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Commercial Feasibility of Growing Interpopulation Hybrids in Pearl Millet

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Single-cross grain hybrids of pearl millet are now widely grown in India, especially in areas receiving 350 mm rainfall in the crop season. But in western Africa, such hybrids, based on inbred parental lines, are likely to face two major adoption constraints: 1) highly virulent and variable pathogen populations may quickly overcome the resistance of genetically uniform inbred parental lines, requiring rapid replacement of cultivars; and 2) seed production will be more uncertain and the cost of seed will be high due to reduced seedling vigor and low yield potential of inbreds. Interpopulation hybrids may be a potential solution to both these problems. Genetic heterogeneity of interpopulation hybrids could be also an advantage in achieving stability for both grain yield and downy mildew resistance.

Commercial feasibility of using interpopulation hybrids will depend on their grain yield advantage over open-pollinated varieties and on the feasibility of breeding male-sterile populations. Interpopulation hybrids have been shown to yield 25–81% more grain yields than the parental populations (Ouendeba et al. 1993). The possibility of developing a male-sterile population was evaluated by conducting two cycles of recurrent selection to improve the ability to maintain male sterility in the Dwarf Nigerian Composite (NCD_2), which has high grain yield potential, long panicles, good resistance to downy mildew, and tolerance for seedling heat (Rai et al. 1995).

Three cycles of recurrent selection in NCD_2 have been completed for the ability of an A_4 system (Hanna 1989) to maintain cytoplasmic-nuclear male sterility (CMS). Male sterility of testcross progenies, based on visual assessment of pollen shedding, was used as the selection criterion. The number of progenies evaluated and those selected for recombination, using the S_1 seed of the NCD_2 plants, is given in Table 1.

Thirty-six percent of the testcross progenies from C_0 bulk did not shed pollen and hence were male-sterile, while 88% of testcross progenies from the C_1 bulk, and all the progenies from the C_2 bulk were male-sterile (Table 1).

Topcross hybrids were also made with these three cycle bulks on $81A_4$ and about 200 plants of each hybrid were evaluated at ICRISAT Asia Center (IAC) during the 1995 rainy season. Results confirmed the improvement observed in the testcross progenies. The frequency of male-sterile plants increased from 62% in the $81A_4 \times C_0$ topcross hybrid to 93% in the $81A_4 \times C_1$, and 100% in the $81A_4 \times C_2$.

Following a sidecar method (Rai 1990), NCD_2 is being backcrossed into the cytoplasm of $81A_m$. Two backcrosses have been completed using pollen from 100–200 plants of the original and improved cycle bulks. The F_1 was produced by crossing $81A_4$ with C_0 bulk of NCD_2. The BC_1 was produced by crossing male-sterile plants of F_1 with C_1 bulk of NCD_2, and BC_2 was produced by

Table 1. Frequency of pollen sterile (S), fertile (F), and segregating (F+S) testcross progenies developed from three cycle bulks of NCD_2 onto $81A_4$ in pearl millet, ICRISAT Asia Center, Patancheru, rainy seasons, 1992, 1994, and 1995.

Cycle		No. of test crosses		Progenies in F/S class (%)		
bulk	Year	Sown	Selected[1]	S	F	F+S
C_0	1992	392	131	36	22	42
C_1	1994	152	76	88	5	7
C_2	1995	123	116	100	0	0

1. Number of testcrosses whose corresponding S_1 progenies of NCD_2 were recombined.

crossing male-sterile plants of BC_1 with C_2 bulk of NCD_2.

Preliminary evaluation of backcross populations done at IAC during the 1995 rainy season showed that 97% of plants of the BC_1 population and all plants of the BC_2 were sterile. This shows that with the use of the A_4 system of cytoplasmic-nuclear male sterility (Hanna 1989), rapid progress towards a completely male-sterile population is possible.

Further backcrossing of the C_2 bulk is under way. At least four more backcrosses will be required to develop the male-sterile population that will be morphologically similar to the NCD_2 population. Maintaining the male sterility and genetic identity of the male-sterile population during seed multiplication in the field will be the next step in this technology.

Male-fertility restorers of the A_4 cytoplasm have been found in a diverse range of composites, indicating that restorers of this CMS system can be developed from a wide range of breeding materials.

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Pathology

Downy Mildew of Pearl Millet in Sudan

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Pearl millet [*Pennisetum glaucum* (L.) R.Br.] is the second most popular cereal in Sudan, after sorghum, and occupies an area of 1.2 million ha mainly in the western part of the country. The crop is grown under traditional cultivation in the drier, infertile sandy soils where annual rainfall is erratic and generally less than 500 mm. The long-term average yield is 275 kg ha^{-1}. Recently, some sorghum growers in *Striga hermonthica* infested areas in the mechanized, clay plain of central Sudan have changed over to pearl millet. In this region, the pearl millet strain of the parasite is not as prevalent as the sorghum strain.

