Recycling of Pearl Millet Cultivars for the Control of Downy Mildew

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Abstract

Evidence shows that there is a high degree of host specificity in *Sclerospora graminicola* (Sacc.) Schroet, the pathogen causing downy midew in pearl millet (*Pennisetum glaucum* (L.) R.Br.). An analysis of the occurence of epidemics and many cultivars abandoned as a result of susceptibility to downy mildew, suggests that recycling of 'abandoned cultivars' could be a useful approach to control downy mildew of pearl millet in India. The cultivars should be rotated in the sequence of their withdrawal or on the basis of their non-specificity to existing populations of the pathogen. Several cultivars such as HB 3, BJ 104, BK 560, MHB 110, and WC-C 75 are available for sequential rotation. Cultivar recycling will keep the pathogen in a state of confusion, help in avoiding epidemics of the disease, and provide an opportunity to exploit the full yield potential of released cultivars. This approach can be an important component of intergrated disease management in pearl millet.

Introduction

Epidemics of downy mildew (*Sclerospora graminicola* (Sacc.) Schroet.) occur, on an average, once every 3 years, on pearl millet (*Pennisetum glaucum* (L.) R. Br.) in one or the other area of India. These epidemics have caused tremendous yield losses (Safeeulla 1977; Singh *et al.*, 1987). As a result of these epidemics, many otherwise useful cultivars have been discarded. The purpose of this paper is to analyze the situation on incidence of downy mildew in pearl millet, and suggest how the cultivars that have been withdrawn due to their susceptibility to downy mildew could be effectively re-used by adopting a rotation approach to minimise the risks of re-occurence of epidemics, and making full use of the available resistance genes.

During the last 30 years, approximately 32 hydrids and 6 open-pollinated varieties have been released for cultivation in India. Some of these cultivars did not reach farmers, while others occupied only a limited area for a few years. However, a few became highly popular; but these had to be withdrawn after a period of 3-5 years. The sole reason for withdrawal was their susceptibility to downy mildew disease. Downy mildew epidemics continue to occur; the last epidemic occurred in 1987 on MBH 110 in Maharashtra. The recurrence of these epidemics shows that we are in a no-win situation; introducing a resistant cultivar, withdrawing it in a few years after its widespread adoption, and then repeating the process. These epidemics also show that we are engaged in a boom-and-bust-cycle of cultivar production (Robinson, 1976).

Genetically uniform F_1 hybrids were produced and released for commercial cultivation in India beginning in 1965. The first to be released was HB 1 followed by HB 2, HB 3, and HB 4. All these hybrids were based on Tift 23A, a cytoplasmic male-sterile line that was developed in the absence of disease at Tifton, Georgia, USA (Burton, 1969). This line was not tested for its resistance to downy mildew, as the disease was not considered important during that period even in India. Within a few years, Tift 23A and hybrids based on this seed parent

began to show susceptibility to the disease. During this period, the hybrids proved their worth. Pearl millet grain production in India reached a record high of 8.2 million t in 1970-71. In the following year, however, downy mildew appeared in epiphytotic form and production was reduced to 5.3 million t (Singh *et al.,* 1987). In the absence of a resistant cultivar, farmers continued to grow susceptible HB 3 even in its advanced generations, and epidemics continued to occur until 1976. This resulted in the build-up of oosporic inoculum in the soil.

To fight this pathogen population; two hybrids, BJ 104 and BK 560, (based on 5141A), were released in 1977. The maintainer (5141B) of 5141A, was developed from Tift 23B with some resistance genes from African sources (Pokhriyal *et al.*, 1976; Dave, 1987). Despite the high levels of soil inoculum, BJ 104 showed resistance throughout India, and this continued for at least 4 years. Downy mildew appeared on 5141A in 1981 in Tamil Nadu, and in 1982, this line developed heavy downy mildew in seed multiplication plots in Andhra Pradesh (S.D. Singh, unpublished). Severe downy mildew epidemics occurred on BJ 104 from 1984-86 in several states in India. Interestingly, both the hybrids were withdrawn before 1982 in Tamil Nadu.

In 1982, cultivar WC-C75, a genetically heterogeneous open-pollinated variety with a very wide genetic base, bred at ICRISAT, was released (Andrews *et al.,* 1985). It gradually occupied large areas and by 1989 it was cultivated on over 1 million ha in India. MBH 110, a private sector hybrid, also occupied a large area in Maharashtra during the same period. BK 560 was also grown quite extensively along with these two cultivars in several states (except in Tamil Nadu).

