Smut Disease of Pearl Millet

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International Crops Research Institute for the Semi-Arid Tropics

Abstract

Thakur, R.P., and King, S.B. 1988. **Smut disease of pearl millet.** Information Bulletin no.25. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Smut of pearl millet *(Pennisetum glaucum),* caused by *Tolyposporium penicillariae,* is an important and widespread disease. It causes direct loss of grain by replacing them with smut sori, and yield losses of up to 30% have been reported. In recent years the disease has become more important on commercial F_1 hybrids in India and on exotic early-maturing cultivars in countries of Africa.

The text describes and illustrates geographical distribution, disease symptoms, disease cycle, morphology of the causal fungus, and disease management methods. Various control measures are presented, with emphasis on host-plant resistance, including screening methods and use of resistance.

Résumé

Thakur, R.P. et King, S.B. 1988. **Charbon du mil.** Bulletin d'information n° 25. Patancheru, A.P. 502 324, Inde : International Crops Research Institute for the Semi-Arid Tropics.

Le charbon du mil (*Pennisetum glaucum*), dû à *Tolyposporium penicillariae*, est une maladie importante et largement répandue. Il provoque des pertes directes des grains en les remplaçant par des sores de charbon et des pertes de rendement s'élévant jusqu'à 30% ont été signalées. Ces dernières années, l'ergot est devenu une maladie néfaste aux hybrides F_1 commerciaux en Inde et aussi aux cultivars précoces exotiques dans plusieurs pays en Afrique.

Ce bulletin décrit et illustre la répartition géographique, les symptômes de la maladie et la morphologie du champignon causal. Il fait aussi le point sur diverses mesures de lutte dont la résistance de la plante-hôte et des méthodes de criblage, en particulier. L'utilisation des cultivars résistants et d'une stratégie de lutte intégrée est préconisée comme une méthode phytosanitaire efficace et économe.

Cover: Smut-infected pearl millet panicles in a farmer's field in Niger. Inset: At left, early stage of infection showing green sori that become dark brown at a later stage (right).

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ICRISAT

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Contents

Preface

This bulletin has been prepared to provide research and extension workers with general information on smut disease of pearl millet. A separate information bulletin has been written on ergot, another important panicle disease of pearl millet that has certain similarities with smut.

As can be seen from the table of contents, this bulletin is intended to be comprehensive in topics discussed. It should be especially useful to workers who are not very familiar with smut disease and to those who do not have ready access to research literature. However, for more in-depth information on various aspects of pearl millet smut, scientific journals and books should be consulted.

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Director
Cereals Program

Introduction

Smut, caused by *Tolyposporium penicillariae* Bref., is a widespread disease of pearl millet [*Pennisetum glaucum* (L.) R.Br]. The disease has been reported from Pakistan, India, and the United States, and from many countries in Africa. The earliest reports of this disease are from Senegal (Chevalier 1931) and India (Ajrekar and Likhite 1933). In India, a survey during the 1950s indicated that smut severity in farmers' fields ranged from 1 to 30% in parts of Tamil Nadu, Andhra Pradesh, and Maharashtra (Rachie and Majmudar 1980). Bhowmik and Sundaram (1971) reported that 50-75% of the crop was infected with smut in some fields, with damage up to 100% in individual panicles. In recent years the disease has become more important in northern India, particularly in the states of Haryana, Punjab, Gujarat, and Rajasthan. The increased severity of this disease is attributed mainly to commercial cultivation of F_1 hybrids. The disease is considered important in some parts of Africa, particularly in countries of West Africa. In order to sustain the high grain yield potential of F_1 hybrids and varieties, the use of an effective and economical method for controlling this disease becomes important. The objective of this bulletin is to provide research and extension workers with basic information on pearl millet smut disease and to outline currently available control measures.

Geographical Distribution

Smut disease has been reported in Burkina Faso, Cameroon, Gambia, Ghana, India, Malawi, Mozambique, Niger, Nigeria, Pakistan, Senegal, Sierra Leone, Sudan, the USA, Zambia, and Zimbabwe (Peregrine and Siddiqui 1972; Rachie and Majmudar 1980; Rothwell 1983) (Fig.1),

