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ABSTRACT

Principles of resistance screening, definitions of resistance and susceptiblity, and summaries of several years trials with downy mildew, ergot, smut, and rust are presented. The greatest number and most effective sources of resistance were found in African germplasm, particularly from the central region of West Africa, which is the center of origin and diversity of this crop. Results are presented indicating the feasibility of building-up levels of resistance through recurrent selection in initially susceptible populations. Resistance to ergot has been the most difficult to develop but lines are now available with a high level of ergot resistance in India, combined with resistance to downy mildew and smut.

I. INTRODUCTION

Pearl millet, Pennisetum americanum (L.) Leeke [syn. Pennisetum typhoides (Burm.) Stapf and Hubb.], the staple cereal of many millions of people in semi-arid regions of Africa and South and West Asia, is the known host of several phytopathogenic fungi and a few viruses and bacteria (Ramakrishnan, 1971; Ferraris, 1973). The diseases of economic importance, however, are all caused by fungi, and, compared with the number of pathogens of the crop, the important diseases are relatively few.

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The most destructive and widespread disease of pearl millet in Africa and South Asia is downy mildew, incited by Sclerospora graminicola (Sacc.) Schroet. This disease decimated the Indian hybrid pearl millet crop in the early 1970's (Safeeulla, 1977), takes a substantial toll of pearl millet yield in West Africa each year (King and Webster, 1970; R.J. Williams, unpublished), and reduces the opportunity to utilize certain high yield potential germplasm in both regions.

The two next most serious diseases are ergot and smut, caused by Claviceps fusiformis Lov. and Tolyposporium penicillariae Bref., respectively, which are characterized by the invasion of the developing ovules by the causal fungi, with consequent loss of grain.

Leaf diseases of potential importance are rust (Puccinia penniseti Zimm.), blast (Pyricularia setariae Nisikado), Cercospora leaf spot (Cercospora fusimaculous Atk.) and zonate leaf spot (Gloeocercospora sp.), with rust being the most important of these in India, and apparently in Kenya and Malawi.

Downy mildew, ergot, and smut have been generally much more severe on F1 hybrids than on open pollinated varieties, the reasons for which were discussed by Thakur and Williams (1980) and Singh and Williams (1980).

Until very recently it was not feasible to attempt disease control in pearl millet in farmers fields with chemical fungicides, and even today downy mildew is the only disease for which effective and economically feasible chemical control is probably available (Williams and Singh, 1981). Thus, the emphasis for disease control in pearl millet has been on the identification and utilization of host plant resistance.

In the ICRISAT pearl millet improvement program initial primary emphasis was given to downy mildew resistance, with a little later a major effort mounted on resistance to ergot and then to smut, and a relatively small amount of work on the identification of sources of rust resistance.

II. THE IMPORTANCE OF GERMPLASM

The basic material for the genetic improvement of any crop is the diversity of germplasm of the species. The establishment and maintenance of a comprehensive germplasm collection is vital to any crop improvement effort. The genes for all the characters that we need are in the germplasm somewhere, all we have to do is find them (through the use of effective, meaningful screening techniques) and put them together (through hybridization and selection). But when faced with germplasm collections of 10s-of-thousands of entries (e.g. the pearl millet world germplasm collection now stands at 14,340 entries) where does one start to look for the needed characters? It would

be possible to start at accession no. 1 and work all the way through, and may be for some characters there is no better way. But for many characters, including disease resistance, there is scope for intelligent directed evaluation of germplasm (and of course before that, directed collection). For disease resistance this means one should concentrate first on accessions that come from areas in which the pathogen or pathogens are known to occur in environments conducive for disease development and spread. Where these conditions coincide with the center of origin or center of diversity of the crop is where the richest sources of resistance will be found, for this is where the host and pathogen will have co-evolved for the longest period of time. This has been our experience with pearl millet downy mildew (see results below), with the most effective sources of resistance coming from central West African areas such as northern Nigeria, southern Niger, Upper Volta, and southern Mali. Pearl millet was domesticated in the Saharan highlands (Brunken, et al., 1977), and the central West African region represents the major center of diversity of this crop. In this region, between the 500 and 1000 mm isohyets, the environment during the growing season is highly favourable for downy mildew development and this is where the best sources of downy mildew resistance occur.

Thus, when faced with a decision on which accessions in our germplasm to screen for stress resistance, or any other character, we should concentrate first on accessions from

regions in which a high selection pressure is likely to have occurred for the needed character(s). When we have chosen the right material to screen, then our success in finding the characters we need depends upon the effectiveness of our screening techniques.