MBH 110 showed sporadic incidence of downy mildew in 1983, but showed susceptibility in 1986, and became highly susceptible in 1987. It was withdrawn completely from Maharashtra in 1989. There are indications that WC-C75 has also begun to show some susceptibility. However, it may take some time for WC-C75 to become susceptible to the point of withdrawal.

Development of Host-Specific Populations

Hybrid HB 3 was released in 1968 for cultivation throughout India (Dave, 1987), and became susceptible to the disease in 1971-72. However, in the sick-plot at Mysore (Karnataka, India) this hybrid was reported as 'immune' during 1970-73 (Bhat, 1973). With the continued cultivation of HB 3 in sick plot for several years, the disease incidence gradually increased (Singh, S.D., unpublished). In fact, this is exactly what has happened with other pearl millet cultivars that were eventually withdrawn (e.g., BJ 104 and MBH 110). These cultivars were also highly field resistant when they were first introduced.

HB 3 was grown widely in Maharashtra from 1968 to 1977. Although it became susceptible in 1971, HB 3 continued to be cultivated until 1976 due to lack of well-adapted alternative hybrid cultivars. In the Khandala area of Maharashtra, the Maharashtra Hybrid Seed Company (MAHYCO), Jalna, tested HB 3 from 1986 to 1989 on an experimental basis. Over 4 years, HB 3 remained free from downy mildew. In the Nakshatrawadi area of Maharashtra, MBH 110 became popular after the withdrawal of HB 3. MHB 110 became totally susceptible to downy mildew in 1987 and was withdrawn in 1989. In this area, we tested a large number of breeding materials along with HB 3 in 1988. HB 3 remained free from downy mildew, whereas the universally susceptible control, 7042, and MBH 110 were highly susceptible (Table 1).

Table 1. Downy mildew reactions[a] (%) of two susceptible controls, NHB 3 and 7042, at three Indian locations, and of MBH 110 at Aurangabad during the 1988 rainy season

Entry	Patancheru	Mysore	Aurangabad[b]
NHB 3	95	97	0
7042[c]	94	66	61
MBH 110	-d	-	52

a Mean of 5 replications.

b Results are from a farmer's field where MBH 110 showed a high degree of susceptibilty in 1987.

c Universally susceptible control.

d - = Not evaluated

Dynamics of Host-Specific Populations

In the downy mildew sick-plot at Durgapura (Rajasthan, India), hybrid HB 3 and NHB 3 were grown until 1977, and as usual heavy downy mildew developed on both of them. The two cultivars were next grown in this plot in 1980 and 1981 as indicators for downy mildew pressure in the nursery. In both these years, the cultivars showed resistance to oospore infections, although limited nodal infection was observed at the heading stage. Several local landraces and 7042, the universally susceptible control, showed high levels of downy mildew incidence in these nurseries (Table 2). At other locations in the state, both hybrids were highly susceptible. However, HB 3 and NHB 3 became susceptible in the sick plot in Durgapura in 1983-84 following their continued cultivation from 1981. From this, it appears that, i) a host-specific population could die out within 3 years of removal of the host genotype, and ii) if such a cultivar is reintroduced 3 years after its withdrawal, it could survive downy mildew attack for at least 2 years. These periods may change if host removal and reintroduction were to occur in monoculture at field-scale instead as components of a heterogeneous group of genotypes.

Table 2. Downy mildew incidence in 7042 and NHB 3 inoculated with oospores and sporangia of pearl millet downy mildew at Durgapura and ICRISAT Center[a]

		Oospore infection			Sporangial infection		
Host genotype	Inoculum source	No.of plants	Percent downy mildew 28 DAI[b,d]	Standard error	No.of plants	Percent downy mildew 28 DAI[b,d]	Standard error
7042	Durgapura	119	54.0	± 4.6	67	70.5	± 5.6
NHB 3	Durgapura	122	0	-	68	14.0	± 4.2
7042	ICRISAT	86	53.5	± 5.9	60	91.7	± 3.9
NHB 3	ICRISAT	134	67.9	± 4.0	60	98.3	± 1.8
Non-inoculated control							
7042	-	107	0	-	45	0	-
NHB 3	-	19	0	-	44	0	-

a Source : Singh and Singh (1987). b Days after inoculation. c Means of 2 tests. d Means of 3 tests

Susceptibility of HB 3 in Downy Mildew Nurseries

Ever since the widespread epiphytotics of downy mildew on this cultivar in 1971, HB 3 has been used as a susceptible control in disease nurseries at most of the research stations in India. Due to its continued cultivation there, it contiunes to be susceptible in the disease nurseries.

