Plant Breeding 109, 54—59 (1992)

ISSN 0179-9541

Reselection of a Pearl Millet Cultivar Utilizing Residual Variability for Downy Mildew Reaction*

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With 5 tables

Received May 25, 1991 / Accepted November 3, 1991
Communicated by W. E. Weber

Abstract

'BJ 104' was the most widely grown pearl millet hybrid in India until it became susceptible to downy mildew (DM) in 1984—85. Residual variability for resistance was found in both parental lines, 5141 B (maintainer of 5141 A) and J 104, and through four generations of pedigree selection under intense disease pressure in the DM nursery, two lines, ICMA 841 (from 5141 B) and ICMP 84814 (from J 104), were selected resulting in a reconstituted DM resistant hybrid ('ICMH 84814') which was equal in yield to the original 'BJ 104'. The reconstituted hybrid, though phenotypically similar, can be distinguished from 'BJ 104' being slightly taller, flowers later, has heavier heads, and 1000-seed weight, but tillers less.

A similar exercise was attempted on Tifton 23 B, the female parent of the first widely grown hybrid ('HB 3' — the male parent was also J 104), but no variability for resistance to DM was found.

Key words: downy mildew — residual variability — resistance — reselection in susceptible cultivar — *Sclerospora graminicola*

Downy mildew (DM) caused by *Sclerospora graminicola* (Sacc.) Schroet, is a major constraint to the longevity of released hybrids of pearl millet [*Pennisetum glaucum* (L.) R. Br.] in India (NENE and SINGH 1976, SAFEEULLA 1977). Several widely grown hybrids, including 'HB 3' (Tifton 23A × J 104) and 'BJ 104' (5141A × J 104), were withdrawn in the past due to increased susceptibility to DM (SINGH and KING 1985). 'BJ 104' maintained high levels of DM resistance in farmers' fields for several years after its release. The hybrid developed widespread DM epidemics in 1984 and 1985 in several parts of India. Recently, 'MBH 110', a hybrid based on parental lines unrelated to those of 'HB 3' and 'BJ 104', also succumbed to the disease. While a knowledge of the causes of such breakdowns of resistance is needed to avoid breeding potentially unstable cultivars, it would be useful if a rapid procedure could be found to increase the life of existing commercial cultivars, particularly if, as in this case, alternative cultivars were not immediately available. The feasibility of selecting a DM resistant version of a cultivar has been demonstrated in the case of a land race of pearl millet (SINGH et al. 1988). This paper describes the results of selecting for DM-resistance in inbred lines Tifton 23 B and 5141 B, the seed parents of hybrids 'HB 3' and 'BJ 104', respectively, and their common pollinator, J 104.

Materials and Methods

Seed source: Original bulk seeds of 5141A, three stocks of its maintainer 5141B and three stocks of pollinator J 104, obtained from the ICRISAT pearl

* Submitted as Journal Article No. 1164 of the International Crops Research Institute for the Semi-Arid Tropics.

millet breeding unit, were used. Seeds of Tifton 23A and B were obtained from Maharashtra Hybrid Seed Company, Jalna, Maharashtra.

Screening procedure: The DM screening nursery that utilizes oospores and also sporangia, supplied by earlier-planted infector rows (a mixture of 'HB 3' and '7042') was used (WILLIAMS et al. 1981). Cultivars 'NHB-3' (5071 A × J 104), and/or 7042, which are highly susceptible to DM, were sown as indicator of DM levels after every 10 test rows. Rows were 75 cm apart and plants within rows were spaced at about 5 cm.

Progeny advancement and selection: The first evaluation of DM reaction of the test entries was done in the DM nursery in the 1982 rainy-season. Each entry was planted in 10-row plots, each 4 m long. A high percentage of plants showed DM symptoms, but a few DM-free plants which were true-to-type were detected for each line. DM-free plants of J 104 were selfed and those of 5141B were selfed and simultaneously crossed to DM-free plants of 5141A. Similarly, DM-free plants of Tifton 23B were selfed and crossed to Tifton 23A. The selfed progenies of DM-free plants of J 104, Tifton 23B and 5141B, and the crossed progenies of Tifton 23A (Tifton 23A × Tifton 23B) and 5141A (5141A × 5141B) were grown head-to-row for four generations (S1—S4), as the process of selfing and crossing was repeated. DM resistance and similarity to the original parent were the major selection criteria. The details of selection are presented in Table 1.