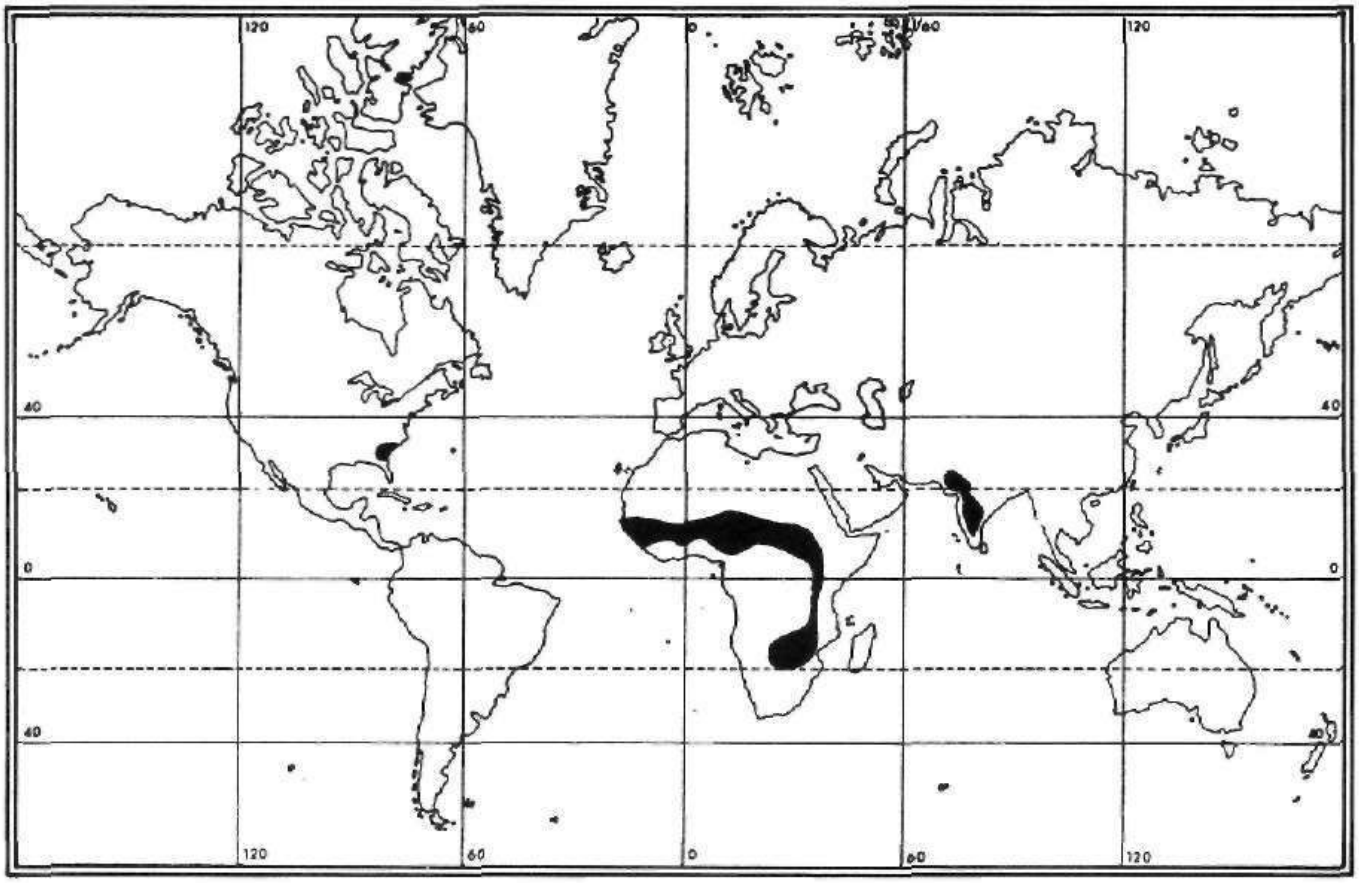


Figure 1. Geographical distribution of smut disease (T. *penicillariae)* of pearl millet.

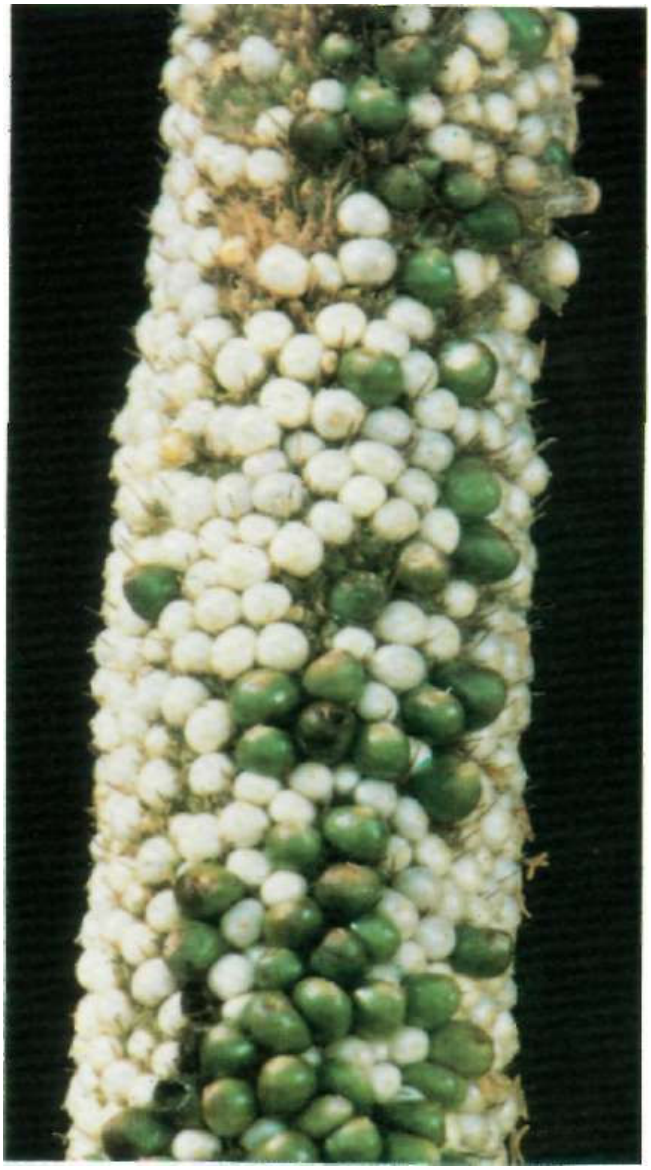


Figure 2. Shiny green smut sori on an infected panicle of pearl millet.

Figure 3. Matured, dark brown smutsorion an infected panicle of pearl millet.

and it is probably present in most countries where pearl millet is grown.

