HSR BSR LAM TNI
Composite Bulk Trial (CBT)	1978	PHF PLF HSR SAM TNI
Composite Bulk Trial (CBT)	1979	PHF PLF HSR BSR KAM PDN .
Composite Bulk Trial (CBT)	1982	PHF HSR BSR PDN
Composite Bulk Trial (CBT)	1984	PHF HSR BSR
Comparison of Composite Bulks & Varieties (CCBVT)	1985	PHF HSR BSR PDN
Comparison of SRC Bulks Trial (SRCBULKS)	1985	PHF HSR BSR
Comparison of SRC Bulks Trial (SRCBULKS)	1986	PHF HSR BSR PDN PSN
Composite Bulk Trial (CBT)	1987	PHF HSR BSR PSI PSD PDN

Genetic Materials

- CXVT

  Entries

  WC-C75 WC-B77
  IVS-A75 IVS-P77
  MC-C75 MC-k77
  SSC-C75 SSC-P77
  LC-C75 LC-A77

- **WCC75CT**

  Entries

  Seed Stocks of WC-C75

Field	Season
NSBW6	1980 kharif
BSBW6	1980 Kharif
NSRCE17	1982 Summer
BSRCE17	1982 Summer
BSP	1983 Summer
NSP	1983 Summer
BSBS-7	1982 Rabi
NSBS-7	1982 Rabi
BW-8	1979

- **COMPOSITE BULK TRIALS**

  The occurence of particular selected populations in trials across years is presented for each composite separately.

Medium Composite (MC)

	Year of trial								
Cycle	'76	'77	'78	'79	'82	'84	'85	'86	'87
C0	X	X	X	X	X	X	X		X
C1	X		X	X	X	X	X		
C2		X	X	X	X	X	X		
C3				X	X	X	X		
C4				X	X	X	X		
C5					X	X	X		
C6						X	X		
C7						X			
C8									X

New Elite Composite (NEC)

	Year of trial								
Cycle	'76	'77	'78	'79	'82	'84	'85	'86	'87
C0					X	X	X		X
C1					X	X	X		
C2					X	X	X		
C3					X	X	X		
C4						X	X		
C5									X

Intervarietal Composite (Synthetic) (IVB)

Cycle	'76	'77	'78	'79	'82	'84	'85	'86	'87
	Year of trial								
C0	X		X	X	X	X	X		X
C1	X		X	X	X	X	X		
C2			X	X	X	X	X		
C3				X	X	X	X		
C4					X	X	X		
C5						X			
C6									X

Smut Resistant Composite (SRC)

Cycle	'76	'77	'78	'79	'82	'84	'85	'86	'87
	Year of trial								
C0							X	X	X
C1							X	X	
C2							X	X	
C3								X	X

D_2 Composite (D2C)

Cycle	'76	'77	'78	'79	'82	'84	'85	'86	'87
	Year of trial								
C0					X	X			X
C1					X				
C2					X	X			
C3						X			
C4									
C5									X

New Early Composite (NEC)

Cycle	'76	'77	'78	'79	'82	'84	'85	'86	'87
	Year of trial								
C0				X	X	X	X		
C1				X	X	X	X		
C2				X	X	X	X		
C3				X	X	X	X		
C4					X	X			
C5						X	X		

Super Serere Composite (SSC)

Cycle	76	'77	'78	'79	'82	'84	'85	'86	'87
	Year of trial								
C0	X	X	X	X	X	X			
C1		X	X	X	X	X			
C2			X	X	X	X			
C3					X	X			
C4					X	X			
C5					X	X			
C6						X			
C7						X			

Serere Composite 1 (SC1)

Cycle	Trials								
	'76	'77	'78	'79	'82	'84	'85	'86	'87
C0			X	X	X				
C1	X		X	X	X				
C2	X		X	X	X				
C3				X	X				
C4					X				
C5					X				

World Composite (WC)

Cycle	Trials								
	'76	'77	'78	'79	'82	'84	'85	'86	'87
C0			X	X					
C1	X	X	X	X	X				
C2		X	X	X	X				
C3				X	X				
C4					X				
C5					X				

Late Composite (LC)

Cycle	Trials								
	'76	'77	'78	'79	'82	'84	'85	'86	'87
C0	X	X	X						
C1	X		X						
C2		X	X						

Several entries in the 1976 and 1977 Composite Bulks Trials were derived from composites other than those presented above. In 1976 these entries consisted of SDS (C2,C3), CDP (C1), ExBornu (C1), C0 and C1 of the original Dwarf and Early Composites. In 1977 the C0 and C1 of Gam73 and Gam 75 were tested.

Data from the 1982, 1984, 1985 and 1987 CBT trials has been completely checked for transcriptional- and other-errors. The corrected data has been stored in files according to the names listed in Appendix 3.

1.4 EXPERIMENTAL VARIETIES TRIALS

Objectives and trials

The purpose of the experimental varieties trials is to assess the performance of varieties developed at ICRISAT at a number of locations.

Trial	Year	Location
Experimental Varieties (EXVT)	1977	PHF PLF HSR BSR DUR KAM SAM BAM WAD PAK
Composite Expt Var Best Prog.(CEBT)	1977	PHF HSR
Experimental Varieties (EVT)	1978	PHF PLF HSR PAK TNI KAM PDN
Experimental Varieties (EVT)	1979	PHF PLF HSR BSR KAM BAM SAM WAD TNI
Experimental Varieties (EVT)	1980	PHF PLF HSR BSR BAM SAM WAD
Experimental Varieties (EVT)	1981	PHF PLF HSR BSR
Initial Expt. Varieties (IEVT)	1982	PHF PLF HSR BSR
Initial Expt. Varieties (IEVT)	1983	PHF PLF HSR BSR
Initial Expt. Var-I (IEVT-I) Early	1984	PHF HSR
Initial Expt. Var-II(IEVT-I) Late	1984	PHF PLF HSR BSR
Initial Popln. Varieties (IPVT)	1985	PHF PLF HSR BSR
Initial Popln. Specific Var (IPSVT)	1985	PHF PLF HSR BSR
Pearl Millet Initial Var (PMIVT-1)	1986	PHF PLF HSR BSR PDN
Pearl Millet Initial Var (PMIVT-2)	1986	PHF PLF HSR BSR PDN

Genetic Materials

- **EXVT-1977**

WC-A76	MC-P76	SSC-A76	G73-P76
WC-P76	LC-A76	SSC-P76	G73-B76
WC-B76	LC-B76	SSC-H76	RF-A76
MC-A76	LC-P76	G73-A76	

- **CEBT-1977**

WC-C2	MC-C2	LC-C2	SSC-C1	GAM73-C1
WC-A76	MC-A76	LC-A76	SSC-A76	GAM73-A76
WC-6173	MC-6052	LC-6027	SSC-6030	GAM73-6018
WC-6199	MC-6108	LC-6156	SSC-6255	GAM73-6172

- **EVT-1978**
  45 varieties derived from EC, DC, SSC, LC, WC, MC, IVS, SC1 NWC, NCGAM73, GAM75, and NEC. Varieites were composed in 1977 from progenies selected at specific locations or across locations, and named accordingly (-P77, -H77, -T77, -L77, -B77, -BB77, -K77, -S77 for single location, and -A77 for across location selections).

- **EVT-1979**
  21 varieties from WC, NEC, NELC, D2, SSC, IVS, SC1, MC. Varieties were based on progenies selected in 1978 across (A78) or within single locations (P78, H78, K78, BB78, W78).

- **EVT-1980**
  27 varieties from SC1, SSC, NELC, NC, SC2, IVS, D1C, 1R1B, 1B. Parental lines were selected at Patancheru, Hisar, and across locations.

- **EVT-1981**
  31 varieties from MC, IVC, SSC, WC, SC1, SC2. Parental lines were selected at Patancheru, Bhavanisagar, and across locations.

- **IEVT 1982**

	Location of progeny selection			
Composite	PHF	HSR	BSR	Across
SC1	8101			
WC	8101-2			
D1C	8105	8102-3		81
NELC	8101-5	8101	8101-4	81
ILC	81		81	81
IVC	8101			
SSC	8101			
MC	8102			
SRC	8101-5	8101-2		81

- **IEVT 1983**
  39 varieties derived from IVC, MC, NEC, NELC, SSC, SRC, Togo. Parental lines were selected at PHF, BSR, HSR, or across locations.

- **IEVT-I 1984 early**
  15 varieties were derived from NEC and D1C. Parental lines were selected at PHF, BSR, HSR, or across locations.

- **IEVT-II 1984 mid to late**
  36 varieties derived from NELC, SRC, MC, WC, and IVC. Parental lines were selected at PHF, BSR, HSR, or across locations.

- IPVT-1885
  32 varieties derived from IVC, SRC, NELC, MC progenies selected in 1984 or in the years 1980 to 1983.

- IPSVT-1985
  Varieties constituted from progenies of D2, SSC, EC, MC, NELC, DIC, EG, and NEC, tested in 1982 to 1984.

- PMIVT-1 1986
  Varieties constituted from progenies of MC, EGP selected at in 1985 PHF, BSR, and across locations.

- PMIVT-2 1986
  Varieties constituted from progenies of NELC or SRC tested in 1985.

1.5 ELITE VARIETIES TRIALS

Objectives and trials

Elite variety trials were conducted to evaluate promising varieties over a range of geographic- and edaphic-environments.