III. THE IMPORTANCE OF THE SCREENING TECHNIQUES

It must be emphasized at the outset that the progress that can be made in identifying and utilizing disease resistance depends, like searches for all other plant characters, on the effectiveness of the screening technique. If the screening technique allows escapes, then progress will be slow, because susceptibility genes will be maintained in the populations. Much effort, therefore, has to be given to the development of effective screening techniques, and considerable effort is needed each season to ensure that they are carried out effectively.

A. Downy Mildew

The "infector-row" technique (Williams et al., 1981) has been shown to be very effective in screening for downy mildew resistance in pearl millet. However, to ensure its success, independence from weather events is needed, and this is achieved by the use of perfospray or sprinkler irrigation to provide the necessary humidity for promotion of disease development and spread.

To attempt the infector row screening system without the irrigation facility is like organizing a cricket test-match without ensuring that cricket balls will be available -- the teams will be there, the crowd will be there, and the umpires will be there, but play cannot occur without the cricket balls. It is most disappointing to learn that despite the proven success of the infector row system for work with downy mildew resistance in pearl millet, and despite the recommendations of the AICMIP Workshop since 1978, no AICMIP Center has yet been provided with irrigation facilities to ensure the success of their downy mildew screening program.

B. Ergot

The occurrence of the pollen-based escape mechanism (Thakur and Williams, 1980) necessitates that all plants to be inoculated to assess ergot reaction are bagged at the boot-leaf stage, so that the inflorescences emerge into a pollen-free environment. Bagged heads should be inoculated with aqueous fresh honey-dew suspension at the maximum protogynous stage and immediately re-bagged. Sprinkler irrigation is needed for 30 min three times a day on rain free days during the inoculation and disease development period. Failure to bag the plants at the right time, or failure to provide sprinkler irrigation when needed will mean a failure of the screening system and a waste of the resources used to plant and raise the crop.

C. Smut

The best inoculation technique for promotion of smut has been to inject a fresh sporidial suspension, grown on potato agar at 35 C for 7-10 days, into the boot just prior to head emergence with immediate bagging of the boot, and provision of humidity during the period from bagging to grain filling.

D. Rust

Though no experimentation has been made on rust promotion, the use of earlier planted susceptible infector rows appears to be effective in promoting the development of this disease in the field. The disease develops well on late planted material at ICRISAT Center. Occasional rains and dew formed at night appear to be sufficient to promote infection and disease spread.

E. The need for irrigation facilities

It cannot be over emphasized that the success of screening techniques will depend upon the provision of the environmental conditions conducive for infection and disease development. This means that perfospray and/or sprinkler irrigation must be available for effective screening for resistance to downy mildew, ergot, and smut. Reliance on the weather will result in frequent failures and consequent slow progress.

F. The need for adequate "checks" or "indicators"

In order to monitor the effectiveness of the screening system it is essential to plant throughout the screening area known susceptible checks to act as "indicators" of disease pressure. At the end of the season it is most useful to draw a map of the screening field and write down the disease levels in the "indicator" rows in the appropriate places on the map to see whether disease development had been uniform throughout the screening area.

IV. THE IMPORTANCE OF MULTILOCATIONAL TESTING

If one chooses the right starting material and uses effective screening techniques it is probable that resistance will be identified that is effective at the home location. But is this resistance going to be effective if the varieties are grown in another region with possibly different pathotypes and different levels of agro-climatic parameters i.e. is the resistance stable or unstable? The best way to answer this question is to subject the varieties to multilocational testing so that the resistance is evaluated against many populations of the pathogen under a wide range of environmental conditions. Test locations in the centers of origin and diversity of a crop are particularly valuable, for in these centers the greatest range of pathogenicity most often occurs. Multilocational testing, in a cooperative effort with national program scientists, has been an integral part of the disease

resistance identification work at ICRISAT since 1976. Through this multilocational testing program valuable sources of resistance have been identified.

V. SOME DEFINITIONS

Before moving into details of resistance identification a few words are necessary on what we mean by "resistance". Resistance is a quantitative phenomenon that is the inverse of suceptibility. Thus, resistance levels can be low, moderate, or high and correspond with high, moderate and low susceptibility, respectively. Absolute resistance is when no disease develops, and this may be based on immunity. The term tolerant is often misused in place of moderately resistant and should be avoided, for tolerance is the capacity to "look susceptible" but "yield resistant", i.e. the variety tolerates the disease.