Disease Symptoms

In the infected florets, ovaries are converted into structures called sori (singular sorus). The sori are larger than grains and appear as enlarged, oval to conical bodies projecting somewhat beyond the glumes in place of grains. Initially the sori are bright green (Fig. 2), but later they turn brown to black (Fig. 3). The sori are usually 3-4 mm long and 2-3 mm broad at the top; they are covered by a thin membrane which often breaks at maturity to release brown to black sporeballs. Infection may involve a light scattering of sori among grain on panicles, up to complete coverage of panicles by sori. In panicles having poor head exsertion, the lower portion covered by the sheath of the flag leaf is frequently heavily infected with smut.

Causal Organism

The accepted name of the causal fungus is *Tolyposporium penicillariae* Bref. (Brefeld 1895). The following description of *T. penicillariae* has been taken from Mundkur and Thirumalachar (1952), Ajrekar and Likhite (1933), Bhatt (1946), and Subba Rao and Thakur (1983), where the fungus was isolated from *P. glaucum.*

The teleutospores occur in compact, ball-like masses called sporeballs. Sporeballs vary in shape from circular to near-polyhedral and measure 42-325 x 50-175 *µm* in diameter. The number of teleutospores aggregated in balls varies from 200 to 1400 (Fig. 4). Individual teleutospores do not separate readily and are mostly angular to round, light brown, and measure 7-12 *µm* in diameter. Maximum germination of teleutospores occurs at 30°C. The promycelium is four-celled and forms both lateral and terminal sporidia (Fig. 5a). Variation in germination patterns of teleutospores occurs while they are held in the sporeballs and sporidia are produced on branched hyphae in chains (Fig. 5b). The fungus readily forms colonies on media containing extracts of pearl millet, maize, or sorghum grain, and also grows well on potato or carrot agar at 30-35°C (Fig. 6). Colonies growing on agar media are composed of bud-

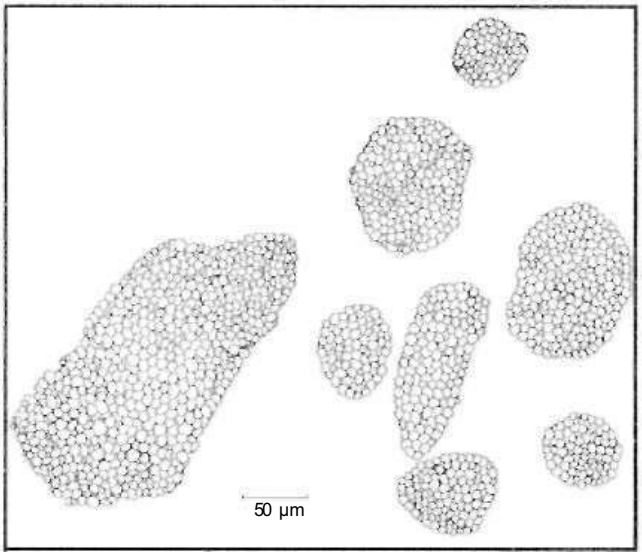


Figure 4. Variations in morphology of sporeballs of *T. penicillariae.*

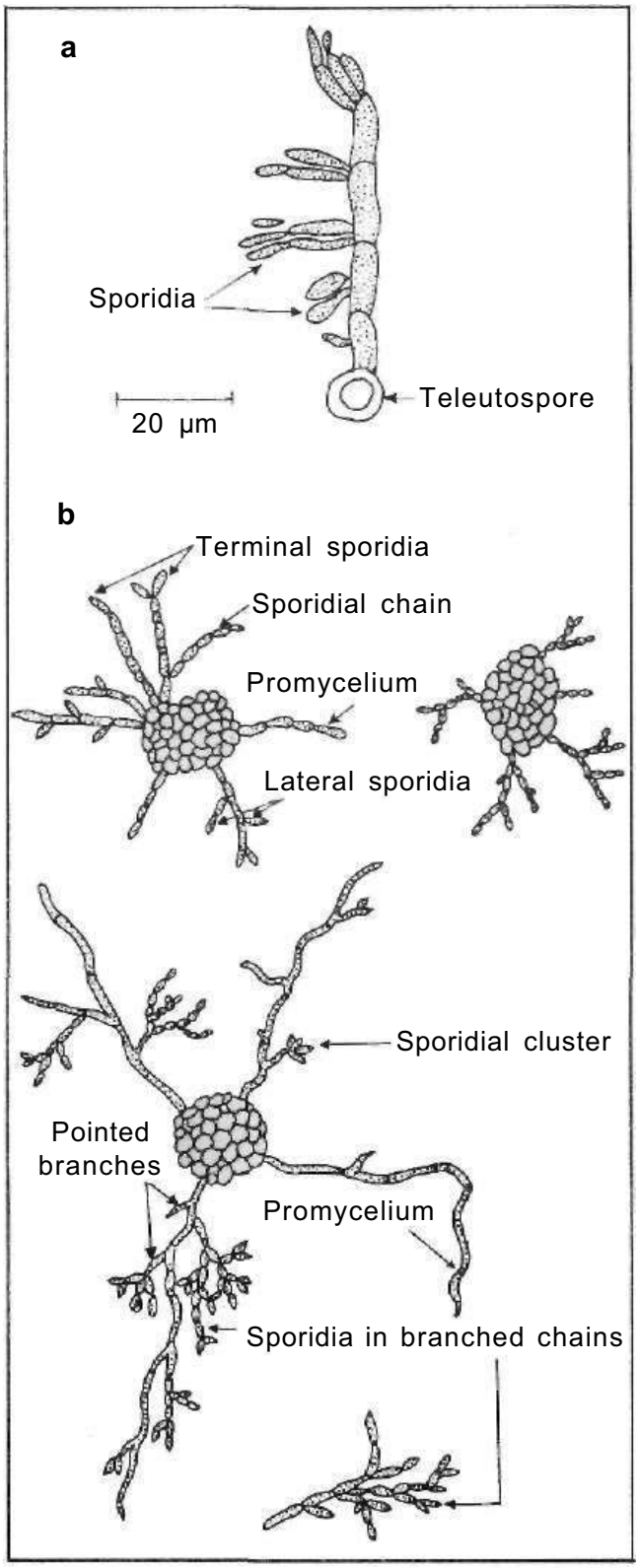
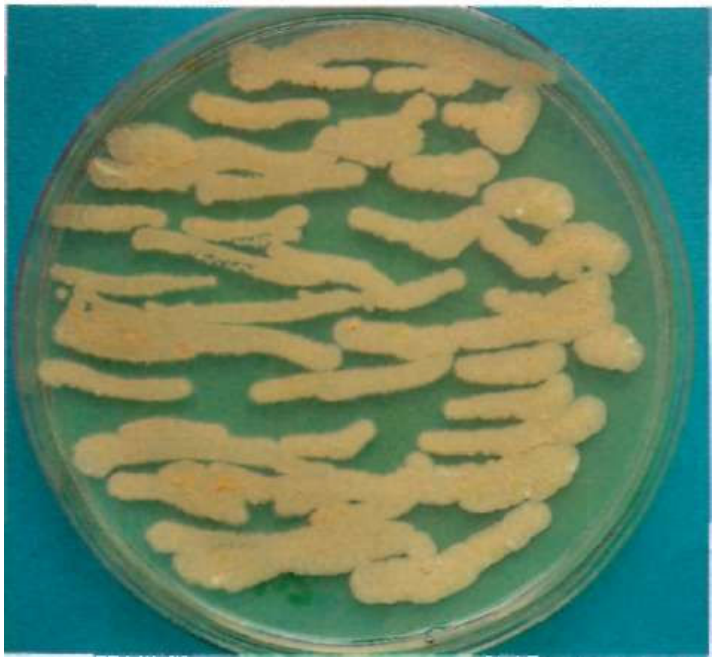