Trials	Year	Location
Elite Varieties Trial (EVT)	1978	PHF PLF HSR BSR TNI BAM WAD KAM GOR PDN
Elite Varieties Trial (EVT)	1979	PHF PLF HSR BSR BAM KAM SAM WAD TNI
Elite Varieties Trial (EVT)	1980	PHF PLF HSR BSR WAD BAM PDN
Elite Varieties Trial (EVT)	1981	No Record
Advanced Popln. Var. Trial (APVT)	1982	PHF PLF HSR BSR
Advanced Popln. Var. Trial (APVT)	1983	PHF PLF HSR BSR ISC ZAM
Advanced Popln. Var. Trial (APVT)	1984	PHF PLF HSR BSR ANA
Pearl Millet Advanced Var (PMAVT)	1985	PHF PLF HSR BSR GUL
Pearl Millet Advanced Var (PMAVT)	1986	PHF PLF HSR BSR PDN

Genetic Materials

- ELVT 1978
  Varieties derived from WC, MC, LC, IVX, SC1 were tested. 13 entries were common with BPPT-1977 and 4 entries with EVT-1977.

- ELVT 1979
  24 varieties derived from WC, IVS, MC, SSC, MC, LC, SC1, and NEC.

- ELVT 1980
  27 varieties consisting of entries retained from ELVT-1979 (8) or promoted from PMHT-1979 (4), EVT-1979 (5), PMST-1979 (2), and BPPT-1979 (8).

- ELVT 1981
  Entries include 3 hybrids, 3 synthetics, 6 experimental varieties, and 3 progeny varieties.

• **APVT 1982**
21 varieties derived from SC1, IVC, MC, WC, and SSC. Nine are common with EVT-1981 and seven are in common with BPPT-1981.

• **APVT 1983**
22 varieties derived from NELC, SRC, MC, DIC, SSC, and IVC.

• **APBT 1984**
28 varieties derived from IVC, MC, NELC, SRC, and SSC.

• **PMAVT 1985**
19 synthetics and 22 varieties of NELC, MC, SRC constituted in 1982 to 1984.

• **PMAVT 1986**
28 varieties of IVC, SRC, MC, NELC and composite bulks and 14 synthetics.

1.6 BEST POPULATION PROGENY TRIALS

Objectives and trials

Individual progenies derived from composites and increased by sibbing were tested multilocationally to evaluate their potential as varieties.

Trial	Year	Location
Best Population Progeny (BPPT)	1977	PHF HSR
Best Population Progeny (BPPT)	1978	PHF HSR KAM
Best Population Progeny (BPPT)	1979	PHF HSR SAMF WAD TNI KAM PDN
Best Population Progeny (BPPT-1)	1980	PHF PLF HSR WAD BAM
Best Population Progeny (BPPT-2)	1980	PHF PLF HSR BSR WAD BAM (no data found)
Best Population Progeny (BPPT)	1981	PHF HSR PDN
Initial Population Progeny (IPPT)	1982	PHF HSR BSR
Initial Population Progeny Var(IPPVT)	1983	(no data found)
Initial Population Progeny Var(IPPVT)	1984	PHF PLF HSR BSR
Initial Population Progeny Var(IPPVT)	1985	PHF PLF HSR

Genetic Materials

• **BPPT 1977**
60 progenies derived from WC, MC, LC, SSC, Gam73, Gam75, and SC.

• **BPPT 1978**
79 progenies derived from WC, IVS, LC, NC, Gam73, Gam75, MC, SSC, SC1, NEC, EC, DC, and EB.

• **BPPT 1979**
60 progenies derived from WC IVS, NEC, NELC, SC1, and MC.

- **BPPT-1 1980**
  60 progenies derived from D2C, SC1, SSC, NELC, SC2, and NC.

- **BPPT-2 1980**
  14 progenies derived from D1, 1R, 1B, and crossed progenies of these composites and of DC and EC.

- **BPPT 1981**
  59 progenies derived from SC1, NEC, MC, IVC, SSC, and WC.

- **IPPT 1982**
  60 progenies derived from D1C, SRC, NELC, MC, SC2, and IVC.

- **IPPT 1983**
  53 progenies derived from NELC, MC, IVC, NEC, SSC, SRC, and Togo.

- **IPPVT 1984**
  36 progenies derived from WC, NELC and SRC.

- **IPPVT 1985**
  32 progenies derived from IVC, WC, NELC, MC, and SRC.

ACCURACY AND STATISTICAL ANALYSIS OF COMPOSITE TRIALS

Data from the 1982, 1984, 1985, and 1987 Composite Bulk Trials were retrieved from storage on computer tapes and were checked against the original values in the fieldbooks. Transcriptional errors and other errors were found in data from every year. Data stored on magnetic tape, therefore, must be rechecked in detail before any reanalysis is initiated.

The accuracy of experiments can be judged by the magnitude of the least significant differences (LSD) between entries. The accuracy of the Composite Bulk Trials, therefore, can be indicated by the $LSD_{0.05}$ for grain yield differences between bulks. The $LSD_{0.05}$ values for the Medium Composite bulks, for example, ranged from 238 to 927 kg ha^{-1} in the nine tests conducted over three years and three locations. These error levels are reasonable for the environments in which testing was done and showed no relationship with the productivity of the environments. Combined analyses over years and locations of the Medium Composite bulks, however, resulted in a $LSD_{0.05}$ for grain yield of 154 kg ha^{-1}. Thus the increased effectiveness in discriminating between genetic materials by repeating trials over years is indicated.

The prior analyses of multilocational Composite Bulk Trials has been very limited. The combined analyses across locations have been incomplete with, for example, no estimations made of entry by location interactions. Furthermore, combined analyses over years has not been done.

SECTION 2

Pearl Millet Composite and Variety Trials at ICRISAT
1977 to 1986: A Data Base

Expt.	Year	Location	Fldbk	Rep	Plot Size	Traits
CBT	1987	PSD	302	4	4x4x0.60	20
CBT	1987	BSR	304	4	4x4x0.60	20
CBT	1987	HSR	306	4	4x4x0.75	20
CBT	1987	PHF	307	4	4x4x0.60	20
CBT	1987	PSI	297	4	4x4x0.60	20
CBT	1987	PDN	310			20
SRCBULKS	1986	PDN	289	4	4x2x.757	16
SRCBULKS	1986	PSN	286	4	4x4x0.75	16
SRCBULKS	1986	PHF	295	4	4x2x.75	16
SRCBULKS	1986	BSR	281	4	4x4x.5	16
SRCBULKS	1986	HSR	283	4	4x4x.075	16
PMAVT	1986	BSR	281	4		49
PMAVT	1986	HSR	283	4		49
PMAVT	1986	PHF	288	4		49
PMAVT	1986	PDN	289	4		49
PMAVT	1986	PLF	292	4		49
PMIVT-2	1986	PHF	288	3		49
PMIVT-2	1986	PLF	287	3		49
PMIVT-2	1986	BSR	281	3		49
PMIVT-2	1986	HSR	283	3		49
PMAVT-2	1986	PDN	289	3		49
PMIVT-1	1986	BSR	281	3		42
PMIVT-1	1986	HSR	283	3		42
PMIVT-1	1986	PLF	287	3	4X	42
PMIVT-1	1986	PHF	288	3		42
PMIVT-1	1986	PDN	289	3		42
SRCBT	1985	BSR	256	4		12
SRCBT	1985	HSR	260	4		12
SRCBT	1985	PHF	272	4		12
ISPVT	1986	BSR	256	3		
ISPVT	1985	HSR	260	3		
ISPVT	1985	PLF	264	3		
ISPVT	1985	PHF	265	3		
PMAVT	1985	GUL	256	4		49
PMAVT	1985	BSR	256	4		49
PMAVT	1985	HSR	260	4		49
PMAVT	1985	PLF	264	4		49
PMAVT	1985	PHF	265	4		49
IPPVT	1985	HSR	260	3		30
IPPVT	1985	HSR	260	3		30
IPPVT	1985	PLF	264	3		30
IPPVT	1985	PHF	265	3		30
IPVT	1985	BSR	256	3		32+4
IPVT	1985	HSR	260	3		32+4
IPVT	1985	PLF	264	3		32+4
IPVT	1985	PHF	265	3		32+4