For downy mildew we generally call resistant (or low susceptible) lines that develop severity indices of less than 10%. Lines that develop no downy mildew are referred to as DM-free. Lines that consistently develop less than 5% DM under high inoculum pressure we refer to as highly resistant.

For ergot, initially, we used the term "relatively less susceptible" to categorize those lines with less ergot than most, and it was not unitl recently that we have had lines with sufficiently low ergot levels to start referring to

resistance. Now we have lines that consistently develop less than 5% ergot and these we call highly resistant. Lines that get consistently less than 10% ergot are called resistant. Lines with no ergot are referred to as "ergot-free".

Reactions to smut are categorized in a similar way to ergot.

Lines with less than 10% rust on the upper four leaves at the soft dough stage of seed development are called resistant to rust.

VI. RESISTANCE TO DOWNY MILDEW

At the ICRISAT Center, downy mildew resistance screening has been conducted in two seasons each year using the infector row system, with perfospray irrigation, since the 1976 rainy (kharif) season. Initially a ratio of 1 infector row to 4 test rows (1:4) was used, but since the 1981 rainy season a ratio of 1:8 has been used successfully. Materials that successfully pass through the screen at the ICRISAT Center move into the multilocational test nurseries.

A. Screening of germplasm

More than 1500 germplasm lines have been selected from the world germplasm collection for screening for downy mildew resistance at the ICRISAT Center. The majority of these originated in West Africa, and the germplasm from that

region has contained the highest frequency of resistance (Table 1)

B. Screening breeding populations

The improvement of downy mildew resistance in populations through recurrent selection has been an important and succesful activity. Both the selection phase and recombination phase is carried out in the DM Nursery and has enabled the conversion of highly DM-susceptible populations to resistant in a few generations (e.g. Table 2). This has been achieved with several populations and is a most important feature of our downy mildew resistance work, for it demonstrates that DM resistance can probably be built-up in any population while maintaining the other desirable and adaptive features of the population.

C. Multilocational testing

Multilocational testing for downy mildew resistance in pearl millet is done cooperatively with national program staff in India and in several West African countries, in two stages. In the first stage a 150 entry Pre-International Pearl Millet Downy Mildew Nursery (Pre-IPMDMN) is tested at a few key DM-hot spot locations in India and West Africa. The best entries from the Pre-IPMDMN in one year go forward to the full IPMDMN in the next year for testing at many more locations.

The Pre-IPMDMN was initiated in 1977 and a summary of performance of test lines is provided in Table 3. The best ten entries in the Pre-IPMDMN in five years of tests are listed in Table 4.

The IPMDMN was initiated in 1976 and has been conducted annually with results returned from cooperators from 9 to 16 locations per year. The mean performance and origin of entries included in this trial for two years or more are given in Table 5. The entries SDN-503, P-7, 700251, 700516, 700651, all of which are from West Africa, have performed well across seasons and locations throughout the IPMDMN program, although there have been occasional occurrences of more than 10% DM, generally in West Africa. Additional entries that have performed well in the last three years are NC-7174, IP-1930, EB-83-2, IP-2058, MPP-7147-2-1, J-1486 x 700787-2-10, SSC-7218, NC-7158 and EB-18-3-1. The detailed results are available in the reports in the Pre-IPMDMN and IPMDMN published annually by ICRISAT.

The performance of SDN-503, P-7, 700251, 700516, and 700651 at Kamboinse (Upper Volta) and at ICRISAT Center (India) has been consistent over 6 years. At Samaru and Kano in Nigeria, however, the five entries have recorded what appears as a gradual erosion of resistance over the years. They have remained resistant in India where the multiplication has been carried out, and it is possible that during the several generations of multiplication there the genes needed to be effective against downy mildew in certain

high-pressure locations in West Africa may have been lost.

Wide differences in the DM severity values among locations have been observed for several entries, between India and Africa, and also among locations in West Africa (Table 6). This indicated the probability of variation in pathogenicity among populations of Sclerospora graminicola. In 1978, therefore, an International Pearl Millet Downy Mildew Differential Trial (IPMDMDT) was initiated to examine the validity of the apparent differential reactions of entries in previous years and to identify potential differential hosts for precise identification of races of this pathogen. The trials were evaluated at key DM-hot-spot locations in India and West Africa. The reactions of selected entries included in the 1979 and 1980 IPMDMDT, presented in Table 7, reveal clear differences in the DM severity values of entries, confirming earlier results and providing clear indications that the pathogen probably possesses several physiologic races. Through this trial we have been able to identify potential differential host cultivars which are being used for identification of races.

