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Pearl Millet Improvement Program
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Report of Work on Ergot and Smut
June 1981 to December 1982

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CONTENTS

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2. INTRODUCTION

This report summarises the research work done on ergot (*Claviceps fusiformis* Lov.) and smut (*Tolyposporium penicillariae* Bref.) diseases of pearl millet (*Pennisetum americanum* (L.) Leeke) from June 1981 to December 1982. For each disease the activities were divided into - Biology and epidemiology; Resistance identification, development and utilization; and devising alternative disease control methods. The major efforts, however, continued to be on resistance identification and development with more attention on utilization of resistance in cooperation with our breeding colleagues. Multilocational testing of resistant lines through the International Pearl Millet Ergot Nursery (IPMEN) and the International Pearl Millet Smut Nursery (IPMSN) was continued and reports of these were published.

With the development of an effective field screening technique for smut resistance the major smut screening work was shifted from Hissar to ICRISAT Center during the 1981 rainy season. Like ergot screening, with the provision of sprinkler irrigation, smut screening has been done successfully during the rainy and post-rainy seasons at ICRISAT Center. Hissar, however, continued to remain one of the important testing locations for IPMSN and other promising entries, and for evaluation of agronomic traits and yield potential.

During the past 6 years of multilocational testing, Aurangabad has provided consistently the maximum natural ergot pressure among the Indian test locations. We therefore, thought to evaluate some of the advanced generation ergot resistant lines, in addition to IPMEN entries. During the 1982 rainy season, in cooperation with Pathologist at Bajra Research Station, Aurangabad, about 600 F6-F8

lines were screened and useful results were obtained. We hope to continue this cooperative activity for few more years.

3. ERGOT

3.1. Summary

Biology and Epidemiology

- Of the eight grass spp. tested for the alternative hosts of the pearl millet ergot pathogen, only Cenchrus ciliaris developed symptoms, confirmed to be millet ergot by cross-inoculation tests.

- In continuation of an earlier experiment, in ergot epidemiology, the positive role of sclerotia was further demonstrated by an experiment in the screenhouse where pearl millet inflorescences were infected with ascospores from germinating sclerotia.
-Phytopathology (submitted)

Identification, development and utilization of resistance

- More than 600 germplasm accessions (S1 and S2 lines) from Tanzania, Togo, ExBornu (Nigeria) and Ghana were screened and individual plants with less ergot (<10% severity) were selected for further screening.

- About 340 entries from the AICMIP trials including hybrids, populations, ms lines and local varieties were screened during the two rainy seasons; most of these were highly susceptible (>50% severity).

-More than 300 entries from 9 ICRISAT Center breeding trials (IPMAT-7, PMHT, PMHT-P, PMHT-2, PMST, PMIST-1, ELVT, APVT and DSC Bulk) were screened; about 98% of the entries showed high susceptibility (>50% severity).

- All the IPMDMN (45) and IPMSN (30) entries were found susceptible with mean ergot severities of more than 30%.

- Selections from Pearl Millet Ergot Nursery (PMEN) entries and germplasm lines (700,000 series from Kano, Nigeria) in the 1981 and 1982 screens provided some resistant segregants and about 100 ergot-free heads were selected for further evaluation.

- Of 247 ergot inbreds and multiple disease resistant inbreds (by BST), most were highly susceptible.

- The 34-entry 1981 PMEN which consisted of advanced generation

ergot resistant lines (F6-F8) continued to show high ergot resistance. Twentysix of the 34 entries had mean ergot severities of not more than 1%, compared with 79% in the susceptible check.

- The 29-entry 1981 IPMEN was tested at 10 locations in India and 2 in Nigeria. Five entries (ICMPE-134-6-9, -134-6-11, -134-6-25, -134-6-34, -134-6-41) showed high ergot resistance (<2%) across 8 Indian locations and ICMPE 34-1-10 showed low susceptibility (<20%) in Nigeria. The 1982 IPMEN entries were evaluated at seven locations in India and one in Nigeria. Thirteen of the 29 entries showed very high levels of resistance (<1%) across locations in India and Nigeria. (Progress Reports:PM Path 67 and 78).

- Advanced generation ergot resistant lines (F7-F9) from the first set of crosses remained highly resistant. Several F8 line bulks (ICMPE and ICMPES Nos.) have shown high levels of resistance in multilocational testing.

- Crosses made between ergot low-susceptible lines (other than those involved in the first set) continued to provide resistant segregants at F5 and F6 stages and some of these have been inter-crossed to further increase the levels of resistance in the progeny lines.

- More than 700 test cross F1 hybrids, between ms lines (111-A, 5054-A, 5141-A, ICM ms 81 and 8 MAHYCO, all of which are susceptible) and 40 ergot resistant pollinators, were screened and all the hybrids were highly susceptible indicating ergot resistance is recessive.