Expt.	Year	Location	Fldbk	Rep	Plot Size	Traits
DTCB	1985	BSR	256	4		18
DTCB	1985	PHF	272	4		18
CCUBT	1985	BSR	256	3	4X5X5	49
CCUBT	1985	HSR	260	4	4X5X.5	49
CCUBT	1985	PHF	272	4	4X5X.75	49
CCUBT	1985	PDN	270	2	2X4X.75	49
CBT	1984	BSR	229	5	RX4X.5	36+12
CBT	1984	HSR	233	6	4X4X.75	36+12
CBT	1984	PHF	247	6	4X4X.75	36+12
IEVT-1	1984	HSR	233	3		36+4
IEVT-1	1984	PHF	247	3		36+4
IEVT-2	1984	HSR	233	3		36+4
IEVT-2	1984	PLF	240	3		36+4
IEVT-2	1984	BSR	242	3		36+4
IEVT-2	1984	PHF	242	3		36+4
IPPVT	1984	HSR	233	3		36+4
IPPVT	1984	PLF	240	3		36+4
IPPVT	1984	BSR	242	3		36+4
IPPVT	1984	PHF	242	3		36+4
APUT	1984	BSR	229	4		28+4
APUT	1984	HSR	233	4		28+4
APUT	1984	PLF	240	4		28+4
APUT	1984	PHF	242			28+4
APUT	1984	ANA	235	4		28+4
APUT	1983	PHF	200	4	4X	22+3
APUT	1983	PLF	200	4		
APUT	1983	BSR	200	4		
APUT	1983	HSR	200	4		
APUT	1983	ISC	200	4		22+3
APUT	1984	ZAM	218	4	4X	22+3
IPPVT	1983					
IEUT	1983	HSR	200	3	4X4X.75	39+3
IEUT	1983	PHF	200	3	4X4X.75	39+5
IEUT	1983	PLF	200	3	4X4X.75	39+3
IEUT	1983	BSR	200	3		39+3
WCC75CT	1983	PHF	210	4	4X4X.75	9+2
WCC75CT	1983	BSR	210	4		9+2
WCC75CT	1983	HSR	210			9+2
CBT-NEC	1982	PHF	181	5	6X4X.75	6
CBT-SC1	1982	PHF	181	5	6X4X.75	7
CBT-DID2	1982	PHF	181	5	6X4X.75	8
CBT-WC	1982	PHF	181	5	6X4X.75	6
CBT-IVC	1982	PHF	181	5	6X4X.75	6
CBT-MC	1982	PHF	181	5	6X4X.75	7
CBT-NELC	1982	PHF	181	5	6X4X.75	5
CBT-SSC	1982	PHF	181	5	6X4X.75	7
CBT-WC	1982	BSR	181	5	6X5X.5	6
CBT-IDC	1982	BSR	181	5	6x5x.5	6

Expt.	Year	Location	Fldbk	Rep	Plot Size	Traits
CBT-NELC	1982	BSR	181	5	6X5X.5	5
CBT-MC	1982	BSR	181	5	6X5X.5	7
CBT-NEC	1982	BSR	181	5	6X5X.5	6
CBT-SC1	1982	BSR	181	5	6X5X.5	7
CBT-SSC	1982	BSR	181	5	6X5X.5	7
CBT-DID2	1982	BSR	181	5	6X5X.5	8
CBT-WC	1982	HSR	181	5	6X4X.75	6
CBT-IVC	1982	HSR	181	5	6X4X.75	6
CBT-MC	1982	HSR	181	5	6X4X.75	7
CBT-NELC	1982	HSR	181	5	6X4X.75	5
CBT-NEC	1982	HSR	181	5	6X4X.75	6
CBT-SC1	1982	HSR	181	5	6X4X.75	7
CBT-DID2	1982	HSR	181	5	6X4X.75	8
CBT-SSC	1982	HSR	181	5	6X4X.75	7
APUT	1982	PHF	183	4	6X4	21+5
APUT	1982	PLF	183	4		21+3
APUT	1982	HSR	183	4		21+3
APUT	1982	BSR	183	4		21+3
IEVT	1982	PHF	181	4		32+4
IEVT	1982	PLF	181	4		32+4
IEVT	1982	HSR	181	4		32+4
IEVT	1982	BSR	181	4		32+4
IPPT	1982	PHF	183	4		60+4
IPPT	1982	HSR	183	4	2X4X.75	60+4
IPPT	1982	BSR	183	4		60+4
WCSMBT	1982	PHF	145	6	8X	25
BPPT	1981	PHF	173	3	4X4	64
BPPT	1981	HSR	173	3		64
EVT	1981	PHF	170	4	6X4X.75	31+5
EVT	1981	PLF	170	4	6X4X.75	31+5
EVT	1981	BSR	170	4	6X	31+5
EVT	1981	HSR	170	4		31+5
EUT	1980	PHF	154	4	6X4	27+5
EUT	1980	PLF	154	4	6X4	27+5
EUT	1980	HSR	150	4		27+5
EUT	1980	BSR	154	4		27+5
EUT	1980	BAM	148	2	4X4	27+5
EUT	1980	SAM	148	3		27+5
EUT	1980	WAD	148	3		27+5
ELVT	1980	PHF	154	4	6X4X.75	27+5
ELVT	1980	PLF	154	4	6X4X.75	27+5
ELVT	1980	HSR	150	4	6X4	27+5
ELVT	1980	BSR	154	4	6X4	27+5
ELVT	1980	WAD	148	3	6X4	27+5
ELVT	1980	BAM	148	4	6X4	27+5
BPPT-2	1980	PHF		3	6X4	14+4
BPPT-1	1980	PHF	148	2	6x4	60+4

Expt.	Year	Location	Fldbk	Rep	Plot Size	Traits
BPPT-1	1980	PHF	148	2	6X4	60+4
BPPT-1	1980	PLF	148	2	6X4	60+4
BPPT-1	1980	HSR	149			60+4
BPPT-1	1980	BAM	148	2	6X4	60+4
CBT	1979	BSR	132	3	8X4X.5	25
CBT	1979	HSR	132	3	8X4X.75	25
CBT	1979	PLF	132	3	8X4X.5	25
CBT	1979	PHF	132	3	8X4X.25	25
CBT	1979	KAM	132	2	2X3.96X.75	25
CBT	1979	PDN				25
BPPT	1979	SAM	130	3	6X4X.75	60+4
BPPT	1979	HSR	130	3	6X4X.75	60+4
BPPT	1979	PHF	130	3		60+4
BPPT	1979	WAD	130	3	5X5X.60	60+4
BPPT	1979	TNI	130	3		60+4
BPPT	1979	KAM	130	2	2X3X.75	60+4
CXVT	1979	PLF	134	4	8X4X.75	10+2
CXVT	1979	BSR	134			
CXVT	1979	HSR	134	7	8X5X.75	
CXVT	1979	PHF	134			
ELVT	1979	HSR	136	3	8X4X.75	24+8
ELVT	1979	BAM	136			
ELVT	1979	KAM	136		6X3.9X.75	24+8
ELVT	1979	SAM	136		.75	24+8
ELVT	1979	BSR	136			24+8
ELVT	1979	PLF	136			24+8
ELVT	1979	PHF	136			24+8
ELVT	1979	WAD	136			24+8
ELVT	1979	TNI			.80	24+8
SINEC	1979	PHF	136	6		4+1
PCT-2	1979	PHF	139	3	1X4X.75	351
PCT-1	1979	PHF	139	5	6X4X.75	
IXVT	1979	PHF	131	3		25
IXVT	1979	PLF	131	3	8X4X.75	25
IXVT	1979	HSR	131	3		25
IXVT	1979	KAM	131	3	6X4X.75	25
IXVT	1979	WAD	131	3	.50	25
IXVT	1979	SAM	131	2	5X.75	25
NPEU	1979	PLF	136	4	6X4	20+1
NPEU	1979	PHF	136	4		20+1
EVT	1979	KAM	134	3	6X3.96X.25	21+4
EVT	1979	WAD	134	3	X.50	21+4
EVT	1979	BAM	134	3	X0.80	21+4
EVT	1979	SAM	134	3	.75	21+4
EVT	1979	BSR	134	3		21+4
EVT	1979	HSR	134	3	6x4x.75	21+4
EVT	1979	PLF	134	3		21+4
EVT	1979	PHF	134	3		21+4

Expt.	Year	Location	Fldbk	Rep	Plot Size	Traits
EVT	1979	TNI	134	3	2x5x.80	21+4
CBT	1978	PLF	106	3	8X4.25X.75	21
CBT	1978	TNI	106	3		21
CBT	1978	SAM	106	3	6.5 ?	21
CBT	1978	PHF	106	3	8X4.25X.75	21
CBT	1978	HSR	106	3	6X5 ?	21
AGT-2	1978	HSR	112	3		14+6
AGT-2	1978	BSR	112	3		14+6
AGT-1	1978	PHF	112	3	8X5X.75	36
AGT-1	1978	HSR	112	3		36
ELVT	1978	PLF	86	3	8X4.25X.75	36+7
ELVT	1978	HSR	86	3		36+7
ELVT	1978	BSR	86	3	8X X.5	
ELVT	1978	TNI	86	2		
ELVT	1978	PDN	86	1		
ELVT	1978	BAM	86	3	X X.80	
ELVT	1978	WAD	86	3	X.50	
ELVT	1978	KAM	86	3	4X4X.75	
ELVT	1978	GOR	86	3	2X4X.75	
ELVT	1978	PHF	86	3		
BPPT	1978	PHF	112	2	8X4.25X.75	79+21
BPPT	1978	HSR	112	2	6X5X.45	79+21
BPPT	1978	KAM	112	2		79+21
EVT	1978	HSR	98	3	6X4X.45	45+4
EVT	1978	PAK	98	3	5X2.7X.45	45+4
EVT	1978	PDN	98	1		45+4
EVT	1978	PHF	98	3		45+4
EVT	1978	PLF	98	3	4X4X.75	45+4
EVT	1978	KAM	98	3		45+4
EVT	1978	TNI	98	2		45+4
CBT	1977	LAM	76	3	8X5X.45	16
CBT	1977	TNI	76	3	8X5X.80	16
CBT	1977	PHF	76	3	8X5X.75?	16
CBT	1977	PLF	76	3	8X5X.75?	16
CBT	1977	BSR	76	3	8X5X.50	16
CBT	1977	HSR	76	3	8X5X.75?	16
BPPT	1977	PHF	70	2	6X5X.75	60+21
BPPT	1977	HSR	70	2	6X5X.75	60+21
CEBT	1977	PHF	76	3	6X5X.75	24
CEBT	1977	HSR	76	3	6X5X.75?	24
AGT	1977	HSR	70	3	6X5X.75	30
AGT	1977	PHF	70	3	6X5X.75	30
EXVT	1977	HSR	70	3	8X5X.75?	15+5
EXVT	1977	PLF	70	3	8X5X.75	15+5
EXVT	1977	PHF	70	3	8X5X.75	15+5
EXVT	1977	BSR	70	3	8X5X.5	25+5
CBT	1976	PLF	60	4		16
CBT	1976	PHF	60	4		16
CBT	1976	BSR	36	3		16
CBT	1976	HSR	41	4	8X5X.50	16