VII. RESISTANCE TO ERGOT

High levels of resistance to ergot do not appear to exist in the germplasm, presumably because pollen interference and day-length sensitivity provide escape mechanisms in land-race populations that have precluded high selection pressure for resistance to this disease.

Considerable progress has been made, however, in developing resistance to ergot through the intermating of relatively-less-susceptible lines (Table 8) and exerting high selection pressure on the progenies (Thakur et al, 1982). Stable sources of resistance were identified at the F6 generation (Table 9). and these were tested at several locations in India and in Nigeria in the 1981 International Pearl Millet Ergot Nursery (IPMEN). The most resistant lines in this trial at Indian locations were five lines from the cross J 2238 x J 2210-2 (Table 10). In Nigeria, however, these lines had much higher levels of ergot (Table 11) and there the best entry, ICMPE 34-1-10, was from the cross between two Nigerian lines (700590 x 3/4-EB-77-2-1). Other lines which had little or no ergot at ICRISAT Center developed more ergot at certain Indian locations, the reasons for which need to be investigated.

Progenies from other crosses are being developed in the ICRISAT ergot resistance development program which should provide additional diversified ergot resistance sources in the near future.

VIII. RESISTANCE TO SMUT

The effort needed to find, develop, and use resistance to downy mildew and ergot consumed a large proportion of our human and material resources in the early years of our program, and it wasn't until 1980 that concentrated attention was given to this disease. Prior to that year

screening was carried out at Hissar by bagging at the boot-leaf stage the lines to be screened, and the best material identified there was tested in the International Pearl Millet Smut Nursery (IPMSN). Nevertheless, the preliminary screening work yielded useful results and materials, and since 1980, when more resources were devoted to smut, sources of resistance have been confirmed in inoculation trials at the ICRISAT Center and in multilocational trials. The most smut-resistant entry available is SSC-FS-252-S-4, which in four years of IPMSN trials has been resistant at all locations including the severe hot-spot locations of Samaru and Kano in Nigeria (Table 12). Other entries that have shown consistent resistance to smut in India are: EB 132-2-S-5-S-DM-1, ICI 7517-S-1, P-10-S-1, 700130-S-1-DM-1, EB 54-1-1-S-7-3, and EB-209-1-6-S-7. The origin of these lines can be determined by their initial letter and numbers -- EB and 700 lines are from Nigeria, P lines are from Senegal, IC lines are from ICRISAT Center, and SSC is from Uganda.

In the 1981 IPMSN, SSC FS-252-S-4 was resistant at all locations tested and 15 additional lines were resistant at all locations except Kano (Table 13).

The development of the smut screening technique to be used at the ICRISAT Center will allow a more concentrated effort to locate sources of smut resistance from the 1982 rainy season. In view of the past results, emphasis will be given first to material from northern Nigeria, Senegal, and

Uganda.

IX. RESISTANCE TO RUST

Our activities on rust have been limited to screening for rust resistance under natural conditions, some at the ICRISAT Center, but mainly at Bhavanisagar where rust has a high probability of appearing in severe form every year. Some germplasm accessions are screened at Bhavanisagar every year. The entries that show high levels of rust resistance are then tested at several locations in India through a cooperative testing network in the International Pearl Millet Rust Nursery (IPMRN). This nursery was first initiated in 1977 and since then has been operated annually. Some entries have given resistant reactions at several locations in 2-3 year's tests (Table 14). However, all of these entries had higher levels of rust at Kudumiamolai in 1978. In 1980 the most resistant entries (with no more than 10% rust at any of the six test locations) were 700481-21-8 and IP-2084-1. More work is needed on resistance to this disease and to evaluate the reasons for apparent differential reactions among locations.

X. MULTIPLE DISEASE RESISTANCE

The lines being developed for ergot resistance have been routinely screened for downy mildew and smut reactions so that resistance to these two diseases has also been developed in these lines. The ergot, smut, and downy mildew

reactions of the five lines with most ergot resistance are presented in Table 15.

XI. SEED AVAILABILITY

Seed of all the lines listed in this paper can be obtained on request from the ICRISAT Center Pearl Millet Improvement Program.

XII. ACKNOWLEDGEMENTS

We are grateful to all the members of the ICRISAT Pearl Millet Pathology team for their diligent assistance, and to the cooperators in the International Disease Nursery Program who have given so much valuable time and facilities to provide data on the stability of disease resistance.