Figure 5.a. A germinating teleutospore producing four-celled promycelium and sporidia. b. Variations in germination patterns of teleutospores while they are held in sporeballs. (Note production of sporidia in chains on branched mycelia).



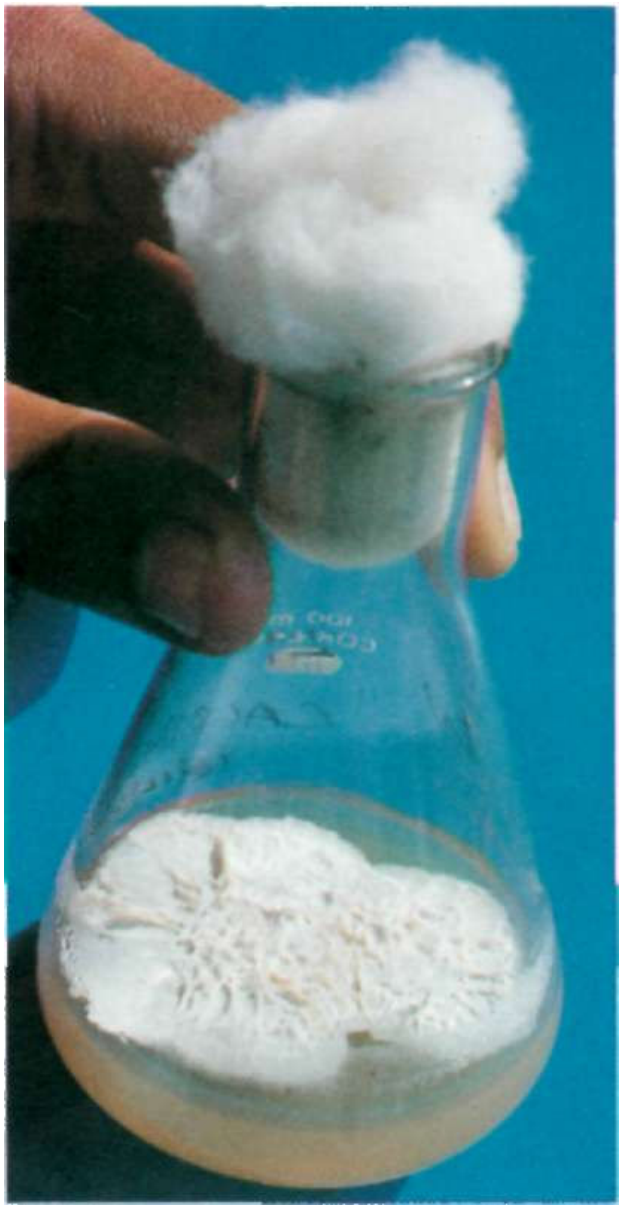


Figure 6. *T*. penicillariaegrowing on potato agar in a petri dish (top) and on carrot agar in a flask (right).

ding sporidia that are spindle-shaped, single-celled, and hyaline, and vary in length from 8 to 25 µm. Frequency of germination of teleutospores is low, and isolated, single teleutospores are seldom seen to germinate.

Disease Cycle

The primary inoculum source is sporeballs in the soil from the previous infected crop and surface contaminated seed used for sowing. Teleutospores germinate following rain showers and produce numerous airborne sporidia that infect the pearl millet crop at flowering. Two sporidia of compatible mating types are believed to be needed to form a dikaryotic infection hypha. Infection is believed to occur through young emerging stigmas and is prevented or reduced by rapid pollination (Bhatt 1946; Thakur et al. 1983a).