Multilocational tests for DM resistance: DM reactions of one selected line of 5141A (5141A-1 designated as ICMA 841) and one of J 104 (designated as ICMP 84814) were determined at 10 locations in India during the 1983 and 1984 rainy seasons (Table 3). Line ICMA 841 was also tested at 11 locations in India and West Africa in the 1986 International Pearl Millet Downy Mildew Nursery (IPMDMN) (Table 4).

Measurement of yield parameters: Fourteen hybrids were made using different selections of 5141A and J 104. These hybrids, along with ICMA 841 and ICMP 84814, were evaluated at Bhavanisagar, ICRISAT Center, and at Hisar during the 1984 rainy season (Table 5). Original 'BJ 104' and 5141A were included as checks. Seeds of original 'BJ 104' and 5141A were treated with metalaxyl at 2 g ai/kg seed to protect them from DM infection. Each entry was planted in four row plots, 4 m long, in three replications in a randomized block design. Observations were made for tiller number, plant height, days to 50 % bloom, ear length, head weight, 1000 grain weight, and grain yield.

Table 1. Details of selection and advance of progenies of 5141B, J 104, and Tifton 23B and their downy mildew (DM) reactions (% incidence, mean and ranges) from S0—S4 in the DM nursery at ICRISAT Center, Patancheru, India

Cultivar	S0		S1			S2			S3			S4		
	No. of plants	DM (%) mean	No. of prog.	DM (%) mean	DM range	No. of prog.	DM (%) mean	DM range	No. of prog.	DM (%) mean	DM range	No. of prog.	DM (%) mean	DM range
J-104-1	205	97	1	2	2	5	24	11—48	24	2	0—25	37	1	0—9
J-104-2	126	96	8	17	0—63	11	23	0—100						
J-104-3	140	89	11	70	16—88	15	26	0—78						
5141B-1	316	82	15	17	0—58	164	9	0—100	81	4	0—50	4	0	0
5141B-2	248	82	10	12	0—40	44	4	0—79						
5141B-3	162	89	3	31	7—55	6	6	0—25						
Tifton 23B	300	98	3	67	50—93	11	76	53—90	9	75	47—91	3	78	65—90
7042 (Susceptible check)		95		92	75—100		96	91—100		99	96—100		89	76—95

Table 2. Downy mildew (DM) incidence (%) in three selections of 5141 A and B, two selections of J 104 along with their bulks and a susceptible check for four generations, in the field DM nursery at the ICRISAT Center, Patancheru, India

Entry	DM incidence (%)				
	S0	S1	S2	S3	S4
5141A-1 ICMA 841	—	0	0	0	0
5141B-1 ICMB 841	—	0	0	0	0
5141A-2	—	4	0	0	0
5141B-2	—	2	1	0	1
5141A-3	—	0	0	0	0
5141B-3	—	0	0	0	0
J-104-1-2-P1-1 (ICMP 84814)	—	2	0	0	0
J-104-1-2-P2-1	—	2	0	0	0
5141A-1 (Bulk)	70	—	71	54	57
J-104-1 (Bulk)	97	—	81	82	81
NHB-3 (susceptible check, mean)	95	85	90	80	95

Results

Variability for DM reaction

All lines showed high levels of DM, but disease-free plants were detected in each of them. Selfed progenies of resistant plants showed a wide range of variability for DM reaction in S1 and S2, despite the fact that each progeny was a descendent of single DM-free plant. However, progenies that were true-to-type and DM resistant were detected in only one stock of each of J 104 (J 104-1) and 5141 B (5141 B-1). By the S4 generation, DM resistance levels in the selected progenies of these two stocks had increased to 91 % and 100 %. Several progenies from the two stocks remained DM-free from S2 to S4 (Table 2). 5141 A-1 and J 104-1-2-P1-1 were designated as ICMA 841 and ICMP 84814, respectively. The progenies of the other two stocks were discarded in the S2 stage. In case of Tifton 23 B, none of the progenies showed an acceptable level of DM resistance.

The reconstituted hybrid 'ICMH 84814' based on ICMA 841 and ICMP 84814 was also tested for DM reaction along with the original 'BJ 104' for two seasons in the DM nursery. The reconstituted hybrid developed 2 % or less DM compared with > 50 % in BJ 104 and > 90 % in the susceptible check NHB-3.