During the droughts of the 1980s, most pearl millet farmers lost their local varieties and the only recommended cultivar, Ugandi. This led to a mass emergency import of seed from western Africa and from other locations within the country. Since then, downy mildew (*Sclerospora graminicola*), previously considered to be an inconspicuous constraint, has become the most serious disease problem. Recent surveys have indicated incidences of 11–81% in provinces within Kordofan State (Table 1). Practically none of the farms surveyed was free of the disease. All local varieties and introductions were found to be susceptible to downy mildew. The distribution of the disease followed the rainfall pattern. Higher severity was recorded in the southern, high-rainfall areas than in the northern fringe areas of the pearl millet belt where the crop received relatively less rain.

Table 1. Incidence of pearl millet downy mildew in farmers' fields in five provinces of Kordofan State, Sudan, 1993/94.

Province	Number of locations	Percentage downy mildew		Mean (%)
		Lowest	Highest	
Sheikan	10	3	69	29
En Nhud	14	20	84	58
Dilling	4	41	54	49
El Salam	3	76	85	82
Um Rwaba	5	1	23	11

Appropriate downy mildew control measures are being developed. Several genotypes have been introduced from ICRISAT Asia Center, India, and from SADC/ICRISAT, Zimbabwe. Preliminary results showed good performance of material from Togo. Okashana 1, for example, was completely free of disease till the end of the season. Of all seed protectants tested, metalaxyl appeared to be the only promising chemical.

Influence of Downy Mildew Infection on the Physiology of Pearl Millet Plants in an Arid Climate

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Pearl millet, *Pennisetum glaucum* (L.) R.Br., is the principal cereal on 25 million ha of the drought-prone semi-arid regions of Africa and the Indian subcontinent. Downy mildew, caused by *Sclerospora graminicola* (Sacc.) J. Schrot., is the most widespread and destructive disease of pearl millet in the temperate and tropical areas of the world. It is especially important in India and western Africa. The pathogen colonizes the growing parts of the plant, through oospore and sporangial infection and deranges the physiological and biochemical processes. The first effect of the pathogen on host tissues appears to be an increase in the permeability of the plant cell, making nutrients available to the parasitizing fungus (Gour and Kumar 1992) and leading to destruction in turgor pressure. This, in turn, disturbs the water balance of the cell (Sadasivan 1968). This report briefly describes the alteration in water balance in the pearl millet plant following downy mildew infection in an arid climate.

Physiological changes induced by the pathogen in the host were studied on the susceptible pearl millet hybrid, HB 3, grown in pots. Thirty-day-old healthy and infected plants were chosen for the experiment. Observations were made on a single day, with only one observation made per plant on three diseased and three healthy plants at each time. Diffusive resistance, DR (S cm^{-1}), rate of transpiration ($\mu g\ cm^{-2}\ S^{-1}$), and temperature (°C) of the abaxial (Ab) and adaxial (Ad) surfaces of the leaves were measured using steady state porometer (Li-Cor®, USA) at 0800, 1000, 1200, 1400, and 1600 in 1992. The porometer was nulled to ambient humidity which did not vary more than 2% during the period of observation. Mean temperature of leaf and total rate of transpiration (TR) were calculated by adding up the transpiration rates of both Ab and Ad surfaces, while leaf diffusive resistance (LDR) was calculated by the following formula (Kumar and Gour 1992).

$$LDR = \frac{DR_{(Ab)} \times DR_{(Ad)}}{DR_{(Ab)} \times DR_{(Ad)}}$$

Diffusive resistance in the infected leaves was significantly higher than in the healthy leaves throughout the day (Table 1). The differences in LDR between the healthy and diseased leaves increased over the day,

Table 1. Effect of downy mildew infection on physiological parameters of pearl millet plants.

Time	Leaf diffusive resistance (S cm^{-1})		Transpiration ($\mu g\ cm^{-2}\ S^{-1}$)		Leaf temperature (°C)	
	Diseased	Healthy	Diseased	Healthy	Diseased	Healthy
0800	0.478	0.316	7.03	7.65	28.82	29.07
1000	0.509	0.368	10.33	13.53	30.93	31.07
1200	0.536	0.401	12.29	15.59	37.87	37.97
1400	0.793	0.468	11.08	15.59	38.63	37.70
1600	0.988	0.632	10.52	14.53	35.17	35.00
Mean	0.661	0.437	10.25	13.38	34.28	34.16
CD (5%)						
Disease	0.04		0.51		NS[1]	
Time	0.06		0.81		0.32	
Disease × time	0.09		1.15		0.45	

1. Not significant.