The latent period (time from inoculation to spore production) is about 2 weeks and sori mature within 3-4 weeks. Matured sori rupture to release masses of sporeballs which, under favorable weather conditions, germinate to produce a second crop of sporidia. These sporidia can infect late-planted crops in nearby fields or panicles of late tillers in the same field, and the cycle is repeated (Fig. 7).

T. penicillariae is not internally seedborne (Bhat 1946; R.P. Thakur and K.V. Subba Rao, ICRISAT, personal communication 1987), but external contamination of seed with sporeballs from ruptured sori in the field and on the threshing floor is common (Fig. 8). Teleutospores remain viable in soil at depths up to 22.5 cm for about 1 year (ICAR 1961, pp. 3-51).

Disease Management

Although no effective and practical cultural or *chemical* control measures are available, there are several reports of chemical control having varying success. Use of resistant cultivars is, of course, the most effective and economical way to combat the disease.

Chemical Control

Various nonsystemic fungicides, including Ceresan®, Agrosan®, zineb, and mancozeb, the systemic fungicides Plantvax®, Vitavax®, and Benlate®, and antibiotics heptaene and aureofungin have been tried either as seed, foliage, or panicle-spray treatments with limited

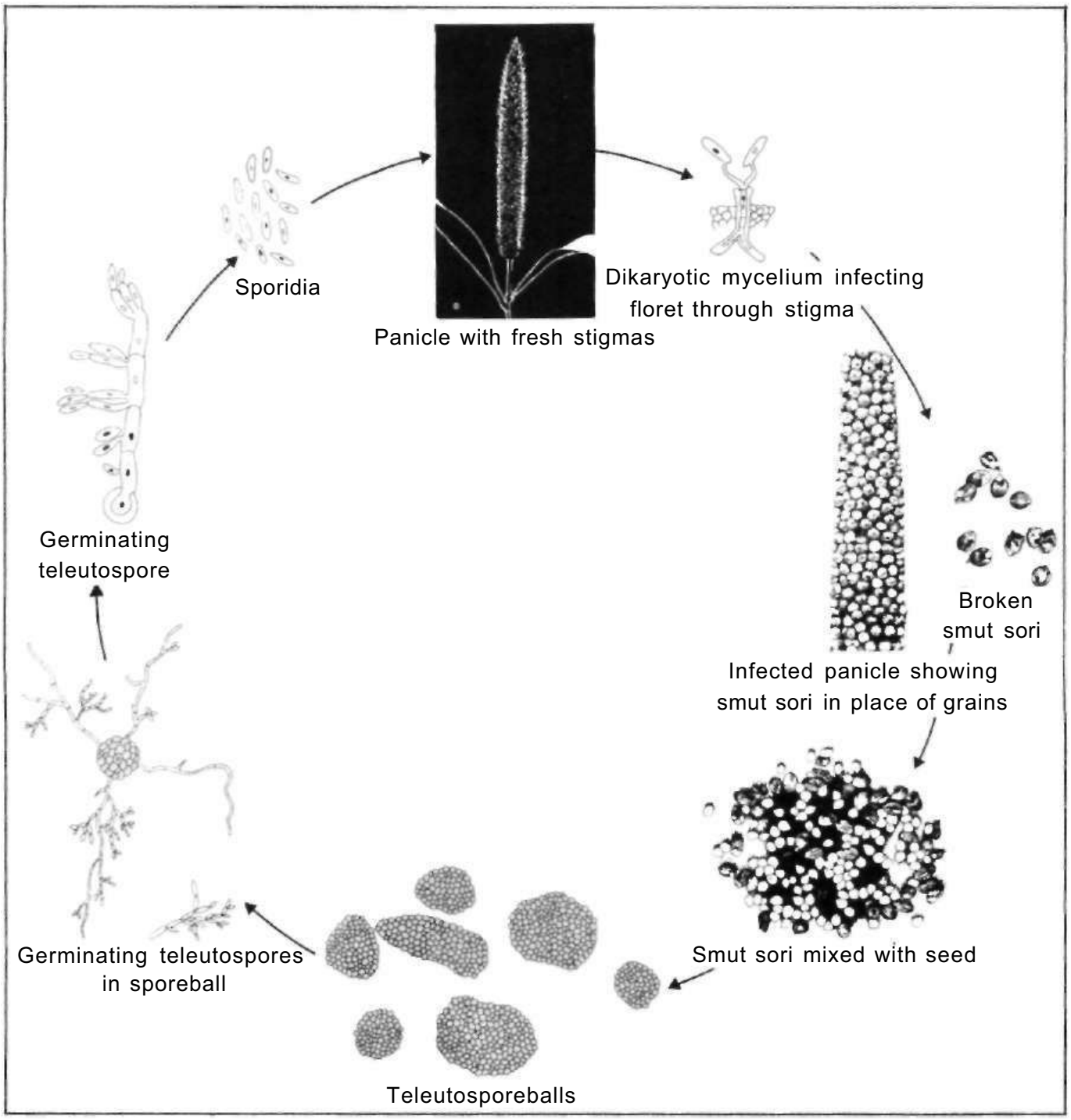


Figure 7. Disease cycle of smut of pearl millet caused by *T. penicillariae.*

Figure 8. Contamination of pearl millet seed with sporeballs from ruptured smut sori.

success, even under low disease pressure (Rachie and Majmudar 1980). Wells (1967) reported effective control of smut by foliar and panicle sprays with Plantvax® and Vitavax®. Bhowmik and Sundaram (1971) reported more effective control of smut with Plantvax® than with Vitavax® and Benlate®. Four sprays with captatol, zineb, and heptaene were also reported to be effective in controlling smut in pearl millet (Pathak and Gaur 1975). Since infection occurs from airborne sporidia at or close to the time of flowering, seed-dressing fungicides are not effective.