Table 3. Mean downy mildew severity (%) in ICMA 841 and ICMP 84814 at 10 locations in the IPMDMN (International Pearl Millet Downy Mildew Nursery) in India during rainy seasons 1983 and 1984

Entries	Downy mildew severity (%)					
	ICMA 841		ICMP 84814		Susceptible check NHB-3	
	1983	1984	1983	1984	1983	1984
Ludhiana	1	1	8	7	59	60
Hisar	0	—	—	0	64	72
Durgapura	0	0	0	7	0	5
Jamnagar	0	0	1	0	53	44
Aurangabad	0	0	12	0	93	39
Patancheru	0	3	2	3	85	86
Vijayapuri	—	4	—	15	—	34
Mysore	9	0	13	0	59	84
Coimbatore	0	—	—	—	30	—
Kovilpatti	—	—	3	—	52	—

Multilocational test for DM resistance

In 2 years of tests, ICMA 841 was either DM free or developed very low levels of disease (1—4 %) at all locations, except at Mysore where it developed 9 % DM in 1983. ICMP 84814 showed less than 10 % DM at all

Table 4. Mean downy mildew severity (%) in ICMA 841 along with resistant and susceptible checks at 11 locations in India and West Africa, 1986 rainy season

Location		Downy mildew severity (%)			
		ICMA 841	P 7-4[a]	7042[b]	NHB 3[b]
Aurangabad	India	0	0	41	40
Jalna	India	1	0	29	50
Patancheru	India	0	4	78	92
Mysore	India	2	3	40	91
Bhavanisagar	India	0	0	50	3
Cuddalore	India	2	0	62	35
Kovilpatti	India	0	0	36	<1
Bambay	Senegal	<1	3	75	33
Kamboinse	Burkina Faso	8	14	94	57
Bengou	Niger	50	25	33	16
Samaru	Nigeria	26	8	94	13

[a] Resistant check
[b] Susceptible check

Table 5. Details of tillering, days-to-50 % bloom, plant height, ear length, 1000 grain mass and grain yield of ICMH 84814, ICMA 841 and original BJ 104 and 5141A at three locations, 1984 rainy season

Parameter/Location	Entry			
	ICMH 84814	ICMA 841	BJ 104	5141 A
Tillering				
ICRISAT	2.8	3.1	3.8	3.3
Days to 50 % bloom				
Hisar	51	58	50	60
ICRISAT	44	53	42	51.3
Plant Height (cm)				
Hisar	234	190	218	170
ICRISAT	127	106	111	96
Bhavanisagar	144	94	131	99
Ear length (cm)				
Hisar	19.8	21.4	22.2	18.7
ICRISAT	15.9	15.0	16.3	11.5
Bhavanisagar	16.6	15.6	16.9	14.4
1000 grain weight (gm)				
Hisar	8.9	7.7	8.1	5.1
ICRISAT	6.9	5.8	6.5	4.9
Bhavanisagar	8.9	7.9	7.8	5.4
Grain weight (qt/ha)				
Hisar	10.6	7.1	10.9	6.8
ICRISAT	20.9	10.5	20.8	9.7
Bhavanisagar	17.8	7.3	15.4	4.3

locations, except, Aurangabad and Mysore in 1983, and Vijayapuri in 1984 (Table 3).

In the 1986 International Pearl Millet Downy Mildew Nursery (IPMDMN), ICMA 841 showed high levels of DM resistance at two West African locations, Bambey (Senegal) and Kamboinse (Burkina Faso), in addition to holding resistance at all the DM hot-spot locations in India. In fact the line showed better DM-resistance than the resistant check (P 7-4) at Bambey (Senegal), whereas at Bengou (Niger) and Samaru (Nigeria) it was susceptible (Table 4). The susceptibility of ICMA 841 at these locations was presumably due to the presence of *S. graminicola* populations that are more aggressive in these parts of West Africa than at other locations (BALL 1983, BALL and PIKE 1984, SINGH et al. 1987).

Evaluation of yield parameters

The reconstituted hybrid, 'ICMH 84814' (ICMA 841 × ICMP 84814) was generally similar to the original 'BJ 104' in traits including days to 50 % bloom, ear length, 1000 grain mass, and grain yield. 'ICMH 84814' was however, taller and produced fewer tillers per plant than 'BJ 104' (Table 5).

ICMA 841 was similar to 5141A in tiller number; it, however, grew taller and produced longer ears at ICRISAT and Hisar, but did not differ in these traits at Bhavanisagar. Interestingly, ICMA 841 appeared to be superior to 5141 A in terms of 1000 grain mass.

Discussion

A large variation for DM reaction was observed in 5141A and J 104. Variability in 5141A was expected, because it was a mixture of several sister lines (S. C. POKHRIYAL, Personal Communication). The occurrence of variation in both 5141 B and J 104 indicated that reselection for DM-resistance in apparently inbred lines of pearl millet including hybrid parents was possible. Such lines, though sufficiently uniform to meet production requirements may carry usable levels of variability for DM resistance. However, our failure to select for resistance in Tifton 23B shows that all inbreds may not necessarily possess residual variability for DM resistance. The usefulness of residual variability in parental lines has important implications for breeding strategies when longevity of resistance to a flexible pathogen like the downy mildew fungus is a primary need. The avoidance of inbreeding to total uniformity is one way, perhaps easier in male than in female parents. For this reason, topcross hybrids are now being produced at the ICRISAT Center and are being tested in the All-India trials (ICRISAT 1989). Topcross hybrids may be especially appropriate for African countries, where downy mildew is both more variable and aggressive (ANDREWS 1987).