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TABLES 1-15

Table 1. Summary performance of germplasm accessions collected from West Africa, Kenya and India screened at ICRISAT Center from 1977-1981

Origin	Entries tested	Low susc. lines (No.)	Low susc. (%)
W. Africa	1125	1072	95
Kenya	47	24	51
India	391	131	34

Table 2. Progress in increasing DM resistance in susceptible pearl millet populations, through a recurrent selection program conducted in the DM-screening nursery[a/]

Season	Super-Serere-Comp		GAM-75	
	Total lines	% lines ≤ 5% DM	Total lines	% lines ≤ 5% DM
1976 rainy	270	12	256	0
1976/77 post-rainy	38	66	21	24
1977 rainy	278	72	198	77

a/ Resistant plants selfed in the rainy season; S1s planted in the DM nursery in the post-rainy season and full-sibs made with resistant plants; full sibs tested in the next rainy season.

Table 3. Total number of entries, free entries and entries with ≤ 10 percent downy mildew severities in the 5-years of Pre-IPMDMN trials

Year	Total entries	Free entries	Entries with ≤10% DM
1977	133	1	68
1978	150	0	95
1979	150	0	71
1980	150	1	95
1981	150	3	93

Table 4. The 10 entries with least downy mildew in the Pre-IPMDMN in 5 years tests

Rank	Entries with least downy mildew in				
	1977	1978	1979	1980	1981
1	EB-74-75-1	WC-7709	E298-2-1-8	P-1423	MBP-8104
2	3/4-Souna 142-1	NC-7174	WC-8220	P-13	P-2904
3	EB-38-1-2	EB-79-2-2 x S9-3-1	700512	P-58	P-535
4	3/4-EB-15-2	EB-17-1-6	EC(S4)-10-4	P-452	P-110
5	EB-90-5-1	B-Senegal-2-5	700633	P-1520	P-454
6	IVS-5216	700042	700792	UPN-3P1-1	P-442
7	SDN-496	7124-3	J-215-1	NC-9040	P-462
8	EB-85-2-1	J-2220	J-92-1	P-77	P-2927
9	WC-5346	NC-7158	IVS-8172	D-10	P-435
10	MC-6081	IP-2058	700590	SSC-9053	P-2943

Table 5. Mean Downy mildew severities (%) of 34 entries evaluated in the IPMDMN for 2 or more than 2 years from 1976 to 1981 at many locations in India and West Africa

SNo	Entry	Origin	YEAR					
			1976	1977	1978	1979	1980	1981
1.	SDN-503	Nigeria	0.6	1.3	2.7	2.5	8.0	9.0
2.	P-7	Mali	5.5	1.7	3.4	3.0	9.0	6.0
3.	700251	Nigeria	3.1	1.8	2.2	1.3	9.0	6.0
4.	700516	Nigeria	2.1	3.0	2.3	0.8	7.0	5.0
5.	700651	Nigeria	1.3	3.0	4.1	0.9	10.0	6.0
6.	IP-1930	ICRISAT	-	-	-	2.0	8.0	2.0
7.	EB-83-2	ICRISAT	-	-	-	1.5	6.0	5.0
8.	IP-2058	Nigeria	-	-	-	0.7	9.0	8.0
9.	MPP 7147-2-1	New Delhi	-	-	-	1.4	7.0	5.0
10	J-1486 x 700787-2-10	ICRISAT	-	-	-	0.9	7.0	5.0
11	SSC-7218	ICRISAT	-	-	-	0.1	7.0	4.0
12	NC-7158	ICRISAT	-	-	-	1.5	7.0	2.0
13	EB-18-3-1	ICRISAT	-	-	1.8	1.0	7.0	2.0
14	SDN-347-1	Nigeria	4.7	3.0	4.1	2.6	-	-
15	SDN-305	Nigeria	3.2	5.0	-	-	-	-
16	PMB-14	Ludhiana	4.5	7.7	-	-	-	-
17	BK-560	New Delhi	8.1	9.1	-	-	-	-
18	J-1188	Jamnagar	5.3	4.8	-	2.3	-	-
19	ICH-190 (111A x E298-2)	ICRISAT	-	2.7	5.6	-	-	-
20	P-10	Mali	-	3.1	3.9	1.4	-	-
21	114 IR	Senegal	-	4.0	6.3	6.1	-	-
22	T-128-3 x 700404-1-5-5	ICRISAT	-	-	-	0.4	8.0	-
23	700619	Nigeria	-	-	-	3.0	12.0	-
24	EB-79-2-2 x EB-59-3-1	ICRISAT	-	-	-	2.2	9.0	-
25	IP-2037	Nigeria	-	-	-	1.3	10.0	-
26	ICM-165 (111A x SC14(M)	ICRISAT	-	-	-	1.5	8.0	-
27	700706	Nigeria	-	-	-	-	9.0	3.0
28	EB-298-2-1-8	ICRISAT	-	-	-	-	5.0	3.0
29	700546	Nigeria	-	-	-	-	7.0	8.0
30	700512	Nigeria	-	-	-	-	6.0	3.0
31	SDN-496	Nigeria	-	-	2.9	2.1	-	-
32	SDN-714	Nigeria	-	-	-	-	6.0	6.0
33	ICH-226 [5141A x (J1623 x 70049-2-6-2)]	ICRISAT	-	-	-	-	11.0	6.0
34	NC-7174	ICRISAT	-	-	-	0.9	8.0	3.0
35	J-1593	Jamnagar	-	27.9	13.5	8.1	17.0	15.0
36	BJ-104	New Delhi	-	13.6	-	12.5	21.0	10.0
37	7042	Chad	-	-	-	58.3	63.0	68.0