Chemical control measures are neither economical nor feasible at the farmers' level. The major limitations to chemical control of smut in pearl millet are low monetary value of the crop, and a widespread scarcity of resources available to pearl millet farmers in the semi-arid tropics.

Control through Resistance

Background

Growing disease-resistant cultivars is the most economical and feasible method of disease control. Breeding of disease-resistant cultivars involves identification of stable sources of resistance and utilization of this resistance. Resistance is identified by screening large numbers of germplasm accessions from the

world collection and breeding lines using an effective field-based screening technique. Stability of resistance is determined through multilocational testing for several years. Resistant sources can then be utilized in breeding programs to produce disease-resistant cultivars which are also high yielding. In India, screening for smut resistance was initiated in the early 1960s, but no lines with consistently high levels of resistance were identified. However, work with the world collection of *Pennisetum* spp, suggests that accessions from Mali, Nigeria, Senegal, and Zimbabwe have some degree of smut resistance (Murty et al. 1967).

A systematic effort to develop a field-based screening technique was initiated at ICRISAT Center in 1977 (ICRISAT 1978-79). An effective resistance-screening technique was developed (Thakur et al. 1983b) and is used on a 2-ha smut nursery every year in the rainy season to screen genetic resource accessions and breeding lines.

Resistance-screening technique

Inoculum:

The most appropriate stage of inoculation is at 'boot'. Inoculations made after panicle emergence result in reduced infection (Thakur et al. 1983b).

An aqueous suspension of sporidia (ca 10^6 sporidia mL^{-1}) is obtained from a 7-day growth of *T. penicillariae,* incubated at 30-35°C on potato or carrot agar. A sporidial suspension can also be obtained by soaking sporeballs overnight in water (Fig. 9). The suspension is filtered through a double-layered muslin cloth before being used for inoculation.

Inoculation and evaluation:

1. Inoculate panicles by injecting 5-7 ml_ of sporidial suspension into the 'boot' to fill the space between flag-leaf sheath and panicle (Fig. 10a) and then cover each panicle with a parchment paper selfing bag (Fig. 10b).
2. Sprinkler-irrigate (Fig. 11) 2-3 times daily (30 min each time) to maintain high humidity during the period from inoculation to symptom expression.
3. Open the bags 15-20 days after inoculation. Green smut sori in place of grains are seen in the infected florets (Fig.12).

Figure 9. *T.penicillariaesporeballs* soaked in water for 16-24 h to encourage sporidial production; sporidia can be used as inoculum after filtration.

Figure 10a. Inoculation of boot with aqueous sporidial suspension of *T. penicillariae.*

Figure 10b. Covering the boot with parchment paper selfing bag immediately after inoculation.

Figure 11. Operation of overhead sprinkler irrigation (see overhead jet) to provide high relative humidity.

Figure 12. Green smut sori in place of grains in infected florets of a panicle about 15 days after inoculation.

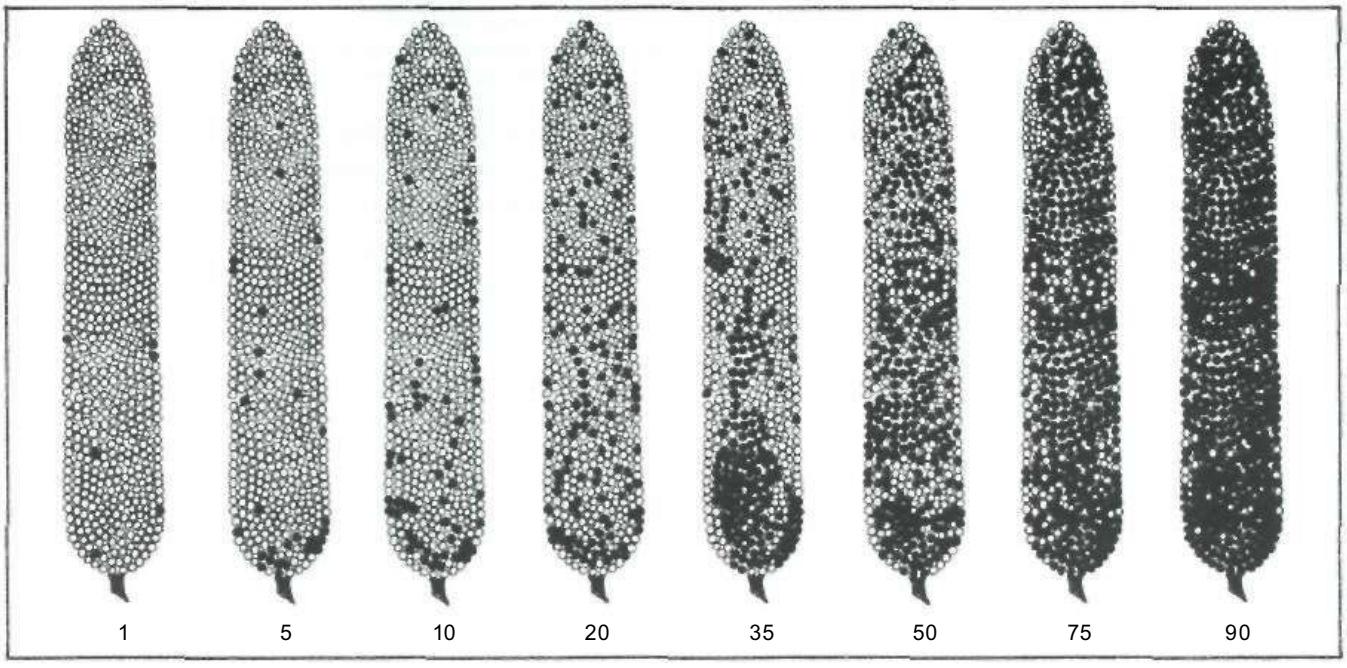
4. Score the inoculated panicles 25-30 days after inoculation using the standard smut severity scales (Fig. 13) to estimate the percentage of florets with smut sori.
5. Select individual panicles that have little or no smut and good selfed-seed set for further evaluation.