SECTION 3

RECOMMENDATIONS FOR ANALYSES AND ANALYSES CONDUCTED

The analysis of highest priority to the population improvement work of the Pearl Millet breeding program is the combined analysis over years and locations of trials evaluating composite bulks (selected populations derived from cyclic selection). This analysis would determine what progress has been made in population improvement of pearl millet by evaluating the direct and indirect changes caused by recurrent selection. The results of such an analysis would suggest how the breeding program should be designed to enhance future genetic improvement of pearl millet. Combined analyses of Composite Bulk trials grown in 1982, 1984, 1985, and 1987 were conducted and are reported in Appendix 4. These results showed that grain yield had been increased through recurrent selection and that increases in yield potential were translated into improved yield under terminal drought. Only one trial was conducted under terminal drought in the off-season, however, and additional testing in natural drought environments is therefore needed to substantiate these results.

The Composite Bulk Diallel Trial of 1985 is another topic with high priority for analysis. Data from this trial will be analyzed by the author during his stay at the University of Hohenheim, Stuttgart, West Germany.

Comparisons of four selection methods were made in a multiyear, parallel, selection study in the World Composite. This study is of great importance to the breeding program but the products of selection were evaluated only in a single environment. It has therefore been suggested that seed of these products be increased in the summer of 1989 and tested at several locations in kharif 1989.

APPENDICIES

APPENDIX 1. LOCATIONS OF VARIETAL AND POPULATION TRIALS

Location	Abbrev.
Patancheru high fertility, India (17°N 78°E)	PHF
Patancheru low fertility,	PLF
Patancheru downy mildew nursery	PDN
Patancheru smut nursery	PSN
Patancheru summer irrigated	PSI
Patancheru summer drought	PSD
Hisar, India (28°N 75°E)	HSR
Bhavanisagar, India (11°N 77°E)	BSR
Guntur, India (16°N 80°E)	LAM
Anantapur, India (15°N 78°E)	ANA
Gulbarga, India (17°N 77°E)	GUL
Yusafwala, Pakistan (31°N 74°E)	PAK
Kamboinse, Burkina Faso (13°N 2°W)	KAM
Samaru, Nigeria (11°N 8°E)	SAM
Bambey, Senegal (14°N 16°E)	BAM
Wad Medani, Sudan (14°N 33°E)	WAD
Tarna A.R.S., Maradi, Niger (13°N 8°E)	TNI
Kaoma, Zambia	ZAM
ISC Niamey, Niger (13°N 2°E)	ISC

APPENDIX 2. DOCUMENTATION OF MATERIALS AND METHODS USED FOR RESEARCH TRIALS AND RECOMBINATIONS OF PEARL MILLET.

Research Trial	Purpose Genetic materials: origins, entry numbers Experimental design: blocking, replication, plot size (total and net), distance between and within rows Dates of planting and harvesting Field in which experiment conducted Applications of fertilizer, irrigations, etc Traits measured and transformations used Name of files and tapes where data is stored
Recombination	Location Planting date Genetic materials: origins, numbers of plants per progeny Method of pollination Description of any selection practiced Method of harvesting the recombined seed

APPENDIX 3. NAMES AND CONTENTS OF FILES WITH CORRECTED DATA FROM COMPOSITE BULK TRIALS OF 1982, 1984, 1985, AND 1987.

File name	Year	Location	Contents
D1D2BHI82.TXT	1982	HSR	REP ENT BD HWT TH%
IVCBHI82.TXT	1982	HSR	REP ENT BD HWT TH%
MCBHI82.TXT	1982	HSR	REP ENT BD HWT TH%
NECBHI82.TXT	1982	HSR	REP ENT BD HWT TH%
NELCBHI82.TXT	1982	HSR	REP ENT BD HWT TH%
SC1BHI82.TXT	1982	HSR	REP ENT BD HWT TH%
SSCBHI82.TXT	1982	HSR	REP ENT BD HWT TH%
WCBHI82.TXT	1982	HSR	REP ENT BD HWT TH%
			HEAD YIELD (T/HA) = (HWT - 1200)/1500
D1D2PH82.TXT	1982	PHF	REP ENT BD HT HWT GWT
IVCPH82.TXT	1982	PHF	REP ENT BD HT HWT GWT
MCPH82.TXT	1982	PHF	REP ENT BD HT HWT GWT
NECPH82.TXT	1982	PHF	REP ENT BD HT HWT GWT
NELCPH82.TXT	1982	PHF	REP ENT BD HT HWT GWT
SC1PH82.TXT	1982	PHF	REP ENT BD HT HWT GWT
SSCPH82.TXT	1982	PHF	REP ENT BD HT HWT GWT
WCPH82.TXT	1982	PHF	REP ENT BD HT HWT GWT
			HEAD YIELD (T/HA) = (HWT - 260)/1500
			GRAIN YIELD (T/HA) = GWT/1500
D1D2BBH82.TXT	1982	HSR	REP ENT BD HT HWT TH%
IVCBBH82.TXT	1982	HSR	REP ENT BD HT HWT TH%
MCBBH82.TXT	1982	HSR	REP ENT BD HT HWT TH%
NECBBH82.TXT	1982	HSR	REP ENT BD HT HWT TH%
NELCBBH82.TXT	1982	HSR	REP ENT BD HT HWT TH%
SC1BBH82.TXT	1982	HSR	REP ENT BD HT HWT TH%
SSCBBH82.TXT	1982	HSR	REP ENT BD HT HWT TH%
WCBBH82.TXT	1982	HSR	REP ENT BD HT HWT TH%
			HEAD YIELD (T/HA) = (HWT -1040)/1000
CBTHI84S.DAT	1984	HSR	REP ENT BD SMUT HT EL PC HC AGS HWT TH%
			HEAD YIELD (T/HA) = (HWT - 2100)/1500
CBTPH84.TRA	1984	PHF	REP ENT BD HC GWT(T/HA) HWT(T/HA)
CBTBS84.DAT	1984	BSR	REP ENT BD HC HWT TH%
			HEAD YIELD (T/HA) = (HWT - 1100)/1000
CBVTHI85.TXT	1985	HSR	REP BLK ENT TH% HWT BD HT EL PC HC
			HEAD YIELD (T/HA) = HWT/1500
CBVTPH85.TXT	1985	PHF	REP BLK ENT TH% HWT BD HT EL PC HC AGS EVIG
			HEAD YIELD (T/HA) = HWT - 2360)/1500
CBVTBS85.TXT	1985	BSR	REP BLK ENT TH% HWT BD HT EL PC HC AGS
			HEAD YIELD (T/HA) = HWT - 2200)/1000

CBTHS87.DAT	1987 HSR		REP ENT TH HWT1 HWT2 BD HT1 HT2 HT3 HT4 HT5 PL1 PL2 PL3 PL4 PL5 PC HC AOS 500SEED HEAD YIELD (T/HA) = (HWT1+HWT2-2800)/1500
CBTHF87.DAT	1987 PHF		REP ENT TH HWT BD HT1 HT2 HTT3 PL1 PL2 PL3 PC HC AOS 500SEED HEAD YIELD (T/HA) = HWT - 450)/1200
CBTBS87.DAT	1987 BSR		REP ENT TH HWT1 HWT2 BD HT1 HT2 HT3 HT4 HT5 PL1 PL2 PL3 PL4 PL5 PC1 PC2 PC3 PC4 HC AOS 500SEED HEAD YIELD (T/HA) = (HWT1+T2-2400)/1200
CBT87SSTR.DAT	1987	PAT SUMMER DROUGHT	REP ENT GWT HWT BD HC PC HT PL SWT A B HEAD YIELD (T/HA) = (HWT-1180)/1200 GRAIN YIELD (T/HA) = GWT/1200 STRAW YIELD (T/HA) = SWT/1200
CBT87SNOR.DAT	1987	PAT SUMMER IRRIGATED	REP ENT GWT HWT BD HC SWT PC HT PL EVIG AOS HEAD YIELD (T/HA) = (HWT - 2360)/1200 GRAIN YIELD (T/HA) = GWT/1200 STRAW YIELD (T/HA) = SWT/1200
NECPDN.DAT	1982 & 1985		YR REP ENT DM% 1982 = YR1
NELCPDN.DAT	1982 & 1985		YR REP ENT DM% 1985 = YR2
IVCPDN.DAT	1982 & 1985		YR REP ENT DM%
MCPDN.DAT	1982 & 1985		YR REP ENT DM%
DM89.DAT	1989		REP ENT DM%

APPENDIX 4. POPULATION IMPROVEMENT FOR GRAIN YIELD AND DISEASE RESISTANCE IN PEARL MILLET.