Table 6. Comparison of downy mildew incidence in five pearl millet cultivars at two Indian and two West African locations in 1976.

Entry	% DM incidence at			
	Hissar[a/]	ICRISAT[a/] Center	Samaru[b/]	Ouahigouya[c/]
Syn. 7601	0.7	1.2	68	18
ICH 105	0.2	1.5	84	15
Ex-Bornu	0.0	2.2	18	2
WC-C75	0.6	1.7	17	1
PHB-14	0.0	14.5	4	14

a/ India

b/ Nigeria

c/ Upper Volta

Table 7. Summary of downy mildew reactions (% incidence) of selected IPMDMDT entries in 1979 and 1980 rainy seasons at ICRISAT Center, Kamboinse, Samaru (Upper Volta) and Kano (Nigeria)

Entry	Group	Locations							
		ICRISAT Center		Kamboinse		Samaru		Kano	
		1979	1980	1979	1980	1979	1980	1979	1980
NWC-7085	A	SS	S	R	R	R	MR	R	MR
SC-2	B	MR	R	MR	R	S	S	MS	S
MC-PX76	B	R	R	R	R	S	S	MS	S
J-2000-1	B	R	R	R	R	MS	S	R	S
111-B	B	R	R	MR	MR	S	S	R	S
IP-2045	B	R	R	R	R	MS	MS	MS	S
7042	C	S	S	S	S	S	S	S	S
SSC-HX76	D	R	R	MR	MR	MS	MS	MR	MS
Cassady 87-2-2-5	D	S	MR	S	S	MS	S	MR	S
NEC-7120	D	R	R	S	S	MR	S	MR	MS

R (Resistant) = <10% DM incidence

MR (Moderately resistant) = 11-20% DM incidence

MS (Moderately susceptible)= 21-30% DM incidence

S (Susceptible) >30% DM incidence

Table 8. Percent ergot infection indeces of 20 pearl millet lines screened for ergot reactions in 1975, 1976, and 1977, and used as parents in a program to develop ergot resistance

Line	Ergot infection indices[a]	
	1976	1977
J 606-2	11	23
J 703-1	5	57
J 797-1	12	25
J 1553	0	44
J 1999	7	31
J 2210-2	3	14
J 2238	4	21
700142	4	21
700583	12	36
700599	0	19
700619	6	27
MPP 7135-3-1	12	32
IP 1926	18	32
IP 1941	0	32
IP 2253	2	52
SC-1(S4)27-2	7	40
SC-1(S4)27-3	9	35
SC-2(M)13-4	13	41
Ex Bouchi 700638-3-2	0	25
ND 2282-79-1	1	45
Susceptible check	66	97

a/ All lines were ergot free in 1975

Table 9. The percentage of pearl millet lines[a/] in seven ergot severity classes in five generations in which the seed for the succeeding generation was taken from the least infected plants in the preceding generation

Mean ergot severity (%)	Percentage[b/] of lines in each class at				
	F_2	F_3	F_4	F_5	F_6
<1	0	0	0	1	42
1-10	0	2	15	14	48
11-20	0	6	21	19	6
21-30	6	11	28	16	1
31-40	9	16	22	20	2
41-50	18	16	9	15	1
>50	67	49	6	16	0

a/ the F_2 lines were from 53 crosses and the F_6 progeny were from only 2 of these crosses

b/ rounded-off to whole numbers

Table 10. Sources of ergot resistance developed at ICRISAT Center effective at Indian locations the 1981 IPMEN results