This screening technique is being used at several locations in India and West Africa. Under some environmental conditions, as in Samaru (Nigeria), Bengou (Niger), and Hisar (India), simply bagging heads before emergence increases the level of smut incidence, but more reliable results are obtained using the above inoculation procedure.

Identification of resistance

More than 6000 breeding lines and germplasm accessions from several countries have been screened by ICRISAT at Patancheru and Hisar. Many lines with high levels of resistance (<10% of florets infected) have been identified and their stability of resistance determined (Thakur

Figure 13. Smut severity rating scale used to score percentage of smut-infected florets in a panicle.



et al. 1986) through a multilocational testing program, the International Pearl Millet Smut Nursery (IPMSN). The nursery has been operated annually since 1977 at several locations in India and West Africa. Six genetic resource accessions have shown stable smut reactions for 3-7 years (Table 1) and these have been recommended for use in resistance-breeding programs. Several of the lines showed some degree of resistance under smut pressure in southern Africa (W.A.J. de Milliano, ICRISAT, personal communication). As a rule, lines that are found to be smut resistant at Patancheru, India, are also smut-resistant at Bengou, Niger. There is no data available to demonstrate the resistance of physiologic races in *T. Penicillariae.*

The scheme to identify, develop, and use smut resistance is outlined in Figure 14. In order to select smut-resistant lines with good agronomic traits, smut-resistant inbred lines were intermated and progenies screened and selected under high disease pressure in the smut nursery from F_2 to F_4/F_5 generations. Agronomically elite, smut-resistant lines were also screened for resistance to downy mildew (*Sclerospora graminicola*) in the downy mildew nursery at ICRISAT Center, and lines with combined resistance to smut and downy mildew were identified (Table 2). Smut-resistant lines are available trom ICRISAT on request.

Use of resistance sources in breeding

Smut-resistant lines are being successfully used at ICRISAT Center to breed smut-resistant composites, varieties, and hybrids (Andrews et al. 1985). From a smut-resistant composite made in 1979 using smut-resistant inbreds, several high-yielding varieties have been developed. One of these, ICMV 82132, has yielded more than the standard variety ICMV 1 (WC-C75) in the 1984 International Pearl Millet Adaptation Trial (IPMAT) across 11 locations in India (ICRISAT 1984). Other composites have also been improved for smut resistance at ICRISAT Center. Similarly, one of the synthetics, ICMS 8283, made using smut-resistant inbreds, has also yielded more than ICMV 1 (WC-C75) in the 1984 IPMAT. Both of these varieties, in addition to having high smut resistance, have high levels of resistance to downy mildew (Table 3).

Table 1. Agronomic traits of six stable, smut-resistant lines released by ICRISAT Center.

ICRISAT designation (pedigree)	Origin	Mean smut severity (%)1	Time to 50% flowering (days)[2]	Plant height (cm)[2]	Panicle length (cm)[2]	1000-grain mass (g)[2]
ICML 5 (SSC FS 252-S-4)	Uganda	<1	50	130-150	20-25	9.0
ICML 6 (ICI 7517-S-1)	Patancheru	<1	53	65-100	25-30	6.0
ICML 7(EBS 46-1-2-S-2)	Nigeria	<1	44	135-145	20-24	9.8
ICML 8(EB112-1-S-1-1)	Nigeria	<1	53	140-160	20-24	8.1
ICML 9 (NEP 588-5690-S-8-4)	Lebanon	<1	45	150-160	25-28	7.6
ICML 10(P489-S-3)	Senegal	<1	60	150-180	22-26	8.3
Control ICMV 1 (WC-C75)	Patancheru	29	46	130-140	18-22	8.3

1. Based on 4-7 years of testing at Hisar, Jamnagar, Patancheru (India), and Bambey (Senegal) through the International Pearl Millet Smut Nursery (IPMSN).
2. Based on the 1984 rainy season results at Patancheru.

Table 2. Reactions to smut and downy mildew of some of the newly-produced, agronomically-elite lines in the International Pearl Millet Smut Nursery (IPMSN) during 1983-85.

