Among sources of variation considered, year was not significant for AUDPC or final rust severity, but genotype was highly significant (P<0.01). Mean separations by Fisher's LSD divided the genotypes into two distinct groups (Table 1). Most genotypes were susceptible to rust, but ICMH 451, GHB 235, Eknath 301, X6, ICMA 88001, and ICMB 88001 showed moderate levels of resistance. Hybrid HHB 117 was free from rust. HHB 117 is a new hybrid yet to be released by the CCS Haryana Agricultural University. Its resistance to both downy mildew (MS Panwar unpublished data) and rust will prove valuable in both grain and fodder production.

References

Muthusamy S, Padmanaban D, Nagarajan R and Ragupathy N. 1981. Incidence of pearl millet rust in relation to sowing time and relative humidity. Madras Agricultural Journal 68:526-529.

Tapsoba H and Wilson JP. 1997. Effects of temperature and light on germination of uredinospores of pearl millet rust pathogen, *Puccinia substrata* var. *indica.* Plant Disease 81:1049-1052.

Screening Pearl Millet against Eritrean Isolates of Downy Mildew

Negusse Abraha[1,*], Wendy A Breese[2], AG Bhasker Raj[3] and S Preston[4] (1. Department of Agricultural Research and Human Resource Development Paradizo. PO Box 4627, Ministry of Agriculture. Asmara, Eritrea; 2. Centre for Arid Zone Studies, Thoday Building, University of Wales Bangor, LL57 2UW, Gwynedd, UK; 3. ICRISAT, Patancheru 502 324, Andhra Pradesh, India; 4. Agriculture Sector Support Programme, Royal Danish Embassy, PO Box 6300, Asmara, Eritrea)

*Corresponding author: negussebraha@hotmail.com

Introduction

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is the second most important cereal (after sorghum, [*Sorghum bicolor* (L.) Moench]) in Eritrea, and was grown on 83,000 ha in 2000 (Saini 2001). In 2000, >50% of plants in most pearl millet surveyed in Anseba and Gash Barka were found to be infected with downy mildew, caused by the pseudo-fungus *Sclerospora graminicola* (Sacc.) J. Schrot. (Bhasker Raj et al. 2000). This disease causes major yield reductions, estimated at 30% in Anseba in 2000. Its resting spores survive in the soil and can reinfect subsequent crops for up to 15 years once a field is infested. Because pearl millet is the staple food and fodder crop in Anseba, extension workers there have described the prevalence of downy mildew as 'a catastrophe' (Samson Zeray, pers. comm.).

A further complication is that this pathogen is highly variable. Several strains probably exist in Eritrea, each adapted to different pearl millet landraces. The experience in other countries is that new, virulent races often develop following the introduction of new varieties. It is therefore important to monitor the development of new races over the years.

The main research strategy to help farmers deal with this devastating disease is to develop resistant varieties, coupled with regular monitoring to follow the development of virulent strains. A secondary strategy is to use fungicidal seed treatment of moderately susceptible pearl millet varieties. Good progress is being made in breeding pearl millet for resistance to downy mildew in Eritrea. This is done by screening for resistance to downy mildew in naturally-infested 'sick plots' (i.e., using field observations) and by crossing selected landraces with selected exotic varieties having reasonable levels of host-plant resistance. However, the shortage of cereal pathologists and infrastructure for controlled screening puts limits on what can be done within the country.

Following the downy mildew survey in 2000, a unique scientific collaboration between Eritrea, ICRISAT, and the Centre for Arid Zone Studies (CAZS) at Bangor, Wales, UK, has produced valuable data on the resistance of 70 pearl millet genotypes to an Eritrean isolate of the pathogen. The screening was done in a tropical greenhouse at the CAZS but provided extremely valuable information for the Eritrean pearl millet breeding program. The pearl millet genotypes tested included Eritrean landraces and promising new varieties from ICRISAT populations for the Eritrean breeding program.

Materials and Methods

Samples of Eritrean isolates of *S. graminicola* were sent to CAZS with the initial objective of using these in resistance and mapping studies. The universally susceptible host cultivar 7042(S) was mixed with ground oospore material (sample F23, from Sosana in Barentu Sub-Zoba) in the CAZS greenhouse in late December 2000. Successful downy mildew infection of pearl millet seedlings was obtained. After 6-8 weeks, these provided enough sporangial inoculum to allow screening of a large number of host genotypes against this isolate.