Entry	Mean ergot severity (%)[a/]								Overall Mean
	Hissar	Pune	Jamnagar	Ludhiana	ICRISAT Center	Pantnagar	New Delhi	Aurangabad	
ICMPE [b/] 134-6-[c/]	1	5	<1	5	<1	3	1	8	2
ICMPE 134-6-11	1	7	<1	2	<1	3	1	8	2
ICMPE 134-6-41	1	6	<1	1	<1	3	4	9	2
ICMPE 134-6-34	<1	7	1	1	<1	2	1	8	2
ICMPE 134-6-25	<1	5	<1	3	<1	1	1	10	2
Local resistant	6	25	43	30	17	51	54	55	35
ICH 220 (Trial-Check)	34	27	41	34	99	57	43	60	49

a/ Based on 20-40 inoculated heads from 2 replications.

b/ ICRISAT Millet Pathology Ergot.

c/ 134-6- selections derived from cross between J 2238 and J 2210-2.

Table 11. Ergot reactions at Kano and Samaru, Nigeria of entries that are ergot resistant in India.

Entry[a/]	Ergot severity (%)		
	Mean of Indian locations[b/]	Kano	Samaru
ICMPE 134-6-9	2	38	46
ICMPE 134-6-11	2	61	43
ICMPE 134-6-41	2	48	35
ICMPE 134-6-34	2	43	35
ICMPE 134-6-25	2	27	44
ICMPE 34-1-10	6	16	13
Local resistant	35	29	24
Trial check	49	33	68

a/ ICMPE - ICRISAT Millet Pathology Ergot lines - selections derived from the cross between J 2238 and J 2210-2

b/ Across 10 Indian locations

Table 12. Smut reactions of eight common entries for 4 years across five locations in India and West Africa

Entry	Hissar				Jamnagar				Bambey				Samaru				Kano				Mean				Overall mean
	78	79	80	81	78	79	80	81	78	79	80	81	78	79	80	81	78	79	80	81	78	79	80	81	
SSC FS 252-S-4	0	0	0	-	1	1	0	0	<1	1	0	-	12	-	4	4	9	-	3	8	4	1	1	4	2
ICI 7517-S-1	0	0	0	<1	<1	<1	0	<1	1	0	1	0	13	-	10	3	34	-	8	24	10	<1	4	5	5
EB 132-2-S-5-2-DM-1	6	2	<1	1	2	1	<1	1	24	7	<1	2	32	-	15	6	14	-	7	23	16	3	4	7	7
P-20-S-1	2	2	3	1	<1	<1	14	4	1	3	6	18	21	-	10	8	18	-	31	24	8	2	13	11	8
P-10-S-1	1	<1	<1	1	<1	0	1	10	<1	1	3	34	10	-	39	16	33	-	27	7	9	<1	14	14	9
700130-S-1-DM-1	2	1	<1	-	1	<1	<1	1	16	5	1	0	49	-	8	8	64	-	13	25	26	2	4	8	10
EB 54-1-1-S-7-3	1	2	7	1	1	<1	6	5	15	2	29	41	9	-	39	24	4	-	20	9	6	1	22	16	11
EB 209-1-6-S-7	2	1	8	1	1	<1	5	2	3	4	6	55	46	-	18	9	32	-	12	32	17	2	10	20	12
Susceptible Check	15	25	30	11	4	11	31	18	17	11	31	84	65	-	68	51	87	-	72	52	38	16	46	43	36

- Trial not conducted/data not provided

Table 13. Mean smut severity (%)[a/] of the 29 1981 IPMSN entries and the local checks at seven locations with across location entry means[b/] and across entry location means