Entry	Smut severity (%					Downy mildew incidence (%)[5]
	1983[1]	1984[2]	1985[3]	1986[4]	Mean	
ICMPS 100-5-1	2	0	<1	<1	<1	2
ICMPS 200-5-5-5	2	<1	8	3	3	<1
ICMPS 700-1-5-4	1	<1	<1	<1	<1	<1
ICMPS 900-1-4-1	2	1	<1			1
ICMPS 900-3-1	3	<1	1			1
ICMPS 900-9-3	4	0	<1			4
ICMPS 1300-2-1-2	3	<1	<1			3
ICMPS 1400-1-6-2	2	<1	1			1
ICMPS 1500-7-3-2	3	0	<1			1
ICMPS 1600-2-4	3	<1	6	3	3	1
ICMPS 1800-3-1-2	1	<1	<1		<1	<1
ICMPS 2000-5-2	4	<1	<1		<1	1
Susceptible control	49	52	63	53	54	32

1. Mean of nine locations: Bambey (Senegal), Gwalior, Hisar (HAU and ICRISAT), Jamnagar, and Patancheru (India), Sadore (Niger), and Kano and Samaru (Nigeria).
2. Mean of four locations: Gwalior, Hisar, Jamnagar, and Patancheru (India).
3. Mean of three locations: Hisar, Patancheru (India), and Bengou (Niger).
4. Mean of six locations: Bambey (Senegal), Bengou and Sadore (Niger), Samaru (Nigeria), and Hisar and Patancheru (India).
5. Mean of four locations: Gwalior, Hisar, Jamnagar, and Patancheru (India) in 1983 and 1984, and two locations, Hisar and Patancheru (India) in 1985 and 1986.

Table 3. Disease reactions and grain yield of smut-resistant varieties.

Entry	Smut severity (%)1	Downy mildew incidence (%)[2]	Grain yield (kg ha^{-1})[3]
ICMV 82131	4	<1	[4]
ICMV 82132	5	2	1870
ICMV 8282	1	1	
ICMV 8283	1	1	1760
Control			
ICMV 1 (WC-C75)	13	3	1640
BJ 104	52	49	-
SE			±53
Mean			1810

1. Based on means of the International Pearl Millet Smut Nursery (IPMSN) at Gwalior, Hisar, Jamnagar, and Patancheru (India) in 1984 and Hisar, Patancheru (India), Bambey (Senegal), and Bengou (Niger) in 1985.
2. Based on means of IPMSN testing in 1984 and 1985 at locations mentioned in footnote 1, except Bengou.
3. Mean of 11 locations in India in International Pearl Millet Adaptation Trial (IPMAT), 1984.
4. Data not available.

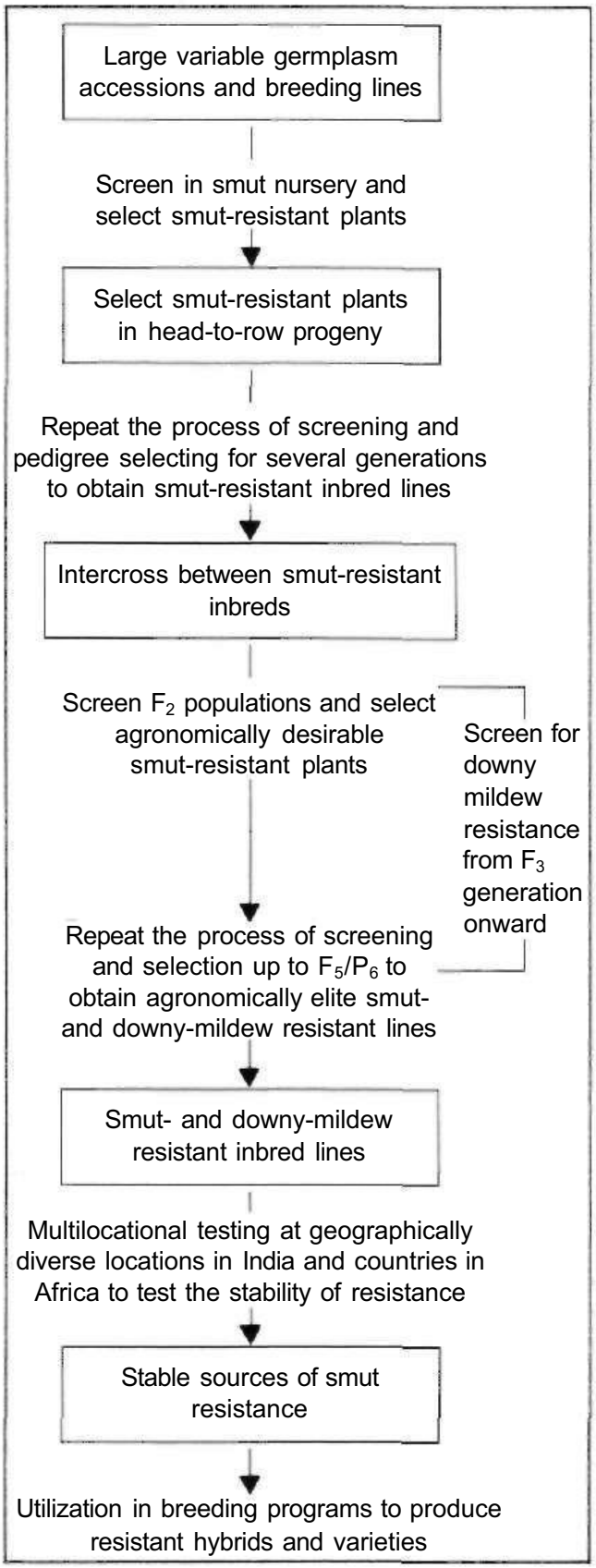


Figure 14. A generalized scheme to identify, develop, and use smut resistance in pearl millet.

Smut resistance is being used to breed smut-resistant seed parents and pollinators to produce resistant hybrids. Several smut-resistant inbred lines, which have proved to be maintainors on established male-sterile lines, are being converted into male-steriles using backcross breeding.

Practical Control Measures

Smut-resistant cultivars should be resistant to downy mildew and, if possible, to ergot, since these are also important diseases. If smut-resistant cultivars are not resistant to downy mildew, the seed can be treated with metalaxyl at 2 g a.i. kg^{-1} of seed.

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