Table 1. Screening for downy mildew resistance in pearl millet: percentage of infected seedlings in each of five single-pot replications (A-E), in Bangor, Wales, UK, three weeks after spraying with a sporangial suspension of Eritrean isolate F23 of *Sclerospora graminicola*.

	Downy mildew incidence (%)					Mean		
Pearl millet entries	A	B	C	D	E	%	Sq. root	Arcsine
Introduced populations								
ICMP 93508	23.5	16.7	22.9	29.4	26.3	23.76	4.86	29.08
ICMP 95490	2.9	0.0	25.0	5.9	3.2	7.40	2.18	12.83
ICMP 96593	11.6	11.9	14.0	9.8	16.3	12.72	3.55	20.82
ICMP 96601	6.3	4.2	21.7	21.7	47.4	20.26	4.15	25.08
ICMP 97754	19.0	0.0	3.6	12.5	22.7	11.56	2.91	17.19
ICMP 98551	12.5	31.0	9.4	10.0	16.7	15.92	3.89	22.99
ICMP 98791	11.4	27.0	32.3	27.8	40.5	27.80	5.18	31.40
ICMR 501	4.8	8.3	4.9	5.1	0.0	4.62	1.91	11.05
PRLDMR TCP1	0.0	0.0	0.0	22.2	22.2	8.88	1.88	11.24
HTBC	5.3	7.1	2.4	8.1	5.1	5.60	2.32	13.45
SRBC	0.0	0.0	0.0	5.6	6.3	2.38	0.98	5.65
AfPop 88	4.8	7.9	7.5	2.6	9.3	6.42	2.48	14.38
AfPop 90	5.3	3.0	3.3	2.8	10.8	5.04	2.16	12.51
SenPop 88	7.7	3.3	4.8	4.7	4.0	5.90	2.38	13.79
ICMV 155 Bristled	10.8	16.2	5.4	26.3	16.2	14.98	3.76	22.19
1CMV 87901 Bristled	26.3	21.1	11.1	23.7	28.9	22.22	4.66	27.86
ICMV 221	17.9	22.5	7.1	5.0	5.3	11.56	3.23	19.01
ICMV 155	14.3	17.9	9.7	22.2	11.4	15.10	3.84	22.65
ICMV 91450	10.3	10.8	0.0	9.5	19.4	10.00	2.80	16.40
Sudan Pop. I CO	11.6	14.3	5.1	7.1	5.1	8.64	2.87	16.74
Sudan Pop. II CO	19.4	5.4	14.3	11.1	15.4	13.12	3.55	20.87
Sudan Pop. III CO	17.1	6.5	6.9	11.4	10.3	10.44	3.18	18.58
MCNELC	2.5	10.0	12.2	7.0	9.3	8.20	2.79	16.21
MCSRC	9.8	17.5	17.1	16.3	21.1	16.36	4.02	23.71
ICMP 89410	10.8	28.1	8.6	21.9	37.0	21.28	4.46	26.72
ICMP 98107	2.9	16.2	16.2	28.6	14.3	15.64	3.77	22.36
EERC CO	11.9	23.3	16.7	21.4	18.6	18.38	4.26	25.25
ICMR 312	15.4	25.0	18.5	6.9	31.0	19.36	4.28	25.53
IAC ISC TCP1	2.4	0.0	12.2	4.8	4.8	4.84	1.88	10.93
IAC ISC TCP3	7.1	29.7	9.5	15.4	23.1	16.96	3.98	23.65
IAC ISC TCP4	4.9	9.8	9.3	7.0	16.7	9.54	3.03	17.65
IAC ISC TCP6	2.6	2.4	0.0	2.4	2.5	1.98	1.26	7.24
IPC MBJ TCP CO	14.3	12.5	14.3	11.8	0.0	10.58	2.91	17.05
POLCOL TCP1	7.7	22.9	13.5	12.1	16.7	14.58	3.76	22.15
Introduced male-sterile lines								
863A	28.0	13.6	16.7	24.1	11.1	18.70	4.26	25.31
ICMA 89111	5.7	0.0	5.9	0.0	5.0	3.32	1.41	8.16
ICMA 91222	0.0	2.9	0.0	2.5	5.0	2.08	1.10	6.36
ICMA 91777	0.0	2.9	2.5	5.0	2.5	2.58	1.42	8.18
ICMA 92444	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00
ICMA 95333	2.4	5.9	0.0	3.1	5.9	3.46	1.63	9.43
ICMA 96222	0.0	2.6	2.7	5.4	8.1	3.76	1.68	9.74
ICMA 97 111	0.0	2.4	2.3	4.9	0.0	1.92	1.06	6.08
ICMA 97333	9.8	4.9	2.6	7.7	0.0	5.00	1.94	11.28
ICMA 98222	0.0	2.4	2.6	2.4	7.5	2.98	1.49	8.60