Abstract

Recurrent selection for increased grain yield and resistance to downy mildew caused by (*Sclerospora graminicola* Sacc. Schroet.) was conducted for at least three cycles in six pearl millet (*Pennisetum glaucum* (L.) R. Br.) composites. We determined the effect of selection on grain yield *per se*, yield under terminal drought, and incidence of downy mildew. C_0 and selected populations were evaluated in a single year across three locations in the rainy season India, and under terminal drought and in irrigated control in the dry season. Susceptibility to downy mildew was tested in field and glasshouse tests with high inoculum levels. Grain yield increased by 72**, 94**, 83**, and 23ns kg ha^{-1} $cycle^{-1}$ in four composites tested over locations and years. Yield increase (linear) x test location interaction occurred in only one composite. Selection increased yields under terminal drought by 18ns to 93** kg ha^{-1} $cycle^{-1}$ in the five composites tested. Yield gains were associated with increases of harvest index under droughted environments and of biomass under irrigated conditions. Maturity and height were generally constant or reduced. Downy mildew incidence was less than 5% except when new material had been introduced into the population. The relevance to ongoing population improvement in pearl millet is discussed.

Key Words: Recurrent selection, G x E interaction, Drought resistance, *Sclerospora graminicola* Sacc. Schroet.

Introduction

Pearl millet is grown for grain or forage on approximately 26 million ha (FAO, 1978). It is a subsistence crop generally grown without use of fertilizers or pesticides, and is the most important source of calories for people living in the dry tropical regions where no other cereal is as well adapted pearl millet growing areas have mean annual rainfalls of 200-800mm, and thus low or poorly distributed rainfall are major yield limiting factors (Bidinger *et al.*, 1982). One of the most serious biotic threats to production of pearl millet is downy mildew, which is endemic in Africa and India and has caused several epiphytotics in India since 1971 (Rachie and Majmudar, 1980; Safeeulla, 1977).

At ICRISAT in India since 1973, a range of genetically broad based populations of pearl millet have been created and subjected to recurrent selection to increase genetic tolerance to major diseases and drought while increasing yield potential *per se*. Recurrent selection was conducted with multilocational progeny testing and exposure of segregating material to high downy mildew disease pressures (Andrews *et al.*, 1985). Experiments evaluating the selected pearl millet populations for grain yield, yield under drought, and levels of resistance to downy mildew have been conducted in India between 1982 and 1989. We report the changes made by recurrent selection in six pearl millet composites for grain yield under normal and terminal drought stress environments, and for downy mildew susceptibility.

Materials and Methods

Genetic Materials

Four pearl millet (*Pennisetum glaucum* (L.) R. Br.) composites were constituted at ICRISAT from lines of both African and Indian origin. Indian lines are sources of early maturity and tillering, whereas African lines contribute large head volume, seed size, and disease resistance (Andrews *et al.*, 1985). These composites, the Medium (MC), Early (EC), Inter Varietal (IVC), and New Elite (NELC), had 196, 115, 61, and 47 parental lines, respectively, chosen on maturity and performance *per se* in one season of testing. Lines entering MC were landraces or lines from other breeding programs, whereas those entering EC and NELC were S_1 or S_2 progenies derived from other composites already undergoing improvement. F_2 bulks from intervarietal crosses were chosen to form the IVC. Two composite had parental material entirely from Africa: The Smut Resistant (SRC) was constituted from 37 smut resistant inbred lines, and the Dwarf (D2C) composites was constituted from 23 dwarf S2-lines.

Recombination of parental lines was done by open pollination in isolation, with single rows of parental lines separated by bulk rows formed from an aliquot of seed from each parent. Recombination was conducted three times in MC, twice in SRC, and once in EC, NELC, IVC, and D2C before selection was initiated.

Population Improvement

The composites were subjected to recurrent selection for increased grain yield by multilocational testing of progenies of various types (Table 1). Progeny trials were conducted at Patanacheru (17^{o}N) and Hisar (29^{o}N), India, for nearly every cycle of selection, although data from Hisar often had to be discarded because of severe and heterogeneous soil salinity. Progenies were selected for superior individual or across locations grain yield. There was no deliberate selection for yield under drought although some progeny trials had below optimum rainfall.

Progenies from each cycle of selection were sown in downy mildew nurseries where inoculation of susceptible cultivars in 'infector rows' and mist irrigation induced high inoculum loads and optimal conditions for infection (Andrews *et al.*, 1985). Selfed seed of symptomless plants in the selected progenies served as the recombination units for intermating progenies to begin the next cycle of selection.

Progenies derived from other composites in the breeding program were included in the recombination phase of certain cycles of selection in MC and IVC (Table 1). New genetic material was introduced to increase genetic variability and not necessarily to increase the population mean.

Evaluating Progress From Selection

Trials to assess the grain yield, maturity, and height of selected populations were conducted in the rainy seasons (May to

October) of 1982, 1984, 1985, and 1987 (Table 2). The base population (C_0) and subsequent four to five selected populations of MC, IVC, EC, and NELC were tested in 1982 to 1985. In 1987, only the C_0 and latest selected populations of MC, IVC, NELC, SRC, and D2C were tested. The trials in each year were conducted at Hisar (29°N), Patancheru (17°N), and Bhavanisagar (11°N) in India. Entries were replicated three to six times per trial. Plots were 4m long with six (1982) or four (1984 to 1987) rows spaced at 0.5m (Bhavanisagar), 0.6m (Patancheru, 1987), or 0.75m intervals. Plots were uniformly over-seeded and thinned to 0.1m between plants within rows. Panicles were harvested from four rows of each plot, air dried, and weighed. Grain yield was determined by threshing all panicles harvested (1982 and 1987) or by multiplying the panicle yield from each plot by its threshing percent, estimated by threshing a kg sample of panicles (1984 and 1985). Days to flower was recorded as the number of days from emergence to when > 50 percent of plants in a plot had emerged stigmas. Plant height was measured from the soil to the tip of primary panicle on 5-10 random plants per plot. The number of panicles m^{-2}, individual seed mass, and number of seeds $panicle^{-1}$ were estimated at each location in 1987. Seed mass was determined by weighing 500 seeds from two replicates of each experiment. Number of seeds $panicle^{-1}$ was calculated by dividing seed mass $panicle^{-1}$ by individual seed mass. Seed mass $panicle^{-1}$ was panicle mass $plot^{-1}$ multiplied by threshing percent and divided by the number of panicles $plot^{-1}$.

The trials at Hisar and Patancheru in 1982 to 1985 were rainfed. The 1987 trial at Hisar was irrigated four times during the growing season due to lack of rain. Bhavanisagar is located in a natural rainshadow and trials at this location received flood irrigation once every 7-14 days.

The soils at Hisar were entisols with 130-200mm available water-holding capacity (AWHC). There were alfisols at both Bhavanisagar (80mm AWHC) and at Patancheru (60-100 AWHC). Fertilizer applications of 40kg ha^{-1} N and 40kg P_2O_5 were made prior to planting and an additional 40kg ha^{-1} N were topdressed 2-3 weeks after planting.

The yield potential of the C_0 and latest selected populations of five pearl millet composites under terminal drought stress was evaluated at Patancheru in the dry season (January to March) of 1987. There were two treatments, a control, which had uninterrupted irrigation until 11 days before harvest, and a terminal drought treatment which was created by stopping irrigation at 47 days after emergence (DAE). Irrigations of approximately 30mm were applied through the furrows with a frequency of once every 14 days in both treatments. The frequency was increased to 10 day intervals after 45 DAE in the fully irrigated control. Both treatments had four replicates with plots of four rows of 4m length and 0.6m width. Fertilization was the same as in the rainy season experiments. Panicle yield was measured on all four rows per plot and the entire sample was threshed to determine grain yield. After the panicles were removed the plots were cut at ground level to harvest the straw which was dried in the sun for two days, and then weighed. Yield of biomass was computed by summing panicle and straw yields. The harvest index was determined by dividing grain yield by biomass and multiplying by 100.

Frequency of plants susceptible to downy mildew in the selected populations were assessed at Patancheru in two replicate disease nurseries in the rainy seasons (June to September) of 1982 and 1985. Infector rows and daily mist irrigations were used to create an optimal environment for infection (Williams and Singh, 1980; Andrews *et al.*, 1985). The selected populations of MC, IVC, EC, and NELC were sown between the infector rows in plots of 4m length with four rows in 1982 (about 130 plants) and two rows in 1985 (about 60 plants). The total numbers of plants and infected plants were counted in each plot.

A seedling test for susceptibility to downy mildew at the most susceptible growth stage of pearl millet (ICRISAT, 1988) was used to evaluate all populations derived from the four composites up to 1988. Approximately 70 seedlings of each entry were grown in each of three pots in March of 1989. The seedlings were spray inoculated with a sporangial suspension ($10^5 ml^{-1}$) of a Patancheru isolate of downy mildew at the coleoptile to one-leaf stage. The inoculated plants were incubated at 20°C and > 95% humidity for 16 hours and then returned to the glasshouse. The number of plants exhibiting symptoms of infection were counted 14 days after inoculation. The pots were randomized in complete blocks before inoculation and of towards in a completely randomized design.