Sl No	Entry	Location[c/]							Overall mean
		Hissar	Jamnagar	ICRISAT	Niamey	Samaru	Bambey	Kano	
1.	SSC FS 252-S-4	-	0	0	0	4	-	8	2
2.	P-489-S-3	<1	0	0	<1	1	9	11	3
3.	EBS 46-1-2-S-2	<1	2	<1	<1	4	<1	16	3
4.	MLC SN 75-1-6-S-1	<1	0	0	<1	3	4	15	3
5.	EB 229-4-1-S-7-3-DM-1	<1	0	0	0	3	-	14	3
6.	EB 137-2-S-7-1-DM-1	<1	<1	<1	1	5	3	15	3
7.	NEP 588-5690-S-8-4	<1	<1	<1	<1	7	3	15	4
8.	EB 116-1-1-S-3-1-DM-1	<1	<1	<1	1	2	<1	26	4
9.	ICI 7517-S-1	<1	<1	0	4	3	0	24	4
10	EB 132-2-S-5-2-DM-1	1	1	1	1	6	2	23	5
11	EB 112-1-S-1-1	0	0	0	<1	4	<1	32	5
12	EB 117-4-3-S-2-2-DM-1	-	1	1	1	2	8	19	5
13	F4FC 1285-8-7-S-1	<1	1	2	6	2	21	9	6
14	700130-S-1-DM-1	-	1	2	<1	8	0	25	6
15	WC FS 42-S-1-2-DM-1	4	4	3	5	1	8	20	6
16	IP 2789-S-2-1-DM-1	6	3	11	3	7	6	15	7
17	WC FS 148-S-1-DM-1	-	1	16	1	1	18	10	8
18	EB 218-3-2-S-4-1-DM-1	9	1	1	8	3	6	27	8
19	EBS 137-2-S-1-DM-1	<1	1	0	25	4	3	39	10
20	WC FS 151-S-1-1	6	2	3	<1	4	7	50	10
21	EB 66-1-S-3-3	2	1	<1	5	29	9	28	11
22	P-455-S-1	0	1	2	1	2	48	26	11
23	P-20-S-1	1	4	19	9	8	18	24	12
24	P-492-S-1	0	0	0	<1	2	55	36	13
25	P-446-S-1	2	1	1	8	2	73	12	14
26	P-10-S-1	1	10	26	11	16	34	7	15
27	P-483-S-2	<1	0	0	5	2	67	34	15
28	EB 54-1-1-S-7-3	1	5	28	4	24	41	9	16
29	EB 209-1-6-S-7	1	2	11	4	9	55	32	16
	Location means for test entries	1	1	4	4	6	17	21	8
	Trial Check (ICH 220)	11	18	91	28	2	84	52	41
	Local Resistant	1	10	3	0	6	33	9	9
	Local Susceptible	6	25	67	10	51	72	50	40

a/ Each datum is the mean of 2 rep. means and each rep. mean is derived from 10-20 inoculated-bagged heads except for Bambey where heads were just bagged. b/Mean for test entries. c/ All figs. are rounded-off to the nearest whole numbers. (-) data not provided.

Table 14. Rust reactions of eight IPMRN entries at eight locations during the 1977, 1978, and 1979 rainy seasons

Entry	Locations																							
	Bhavanisagar			Ludhiana			ICRISAT			Pune			Hissar			Bangalore			Kudumiamalai			Kovilpatti		
	77	78	79	77	78	79	77	78	79	77	78	79	77	78	79	77	78	79	77	78	79	77	78	79
SC-1(S)-4-4-5	0	0	-	10	0	-	0	6	18	10	9	-	-	5	0	-	7	7	-	42	37	-	-	18
700481-7-5	0	0	-	0	0	-	0	0	5	5	4	-	-	10	0	-	3	6	-	39	3	-	-	3
700481-23-14	0	0	-	10	3	-	5	0	18	0	7	-	-	5	0	-	4	4	-	17	8	-	-	8
700481-27-2	0	0	-	5	3	-	5	0	5	0	10	-	-	10	0	-	5	<1	-	43	<1	-	-	3
700481-27-5	5	0	-	10	9	-	0	0	18	5	7	-	-	5	0	-	8	13	-	15	3	-	-	5
700481-34-5	0	0	-	0	0	-	5	5	45	10	15	-	-	5	0	-	27	18	-	43	27	-	-	15
700481-34-8	0	0	-	0	0	-	0	15	8	0	11	-	-	20	0	-	15	3	-	27	1	-	-	5
700557-10-1	5	0	-	0	0	-	0	3	10	5	21	-	-	11	13	-	6	24	-	21	37	-	-	33

Table 15. Sources of multiple disease resistance in pearl millet in India

LINE	MEAN ERGOT SEV. (%) [a/]	SMUT SEV (%) [b/]	DOWNY MILDEW INC. (%) [c/]
ICMPE 134-6-9	2	0	7
ICMPE 134-6-11	2	0	0
ICMPE 134-6-41	2	0	3
ICMPE 134-6-34	2	0	4
ICMPE 134-6-25	2	0	4
Susc. Check	41	54	45

a/ Based on the 1981 IPMEN results of 10 locations in India.

b/ Based on 20 inoculated heads during the 1981 rainy season at ICRISAT Center.

c/ Based on ICRISAT Center 1981 rainy season downy mildew nursery.