Cultivar Rotation

Being highly host specific, the structure of the pathogen population is altered dramatically with the continued cultivation of a specific host genotype. A host-specific population is formed and continues to increase and infect the host as long as that host genotype is grown, but once the host genotype is withdrawn, the host-specific population loses its competitive advantage and is replaced by a more competitive mixed population in about 3 years (Singh and Singh, 1987). It is likely that the host-specific population may die out even earlier.

When a host-specific population dies out, the host will then show resistance to downy mildew as good as that of a newly developed cultivar or as good as it showed when introduced. Such a cultivar, if reintroduced, may not develop disease or may develop very little disease (due to infection by sporangia). A downy mildew population with specific pathogenecity to the cultivar will gradually buildup, and the cultivar may succumb to the disease within a period of 2-3 years. At that stage, the cultivar can be withdrawn and replaced with another cultivar to which the existing population of the pathogen is not adapted. The process will in fact be exactly the same as we are now doing with the newly developed downy mildew resistant cultivars. In this way, cultivar rotation can effectively be used to prevent buildup of host-specific populations on popular cultivars, and these cultivars can be used repeatedly until alternative cultivars that are superior to the existing ones become available. In fact, rotation of host cultivars has been suggested as a method of plant disease control as early as 1949 (Stevens,1949).

Cultivars Available for Rotation and Rotation Sequence

One of the limitations of rotation approach is the availability of cultivars. In the case of pearl millet, we have several discarded cultivars that can be used in a sequential rotation along with those still in use, and the new cultivars. The discarded cultivars include HB 1, HB 2, HB 3, BJ 104, BK 560 and MBH 110 - all single cross hybrids.

The only factor that will decide the sequence of rotation is the presence of the pathogen population in the field, and the degree of relatedness of the cultivars. A cultivar should be brought into rotation only when the host-specific population that can infect this cultivar has died out. Therefore, the abandoned cultivars should be rotated in the sequence in which they were introduced or on the basis of their non-specificity to the existing population of the pathogen. This will ensure the timely disappearance of the relevant host-specific populations.

Although the data presented in Figure 1 indicate that hybrids such as BJ 104, BK 560, and MBH 110 have been cultivated for several years, the fact is that these hybrids were not widely cultivated in the early years following their release. BK 560, for instance, was released for cultiation in 1977 along with BJ 104, but became popular and was cultivated widely only when BJ 104 became susceptible and was withdrawn from cultivation. Similarly, HB 3 also showed high levels of disease only after 2-3 years of cultivation on a larger area. Thus, a hybrid may possibly be cultivated on a

large area for 2-4 years before its withdrawal would be necessary.

Experience with pearl millet open-pollinated varieties is not very long. WC-C 75 is the only open-pollinated variety that has been cultivated widely for several years in India. It has a wider genetic base than single cross F_1 hybrids as it is based on seven full-sib progenies selected from the World Composite (Andrews *et al.*, 1985). From 1984 onwards, its coverage has increased substantially and there has been no report of any downy mildew epidemic on this variety through 1988. In 1989, reports were received from several places about the appearance of downy mildew on this variety. But these reports could not be confirmed in 1990. However, it has yet to be assessed in the future. A variety with a genetic base as wide as that of WC-C 75, may survive much longer than single-cross F_1 hybrids. Further, there is much greater scope for re-selection to eliminate susceptible components of an open-pollinated variety such as WC-C 75 than is there in the inbred parents of a single cross F_1 hybrids (Singh *et al.*, 1988).

Conclusions

Cultivars that have been withdrawn or are likely to be withdrawn in future due to their susceptibility to downy mildew are valuable resources and must be preserved. These cultivars have many traits in desirable backgrounds. The speed with which we are utilizing newer sources of resistance is so fast that it is likely that the resistance sources in desirable backgrounds will be exhausted. When that occurs, the discarded cultivars will be the most valuable resource. It would be wiser to begin rotation of all well-adapted genotypes to permit judicious management of the disease. Rotation of these genotypes is an excellent approach which not only manages downy mildew susceptiblity but also enables explotation of their yield potential. This could greatly reduce occurrence of epidemics and thus help in stabilising yield. The approach will be highly economic as less effort will be needed to incorporate disease resistance.

Use of discarded cultivars is similar to the use of newly bred resistant cultivars. A disease-resistant cultivar is bred and released to combat the existing population of the pathogen; in other words, the cultivar should possess non-specificity to the existing pathogen population. Similarly, a discarded cultivar will be reintroduced into cultivation only when the host-specific pathogen population has died out or its frequency has fallen below detectable levels, and the existing population is either non-specific or mixed.

The integrated pest management concept, which is being widely practiced for pest control, is currently getting attention for the management of diseases as well. Cultivar rotation is one approach that could form an important component of integrated disease management in pearl millet.

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