Continued

Table 1.(*continued*)

Pearl millet entries	Downy mildew incidence (%)					Mean		
	A	B	C	D	E	%	Sq. root	Arcsine
ICMA 98333	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00
ICMA 99111	0.0	6.5	0.0	0.0	3.6	2.02	0.89	5.14
ICMA 99222	10.5	18.4	16.7	18.2	16.2	16.00	3.98	23.48
ICMA 00888	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00
Eritrean cultivars								
Bultug Keren	75.6	79.1	50.0	79.1	84.2	73.60	8.54	59.52
Bultug Mebred	44.2	47.6	46.3	51.2	57.9	49.44	7.02	44.68
Bultug Mogolo	59.0	59.0	65.9	82.5	80.0	69.28	8.30	56.67
Tosho	42.9	47.5	37.2	47.4	66.7	48.34	6.92	44.07
Zibedi	39.5	53.7	45.0	37.2	27.9	40.66	6.34	39.53
Gudmay	58.1	69.2	58.5	83.7	60.0	65.90	8.10	54.56
ICMV 221	10.0	9.5	9.8	12.8	14.3	11.28	3.35	19.56
Tokroray	67.5	79.1	59.0	47.4	71.4	64.88	8.02	53.88
Mapping population parents								
IP 18293	5.6	4.0	0.0	20.0	25.0	10.92	2.77	16.36
Tift 238DI	100.0	95.2	100.0	79.2	64.7	87.82	9.34	74.75
841B-P3	12.5	16.0	8.0	15.6	22.7	14.96	3.82	22.48
863B-P2	15.2	18.4	27.5	28.2	48.6	27.58	5.14	31.25
H 77/833-2	56.1	47.6	31.7	65.0	33.3	46.74	6.77	43.07
PRLT 2/89-33	0.0	2.5	24.4	-	7.0	9.02	2.36	13.98
PT 732B-P2	52.9	57.1	20.7	73.9	66.7	54.26	7.23	47.37
P 1449-2	0.0	0.0	7.7	0.0	0.0	1.55	0.55	3.22
ICMP 451-P6	0.0	0.0	3.3	8.3	0.0	2.32	0.94	5.44
W 504-1-1	23.8	37.9	36.0	67.9	52.2	43.56	6.50	41.16
P310-17B	0.0	9.1	0.0	0.0	0.0	1.82	0.60	3.51
Controls								
7042(S) (susceptible)	57 5	48.8	50.0	69.4	65.8	58.30	7.62	49.85
7042(S) (susceptible)	39.5	62.9	50.0	58.3	51.4	52.42	7.22	46.40
HB 3 (susceptible)	38.5	47.5	40.0	64.1	48.8	47.78	6.88	43.73
P 7-3 (resistant)	42.3	31.3	57.7	60.9	41.4	46.72	6.78	43.07
Mean						20.00	3.70	22.99
SE						±3.56	±0.47	±3.11
CV(%)						39.85	28.27	30.29
F ratio						34.48	24.97	26.95
h^2 (plot-basis)						0.87	0.83	0.84

Seventy-two pearl millet genotypes were screened. These included:

- Eritrean landraces (Bultug Keren, Bultug Mebred, Bultug Mogolo, Tosho, Zibedi, Gudmay and Tokroray),
- promising new open-pollinated varieties (notably ICMV 221),
- 48 populations and male-sterile lines from ICRISAT-Hyderabad (potential parental material),
- two susceptible controls 7042(S) and HB 3, and one resistant control (P 7-3), and
- 11 parents of the pearl millet mapping populations available at CAZS.