DM resistant plants phenotypically similar to the original parent were detected in only one stock of each of 5141B and J 104. Segregation for the phenotypic traits continued to occur in the other two stocks but, true-to-type, resistant plants were not found. If larger populations had been examined, it might have been possible to find the desired combination of DM-resistance and phenotype in these other stocks.

High levels of DM-resistance were obtained by taking many selections from S1 to S4 and continually subjecting them to intense DM-pressure. It appears that DM-resistance in progenies selected from inbreds can be stabilized quicker than that isolated from land races which require several cycles of reselection and inbreeding (SINGH et al. 1988).

Many progenies derived from resistant plants showed high susceptibility. This was attributed to i) escapes, and ii) the possibility that plants initially found to be disease-free were heterozygous at loci contributing to resistance. Further selfing would then result in susceptible segregants. To minimize escapes, progenies should be screened using the seedling inoculation technique (SINGH and GOPINATH 1985). In the latter process, however, selfing of disease-free plants for several generations will still be needed to recover relatively fixed segregants.

The approach of selection for DM resistance within a line, however, has two major defects; i) the derived lines may be phenotypically different and the resultant hybrid, or the product, may be different, with some genes for yield and adaptation being lost during the process of selfing for several generations, and ii) the selected resistance may be short-lived. The change from the original will depend on the

amount of residual variability available and population size used (SINGH et al. 1988).

In the present program case, neither the yield of ICMA 841 nor of the resultant hybrid was reduced, although there was some change in height and maturity. Thus, the hybrid looks similar to the original 'BJ 104'. Considerable increase in stem thickness of the hybrid due to increased thickness of the stem of ICMA 841, is likely to improve lodging resistance and make this hybrid more suitable for high input conditions. ICMA 841 has become available for commercial utilization (SINGH et al. 1990) and is a seed parent of two DM resistant commercial hybrids that have been released in India. Doubts regarding the longevity of such resistance are speculative, because there are no methods by which its durability can be predicted. Moreover, the procedure demonstrated here on the parents of 'BJ 104' should be regarded as a cultivar "maintenance operation" and should be pursued only if insufficient alternative superior genotypes are available and only on leading cultivars which have started to lose resistance. In 'BJ 104', for example, had it been done soon after the detection in early 1981 of a breakdown of resistance, then losses in 1984 and 1985 might have been avoided. Reselection can be achieved in less than two years, because three generations of pearl millet can be grown in a single year. This procedure would enhance the useful life of commercial cultivars, minimize epidemic development, and serve as an adjunct to breeding approaches such as transfer of resistance and breeding of heterogenous parental lines.

Zusammenfassung

Reselektion einer Perlhirsesorte unter Nutzung von Restvariabilität für Mehltauresistenz

Die Perlhirsesorte 'BJ 104' war in Indien die am weitesten verbreitete Hybride, bis sie in den Jahren 1984—85 gegen Mehltau anfällig wurde. Bei den elterlichen Kombinationspartnern 5141 B (mit der entsprechenden Ergänzungslinie 5141 A) und J 104 wurde jedoch noch eine Restvarianz für Resistenz gefunden. Unter starkem Befallsdruck wurden in einem Mehltau-Zuchtgarten im Verlauf von 4 Generationen aus Familiennachkommenschaften zwei Linien, ICMA 841 (aus 5141 B) und ICMP 84814 (aus J 104), selektiert, aus denen eine neue mehltauresistente Hybride ('ICMH 84814') entwickelt wurde, die den gleichen Ertrag aufwies wie die alte Sorte 'BJ 104'. Obgleich die wiederhergestellte Hybride phänotypisch der Sorte 'BJ 104' ähnlich ist, kann sie von ihr unterschieden werden, da sie etwas höher wird, später blüht, schwerere Ähren hat, ein höheres TKG besitzt und weniger Halme ausbildet. Ein ähnliches Verfahren wurde bei dem weiblichen Partner, 'Tifton 23 B', für die früher weit verbreitete Hybride 'HB 3' (der männliche Partner war ebenfalls J 104) versucht; aber es wurde keine Variabilität für Resistenz gefunden.

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