Statistical Analysis

Analyses of variance among the selected pearl millet populations tested in 1982, 1984, and 1985 were conducted within each composite to assess the effect of selection on grain yield and agronomic traits. Data were pooled over years and locations and analyzed within and across locations using a randomized complete block design. Error variances did not differ by more than a factor of 3 across experiments. Linear and quadratic contrasts for cycle of selection were computed to describe the pattern of trait changes over cycles. Mean squares from these contrasts were tested against the entry by year interaction mean square when it was larger then the pooled error term, since years were considered random whereas locations were fixed. Variance attributed to entry by year and entry by location interactions were partitioned into linear (cycle) and residual components.

Linear regressions of yield and of agronomic traits on the cycle of selection were computed. Their significance was determined from the linear (cycle) contrasts. The General Linear Model procedure of SAS (1985) was used for both the analyses of variance and regression.

Variance among the C_o and latest selected populations of the five composites tested in the 1987 rainy season was described by analyses within and across locations using a randomized block design. LSDs were computed using the pooled error mean square to compare the C_o and latest selected populations within each composite.

Data on the incidence of downy mildew (DM%) from the 1982 and 1985 downy mildew nurseries as well as the 1989 seedling test were transformed to $(DM\% + 0.5)^{0.5}$ prior to analysis (Gomez and Gomez, 1984).

To determine if specific drought tolerance contributes to yield differences under drought a drought response index (DRI) was used (Bidinger *et al.*, 1982; Bindinger *et al.*, 1987). This index,

$$DRI_i = \frac{Ys_i - Ys_i}{SE_{Ys}}$$

is computed for the ith genotype as the difference between its observed yield under stress (Ys_i) and its predicted yield under stress (Ys_i) and expressed as a ratio over the standard error of Ys (SE_{Ys}). Ys_i is estimated from the yield (Yc_i) and days to bloom (Bc_i) of the ith genotype under irrigated conditions according to the following equation:

$$Ys_i = a + b_1(Yc_i) - b_2(Bc_i)$$

where the intercept (a) and regression coefficients (b_1 and b_2) are estimated by multiple regressions of yield and bloom date under irrigation of all genotypes under test onto their mean yields under stress. The existence of specific resistance to drought is considered to be indicated by $DRI_i > 1.3$.

Results

Grain yield and agronomic traits

Four to five cycles of recurrent selection increased grain yields by 72**, 83**, 94** and 23ns kg ha^{-1} $cycle^{-1}$ (linear response) in the MC, IVC, EC, and NELC pearl millet composites, respectively, averaged over three years at three locations in India (Table 3). This is a range of 0.9-4.9% increase per cycle. The largest increases of grain yield occurred in the first cycle of selection, in which 75% of the total yield increase predicted by linear regressions over all cycles was obtained in MC and IVC, and 43% in EC. Only the EC populations, however, had significant quadratic response of grain yield across cycles of selection.

Number of days to flower and plant height of the populations selected in EC exhibited significant curvilinear increases over cycles of selection. Selection in IVC and MC, however, resulted in significant linear decreases of days to flower and decreased or unchanged plant height.

The linear increases of grain yield over cycles of selection in MC and IVC did not differ ($P>0.05$) between the three test locations in Peninsular India. Selected populations derived from EC, however, had linear yield gains that interacted strongly with location ($P<0.01$), with large gains exhibited at Hisar but none at Patancheru (Table 4). Yields of EC populations at Patancheru, however, exhibited a quadratic response ($P<0.01$) with an increase of 214 kg ha^{-1} * between C_0 to C_2 and a decrease of 253 kg ha^{-1} ** from C_2 to C_4.

The linear changes of days to bloom and plant height showed almost no interaction with locations or years of testing. Only the linear increase of days to bloom in selected populations of

EC showed interaction with the year of testing ($P<0.01$), having linear changes of 1.14**, 0.89** and 0.51** days cycle^{-1} in 1985, 1984, and 1982, respectively.

The 1987 evaluation of the C_0 and latest selected populations of five composites again showed that recurrent selection had increased grain yields, with increases of 4.7** (MC), 0.7ns (IVC), 6.9** (NELC), 18.3** (SRC), and 3.6** (D2C) percent cycle^{-1} when averaged over three locations (Table 5). These rates of gain compare favorably with those observed in the first 4 to 5 cycles in MC and NELC but not in IVC (Table 3). The yield increases shown by MC and IVC selected populations were significant ($P<0.05$) at all three locations. Yield increases in NELC and D2C were smaller at Hisar (2.8ns and 1.6ns percent cycle^{-1}, respectively) than their yield gains averaged over Patancheru and Bhavanisagar (11.3** for NELC and 4.4* percent cycle^{-1} for D2C). The selected population of IVC, however, exhibited no yield advantage at any location.

The yield gains in the composites tested in 1987 were achieved without increasing the days to bloom. Measurements of the three yield components, ie. individual seed mass, seed number panicle^{-1}, and panicle number m^{-2}, did not reveal any one component to be responsible for the yield gains observed (Table 5). Several of the selected populations exhibited nonsignificant ($P>0.05$) increases of seed mass and a two populations had significantly ($P<0.05$) increased seed number and/or panicle number relative to their C_0 populations.

Performance in terminal drought

Mean grain yields were much lower in the planting without post-flowering irrigation as compared to the irrigated control, showing that considerable drought stress was created (Table 6). Grain yields under terminal drought were higher in the latest selected populations as compared to their respective C_0 populations. The magnitudes of yield increase ranged from 90ns to 350** kg ha^{-1} in the five composites studied. Associated with these yield increases were increases of harvest index that ranged from 3ns to 9** percentage points. The total biomass produced by the latest selected populations, however, was not significantly increased over that of their C_0 populations ($P>0.05$).

Downy mildew susceptibility

The incidence of downy mildew was generally below 5% in the selected populations, both when tested under field conditions (Table 7) and when inoculated as seedlings in the glasshouse (Table 8). The level of susceptibility of the selected populations did not generally differ from the C_0 populations. In two instances where germplasm from sources other than the previous cycle was introduced, however, incidence of downy mildew was significantly increased ($P<0.05$).

Discussion

The range of linear increase in grain yield cycle^{-1} were from 0.2-29.89% cycle^{-1} when all data are considered. However, these extreme values occur when there is either only one location considered across years, or there is only one year one location data (Table 9). If we consider the percent gain in grain yield across locations the range is from 1.3 to 4.9% cycle^{-1}, excluding SRC (Table 9). This range of gain per cycle is satisfactory, and compares favorably with results reported in the literature for mass selection in maize, but is about the same or less than results reported for progeny selection in maize (Hallauer and Miranda, 1981). The gain in the Smut Resistant Composite of 21.4% cycle^{-1} across five environments is high, but the C_0 cycle of this composite is the lowest yielding of the composite in the trials indicating that the scope for improvement is greater. As this gain is over only the first three cycles of selection, it is safe to assume that this population initially had a low mean but a very high genetic variance for yield.

In the four composites studied in most detail four to five cycles of recurrent selection increased grain yield by 23ns-94** kg ha^{-1} (0.9-4.9%) over three years and three locations (Table 3). The largest increases of grain yield occurred in the first cycle of selection, in MC and IVC and EC. However, only in EC was there a quadratic response of grain yield across cycles. When this evidence, along with the high gains made in the three cycles of selection in SRC are considered we conclude that better progress can be expected in newly created composites. However, the lack of response in NELC indicates that new composites must have sufficient genetic variability. Of the four composites studied across three years and three locations NELC had the smallest number of parents, all derived from existing composites, and unlike IVC no new material was introduced into the composite.

When responses are considered at specific sites across years the results indicate that genetic gains have been achieved across a broad geographic range in IVC, MC and EC (Table 4). Patancheru in south-central India has been the most frequently used location for rainy season yield trials (Table 1) and has also been used for recombination and production of progenies in the dry season. Since temperatures are lower and drought stress less frequent at Patancheru than in the main millet growing regions in northern India, the breeding strategy of relying a Patancheru may not have led to genetic gains in the most important millet growing regions. The greatest increases in yield occurred at Hisar (Table 4), the testing site most representative of major millet regions are therefore most encouraging. We conclude that year to year and season to season environmental variation in Patancheru, and the progeny evaluations outside of Patancheru has been sufficient to achieve gains across a broad environmental range.

To reduce dependence of Patancheru and the risk of selecting for specific adaptation to its environment progenies are now produced in northern India. We also have restricted selection in the off-season to traits which have little season x season interaction such as downy mildew screening and smut screening under artificially controlled conditions, or in the case of selection for flowering the environment is manipulated to mimic northern Indian conditions by late planting in March and artificially extending the daylength.

However, in the EC yield gains over cycles did significantly interact with environment. This may be due to the increases in grain yield being associated with an increase in growth duration in this composite, since it is only in EC that there was a significant interaction with days to bloom and years of testing. In the composites other than EC yield gains have been made without changing phenology. The failure to improve yield in EC without increasing crop duration means that it is less adapted to regions prone to end of season droughts. It should be possible to increase yield in early maturing material as has been done in other cereals (De Leon and Pandey, 1989). This result indicates the need in short duration material of exerting a selection pressure for earliness before selecting for yield.