The latter are part of a DFID-PSP-supported project to map pearl millet downy mildew resistance genes, in which ICRISAT and CAZS are collaborating.

There were 5 pots per host entry, with 42 seeds sown per pot. The pots were arranged in 5 randomized complete blocks on flood benching. The seed was sown on 26 February 2001 and the seedlings were spray-inoculated with sporangial suspension of isolate F23, on 2 March 2001, when most seedlings were at the one to two leaf stage, using the method described by Jones et al. (2001). The inoculum concentration used was 1.7×10^5 sporangia mL^{-1}, and each pot of seedlings received approximately 4 mL of inoculum. Seedlings were assessed for disease during 19-22 March 2001. Downy mildew incidence (percentage infected seedling per pot, and its square root and arcsine-transformed values) data were subjected to ANOVA, and broad-sense heritabilities (plot-wise) were calculated.

Results and Discussion

The results are given in Table 1, where the number of infected plants in each replication is expressed as a percentage of the total number of plants per pot. Note the general consistency across replicates achievable by this screening method. The high heritability estimates reflect the effective control of inoculum quantity and uniformity, and seedling growth (ie, tight control of environmentally-induced variation) in this experiment.

Susceptible control genotypes 7042(S) and HB 3 showed approximately 50% infection (rather less than expected), and the resistant control genotype P 7-3 proved surprisingly susceptible to this isolate of the pathogen. There was a good range of values among the other materials tested: the Bultug Keren landrace was particularly susceptible with an overall mean infection of 79.5% (omitting block C as an outlying value). Three introduced male-sterile lines (ICMA 98333,ICMA 92444 and ICMA 00888) had 0% infection for each block, and three other introductions (ICMA 99111, P 1449-2 and P 310-17B) showed <2% downy mildew incidence. Downy mildew resistant lines P 1449-2 and P 310-17B are parents of pearl millet mapping populations derived from crosses to susceptible lines PT 732B-P2 and W 504-1-1, respectively, so it should be possible to map resistance loci effective against this pathogen isolate using genetic stocks previously developed by ICRISAT and its DFID-PSP-supported UK collaborators. Finally, improved cultivar ICMV 221 (recently released as 'Kona') showed 11.3-11.6% disease incidence.

The results were used in developing crossing programs from which future pearl millet varieties for Eritrea will be derived. It is clear that the Eritrea-ICRISAT-CAZS collaboration works well and is tackling a serious problem in an efficient and cost-effective way. However, studies to date have looked at just one Eritrean isolate of the pathogen that causes downy mildew. Further, at present all the pearl millet breeding work in Eritrea is done at Hagaz in Anseba. It is therefore important to determine whether resistance identified by field screening at Hagaz is valid for the rest of the country. Is there just one, or more than one, major pathotype of downy mildew in Eritrea? It would be of great value to have information on this.

Acknowledgments. Thanks are due to the Plant Sciences Research Programme of the UK's Department for International Development (which supported the DM screening work in the UK) and the Danish Ministry of Foreign Affairs to the Agriculture Sector Support Programme in Eritrea, and to Fran Bidinger, Tom Hash, and Panduranga Rao of ICRISAT for valuable technical assistance.

References

Bhasker Raj AG, Bidinger FR, Panduranga Rao V and Negusse Abraha. 2000. Report of a survey of downy mildew incidence in farmers' fields in Anseba and Gash Barka Regions and an evaluation of the pearl millet breeding trials and nurseries at the Hagaz research station. ICRISAT, Patancheru, India, and ARHRD, Ministry of Agriculture, Eritrea.

Jones ES, Breese WA and Shaw DS. 2001. Infection of pearl millet by the downy mildew fungus *Sclerospora graminicola:* chilling inoculum to prevent zoospore release and subsequent spray damage to zoospores. Plant Pathology 50:1-8.

Saini RS. 2001. Operational plan for seed production programme. Asmara, Eritrea: Department of Land Resources and Crop Production, Ministry of Agriculture.