The increased yield of selected pearl millet populations appears to be due to the very large increases in production of biomass under optimal moisture, and the increased efficiency of dry matter partitioning, particularly under terminal drought (Table 6). Edmeades *et al.* 1989 report that in both wheat and maize improvement in yield in droughted environments in due to improved biomass partitioning. However, six cycles of selection in maize in non-droughted environments did not improve performance under drought, progress was only made when there was selection in droughted environments. These results need to be confirmed with additional testing, however, since they were obtained in a single year in the offseason.

The higher yields under terminal drought of our selected populations, relative to their C_0 populations, could reflect 1) changes relating specifically to drought resistance, 2) altered phenology enabling escape of drought, or 3) increased yield potential *per se* (Bidinger *et al.*, 1982).

(DRI) values were computed, as described in the materials and methods, for each of the populations in Table 6. The DRI_i values were less than 1.3 for both selected and C_0 populations of MC, SRC, and D2C. Gains for grain yields under stress in these composites, therefore, are due primarily to increased productivity *per se*, since the time to bloom was not changed. Only the C_6 population of IVC had a DRI > 1.3 (1.63), which suggests a slight increase of specific drought resistance. However, the earlier maturity under terminal drought of IVC-C_6, relative to IVC-C_0, points to drought escape as the reason for its better than expected performance under drought.

The sporadic increases of downy mildew susceptibility in the selected populations of pearl millet show the need of continued selection pressure for disease resistance in a recurrent selection program. There is evidence that pathogenicity of pearl millet downy mildew populations varies over space (Ball *et al.*, 1986) and time (Singh and Singh, 1987). This suggests the need of conducting screening with isolates of downy mildew obtained from the region where the population is intended for use and for maintaining selection pressure over years.

Yield evaluations of the selected populations were conducted on experiment stations. On-farm testing of these populations to determine if the yield increases of selected material are also expressed under environmental conditions experienced by typical millet producers is therefore advisable. Also, further evaluation of the selected populations under natural drought conditions is needed to confirm that increases in yield potential are expressed under drought, since only a single test under terminal drought in the off-season was conducted in this study.

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Table 1. Recurrent selection methods used for improving six pearl millet populations.

Composite	Cycle	Progeny[a]	No. seleced[b]	Selection (%)	Location of progeny tests[c]
Medium	C_1	FS	46	9	PH H B
	C_2	FS	24	12	PH PL
	C_3	FS	22	8	PH H G
	C_4	FS	30	15	PH PL H
	C_5	S2	40	19	PH PL
	C_6	S2	54+37	21	PH B
	C_7	HS	107+ 4	15	PH H
	C_8	S1	54	4	PH B
Inter Varietal	C_1	S1	45	9	PH H B
	C_2	S2	21	8	PH PL H
	C_3	FS	25+10	11	PH H S
	C_4	S2	45	21	PH PL
	C_5	S2	44+ 5	17	PH B
	C_6	S1	78+11	9	PH B
Early	C_1	FS	31	11	H
	C_2	FS	22	10	PH BS
	C_3	TC	49	23	PH PL
	C_4	HS	54	20	P L
New Elite	C_1	HS	40	17	PH H
	C_2	FS	27	13	PH H
	C_3	S2	60	20	PH H B
	C_4	S1	51	5	PH B
	C_5	S1	66	4	PH B
Smut Resistant	C_1	S2	53	22	PH H
	C_2	S1	50	8	PH H B
	C_3	S1	40	2	PH H B
Dwarf	S1	FS	32	19	PH PL B
	C_2	HS	48	18	PH
	C_3	HS	50	9	PH
	C_4	S1	46	12	PH B
	C_5	HS	119	22	PH

a HS, FS, TC denote half-sib, full-sib, and testcross, respectively.

b Number of progenies selected from the previous cycle, plus any lines from other sources that were introgressed during recombination.

c PH, PL, H, B, G, S, BS, denote Patancheru High-fertility, and low-fertility (17°N), Hisar (29°N), Bhavanisagar (11°N), Ludhiana (31°N), and Guntur (16°N) in India and Samaru Nigeria (12°N), and Bambey Senegal (14°N), respectively.

Table 2. Environmental data and number of replications for experiments testing selected populations of pearl millet for four years at three locations in India.

	1982	1984	1985	1987		
Hisar						
Planting date	20 Jul	13 Jul	8 Jul	15 Jul		
Replication	5	6	4	4		
Rainfall(mm)[a]	210	325	349	50(I)		
Max. temp.(°C)[b]	33 to 40	32 to 40	32 to 40	29 to 41		
Min. temp.(°C)	18 to 27	18 to 27	21 to 28	20 to 30		
Patancheru						
Planting date	29 Jun	4 Jul	17 Jun	26 Jun	12 Jan	20 Jan
Replication	5	6	4	4	4	4
Rainfall(mm)	388	418	313	371	2(I)	2(I)
Max. temp.(°C)	28 to 34	27 to 32	28 to 35	29 to 34	29 to 39	29 to 39
Min. temp.(°C)	22 to 24	21 to 23	22 to 23	22 to 24	13 to 23	13 to 23
Bhavanisagar						
Planting date	8 Jun	13 Jun	8 Jun	30 May		
Replication	5	5	3	4		
Rainfall(mm)	26(I)	29(I)	121(I)	119(I)		
Max. temp.(°C)	33 to 34	31 to 35	32 to 35	34 to 39		
Min. temp.(°C)	-	23 to 27	24 to 26	25 to 28		

I = also irrigated.

a Calculated rainfall during the growing season.

b Temperature range during the growing season.

Table 3. Means and linear regressions on cycle of selection for three traits, average over three locations in three years. in four pearl millet composites.

Cycle	Grain (kg ha^{-1})	Flowering (day)	Height (cm)	Cycle	Grain (kg ha^{-1})	Flowering (day)	Height (cm)
Medium Composite				**Early Composite**			
C_0	2000	48.2	226	C_0	1900	40.0	198
C_1	2270	47.0	229	C_1	2060	41.8	207
C_2	2140	47.0	224	C_2	2230	44.1	212
C_3	2300	45.9	222	C_3	2260	43.4	212
C_4	2420	46.8	227	C_4	2270	44.3	206
C_5	2370	46.7	224				
LSD 0.05	154	0.7	7	LSD 0.05	132	1.5	13
b	72**	-0.3**	-0.6	b	94**	1.0**	2.1**
Gain cycle^{-1} (% C_0)	3.6	-0.6	-0.2	Gain cycle^{-1} (% C_0)	4.9	2.6	1.0
Inter Varietal Composite				**New Elite Composite**[a]			
IVC C_0	2080	51.1	234	NELC C_0	2520	50.9	245
C_1	2330	49.6	225	C_1	2640	50.9	249
C_2	2320	49.7	227	C_2	2480	51.4	242
C_3	2300	48.8	221	C_3	2390	53.1	239
C_4	2510	48.8	229	C_4	2760	51.0	237
LSD 0.05	153	0.6	5	LSD 0.05	169	0.6	11
b	83**	-0.6**	-1.4*	b	23	0.3*	-2.6*
Gain cycle^{-1} (% C_0)	4.0	-1.1	-0.6	Gain cycle^{-1} (% C_0)	0.9	0.5	-1.0

*,** Denotes significance at the 0.05 and 0.01 level, respectively.

a Data from 1984 and 1985 for grain and flowering and 1985 for height.

Table 4. Linear regressions on cycle of selection at three locations for three traits averaged over three years in four pearl millet composites.

		Composite[a]							
		Medium		Inter Varietal		Early		New elite[b]	
Trait	loca-tion[c]	b	% gain cycle^{-1}	b	% gain cycle^{-1}	b	% gain cycle^{-1}	b	% gain cycle^{-1}
Grain (kg ha^{-1})	HSR	114**	5.0	92**	3.8	197**	9.5	47	1.8
	PAT	63**	3.3	91**	4.6	3	0.2	11	0.5
	BSR	38	2.1	65	3.5	81**	4.6	11	0.4
Flowering (days)	HSR	-0.15	-0.3	-0.62**	-1.1	1.15**	2.7	0.28	0.5
	PAT	-0.33**	-0.7	-0.40**	-0.8	0.99**	2.5	0.10	0.2
	BSR	-0.32*	-0.7	-0.62**	-1.2	0.95**	2.4	0.36*	0.8
Height (cm)	HSR	0.1	0.0	-1.8	-0.6	-2.3*	1.0	-3.5*	-1.3
	PAT	-1.9*	-0.9	-2.1*	-1.0	3.1**	1.8	-1.8	-0.8
	BSR	0.2	0.1	-0.3	-0.2	0.6	0.4	1.7	0.8

a data from 1984 and 1985.

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

a Across 5 cycles in MC, four cycles in IVC, and EC and NELC.

b HSR, PAT, and BSR denote Hisar, Patancheru, and Bhavanisagar, respectively.

Table 5. Trait means of C_0 and C_n populations of five pearl millet composites evaluated at three locations in India in the 1987 rainy season.

Population	Grain ($t\ ha^{-1}$)	Bloom (days)	Height (cm)	Individual seed mass (mg)	Seeds $panicle^{-1}$	Panicles m^{-2}
Medium						
C_0	2.30	50.3	226	8.86	2160	12.5
C_8	3.16**	50.9	222	9.41	2590*	12.3
Inter Varietal						
C_0	2.55	53.0	242**	9.61*	2730	9.9
C_6	2.66	53.5	225	8.52	2540	11.1*
New Elite						
C_0	2.14	54.2	210	8.33	2440	11.4
C_5	2.88**	54.5	224**	8.95	3030**	11.0
Smut Resistant						
C_0	1.86	55.3**	219	8.50	2190	9.3
C_3	2.88**	52.3	235**	8.79	2640**	11.8**
Dwarf						
C_0	2.11	51.0	153	8.37	2170	12.2
C_5	2.49**	50.4	160	8.63	2500	11.3
WC-C75	2.68	50.8	214	8.74	2520	11.8
LSD 0.05	2.79	1.6	10	0.85	394	1.1

*,** denote differences between C_0 and C_n that are significant at 0.05 and 0.01 levels respectively.

Table 6. Trait means of C_0 and C_n populations of five pearl millet composites evaluated in the 1987 dry season under terminal drought and fully irrigated conditions.

Population	Terminal drought Grain (kg ha^{-1})	Bloom (day)	Biomass (kg ha^{-1})	HI (%)	Fully irrigated Grain (kg ha^{-1})	Bloom (day)	Biomass (kg ha^{-1})	HI (%)
Medium								
C_0	810	62	3020	26	2390	58	6590	36
C_8	1050+	62	2980	35**	3020*	57	6600	46**
Inter Varietal								
C_0	800	64*	2880	28	2200	59	5130	43
C_6	1150**	61	3150	37**	3140**	60	6930**	45
New Elite								
C_0	640	65	2470	26	2070	63	5470	39
C_5	730	66	2550	29	2860**	62	7200**	39
Smut Resistant								
C_0	420	66	1960	21	1550	63	4130	38
C_3	700*	65	2430	29*	2940**	62	6700**	44**
Dwarf								
C_0	540	62	1960	28	1810	55	4100	45
C_5	790+	62	2130	37**	2590**	57	5740**	46
LSD .05	259	2.5	643	5.9	504	2.3	1150	4.7

+,*,** denote differences between C_0 and Cn that are significant at 0.10, 0.05, and 0.01 levels, respectively.

Table 7. Mean incidence of downy mildew, averaged over two years of field testing, in populations of four pearl millet, composites, expressed in transformed units[a] and as percentages (in parentheses).

Cycle of selection	Composites MC	IVC	EC	NELC
C_0	2.0 (4.2)	1.3 (1.4)	2.9 (8.2)	1.5 (2.0)
C_1	2.0 (4.0)	1.4 (1.7)	1.7 (2.7)*	0.8 (0.2)
C_2	1.9 (3.6)	1.4 (1.6)	1.8 (3.1)	1.2 (1.3)
C_3	1.2 (1.0)	1.8 (3.2)	1.3 (1.5)*	0.7 (0.0)
C_4	1.6 (2.4)	1.3 (1.4)	1.9 (3.1)	
C_5	1.6 (2.5)			
LSD .05	1.3	1.0	1.2	1.2

Resistant check: WC-C75 1.7 (2.4)

*Denote differences from C_0 significant at $P<0.05$.

Table 8. Mean incidence of plants with downy mildew following sporangial inoculation in the glasshouse, expressed in transformed units[a] and as percentages (in parentheses).

Cycle of selection	Composite: Medium	Composite: Inter Varietal	Composite: Early	Composite: New Elite
C_0	1.7 (3.0)	1.7 (2.7)	2.2 (4.2)	0.7 (0.0)
C_1	2.2 (5.3)	1.2 (0.9)	2.1 (5.0)	1.1 (1.0)
C_2	1.5 (2.1)	1.8 (3.3)	2.5 (6.2)	1.3 (1.4)
C_3	1.6 (2.8)	<u>1.7</u> (3.1)	2.4 (5.7)	2.5 (6.4)*
C_4	2.0 (3.6)	1.7 (2.9)	-	1.7 (3.2)
C_5	1.9 (3.9)	<u>1.0</u> (0.6)		1.6 (2.6)
C_6	<u>3.7</u> (14.5)**	<u>3.2</u> (10.8)*		
C_7	<u>1.2</u> (1.3)	2.4 (5.2)		
C_8	2.0 (4.1)			
C_9	1.4 (1.7)			
Resistant check: 700651		1.8 (2.9)		
Susceptible checks: BJ 104		7.6 (57.3)		
HB 3		9.8 (96.3)		
LSD .05 = 1.4 (transformed data)				

*,** denote differences from the C_0 that are significant at $P<0.05$ and $P<0.01$, respectively.

- Underline indicates selected populations into which outside material was introgressed.

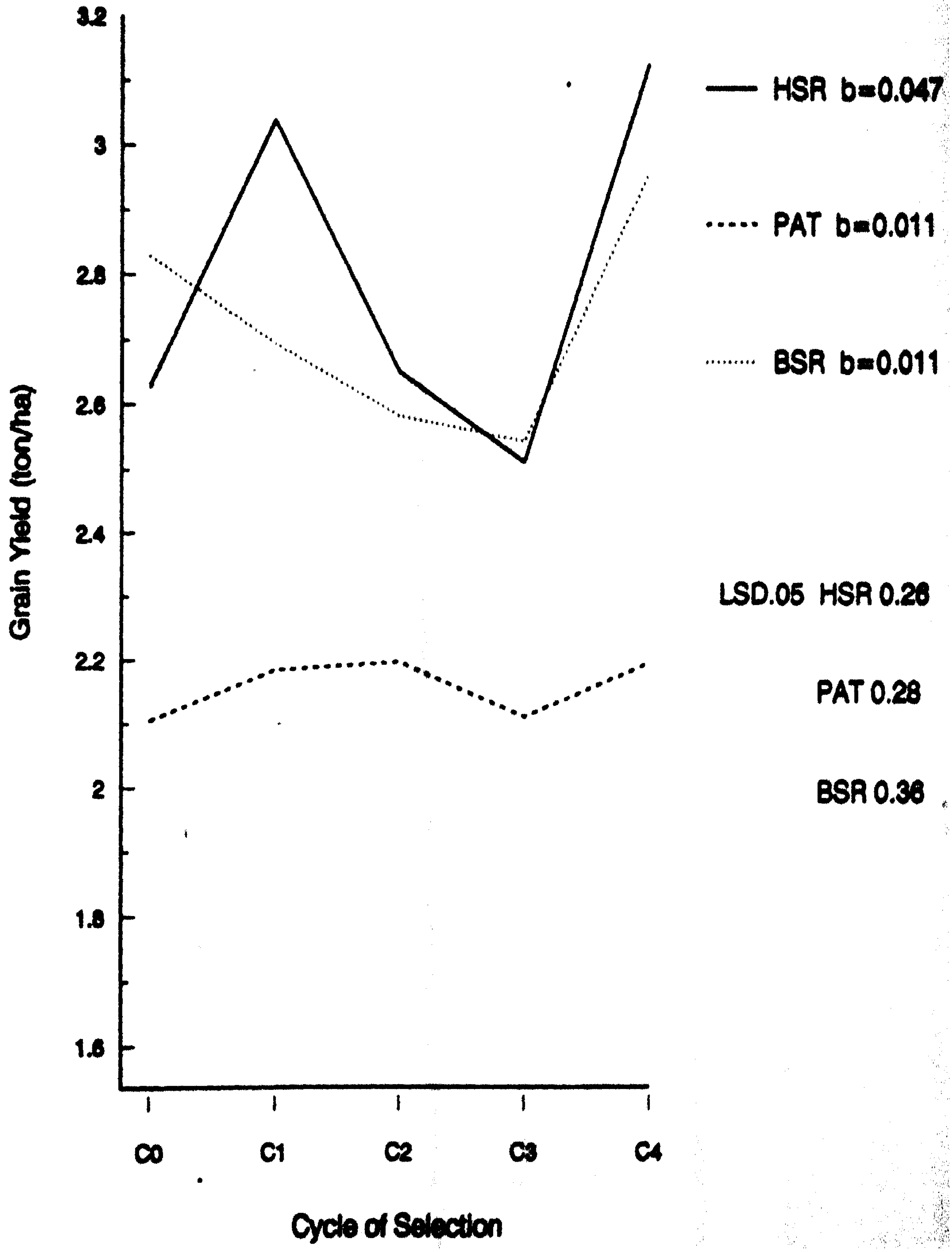
a (percent infected plants + 0.5).

Table 9. Summary of linear gains in grain yield per cycle over a range of composites and environments.

	Testing environment											
			3 year mean							1 loc 1 year		
Composite	3 locs 3 years		HSR		PAT		BSR		3 locs 1 year	Terminal drought	Fully irrigated	Mean
Medium	3.6	72	5.0	114	3.3	63	2.1	38	4.7	3.3	3.3	3.8
Early	4.9	94	9.5	197	0.2	3	4.6	81	-	-	-	4.9
Inter Varietal	4.0	83	3.8	92	4.6	91	3.5	65	0.7	7.29	7.12	3.8
New Elite	0.9	23	1.8	47	0.5	11	0.4	11	6.9	2.8	7.6	1.3
Smut Resistant	-	-	-	-	-	-	-	-	18.3	22.2	29.89	21.4
Dwarf	-	-	-	-	-	-	-	-	3.6	9.2	8.6	5.7

The following figures are graphical preparations of some of the data presented in the tables of this appendix

Grain Yields of NELC Populations
Averaged Over 3 Years at HSR, PAT, and BSR



Grain Yields of IVC Populations

Averaged Over 3 Years at HSR, PAT, and BSR