- Several of the ergot resistant lines have been identified as maintainers on ms lines and these are being converted into ms lines through a backcross program.

- Although the ergot reactions (in the absence of pollination) of an 'A' and 'B' pair do not usually differ, results from a preliminary experiment where the equivalent hybrids were made with both the A and the B line as the female parent (and ergot resistant line as male parent), showed that the hybrid with the A line (with male sterile cytoplasm) was more susceptible than the hybrid with the male fertile line (normal cytoplasm).

- Efforts are underway to transfer ergot resistance into 'R' and 'B' lines and crosses between B x ergot resistant lines have provided ergot resistant segregants at F4 and F5 generations.

- Using ergot resistant F5-F9 lines, 5 synthetics have been constituted and these are being improved for *per se* yield performance.

- Studies on the inheritance of resistance were continued, data indicate resistance to be recessive with additive effects. Detailed analysis is underway to unravel the situation.

Alternative control measures

- Results of a demonstration trial on "ergot control in hybrid through pollen management" supported our earlier findings that the disease could significantly be reduced by strategically planting a pollen-donor line with the hybrid, which could be a practical control measure.
  - Ann.appl.Biol.1983 (in press).

3.2.Biology and Epidemiology

3.2.1.Alternative host. There are several grass species reported in the literature, to be alternative/collateral hosts of the pearl millet ergot pathogen. Recently there have been reports of two grasses, Cenchrus ciliaris from Rajasthan and Panicum antidotale from Haryana, to be heavily infected with ergot under natural conditions. Panicum antidotale has been confirmed by cross-inoculation test to be a host of the pearl millet ergot pathogen (Thakur, D.P., and Z.S. Kanwar. 1978. Indian J. Agric. Sci. 48: 540-542). During the rainy seasons (1981 and 1982) we inoculated inflorescences of eight grass species (Cenchrus ciliaris, Panicum antidotale, Panicum maximum, Paspalum notatum, Pennisetum massaicum, Pennisetum squamulatum, Pennisetum ruppelli, and Setaria sphacelata) growing in the ICRISAT Center botanical garden, with pearl millet ergot conidial suspension. Only Cenchrus ciliaris and Pennisetum americanum (Pearl Millet as the check) developed infection. Infection on C. ciliaris was confirmed to be of millet ergot in the screenhouse on pot-grown plants by cross-inoculation tests. Repeated inoculations of P. antidotale inflorescences with the pearl millet ergot pathogen either in field or screenhouse did not produce infection. In view of the published report from Hissar this needs to be

rechecked at other locations where P. antidotale exists.

3.2.2.Ascosporial infection: To confirm the results from field experiments (1978-80) on the role of sclerotia in ergot epidemiology, an experiment was planned in the screenhouse during summer 1982 where inflorescences of a male-sterile pearl millet line 5141-A, at the maximum fresh stigma stage, were exposed for 72 and 96 hr to germinating and non-germinating sclerotia in the pot-soil.

All the six inflorescences exposed for the two time periods to germinating sclerotia developed ergot within a week after exposure while the inflorescences exposed to nongerminating sclerotia did not show any ergot (Table 3.2.2). The result thus indicates that infection must have occurred by ascospores released from germinating sclerotia. This was further confirmed by ascospores trapped on cellophane tape, greased micro-glass slides and PDA plates exposed to germinating sclerotia in the laboratory.

3.3.Resistance identification

3.3.1.Screening germplasm lines. During the post-rainy, summer and rainy seasons of 1981 and 1982, 620 germplasm lines and S1 or S2 selections from Tanzania, Togo, Ex-Bornu (Nigeria) and Ghana were screened. Of 1,290 plants screened in 129 (S1) lines from Tanzania, only 26 plants (2% plants) with less ergot susceptibility (≤10% severity) were selected for further evaluation (Table 3.3.1).

Togo and ExBornu lines were screened in the Multiple Disease (downy mildew, ergot and smut) Nursery (MDN) during March 1982. Because of dry-hot weather ergot development was not adequate and many lines showed low ergot susceptibility. Of 223 lines screened (2230 plants inoculated), 145 heads (6.5%) were selected for further evaluation. These were screened during the 1982 rainy season in ergot nursery and 57 plants (heads) were selected with low ergot. Of 123 Ghana lines (S1) screened in the MDN during the 1982 rainy season 19 plants (1.5%) were selected with low ergot (Table 3.3.1).

3.3.2.All India Coordinated trial entries: In continuation of our cooperative service to the Indian national program (AICMIP) we screened 341 pearl millet lines during the 1981 and 1982 rainy seasons. These lines included F1 hybrids, populations and varieties, ms-lines and local collections. In 1981 screening was conducted for individual diseases in the respective disease nurseries but in 1982 screenings were done in the MDN.

Results presented in Table 3.3.2 indicate that all the entries were susceptible in both years to ergot except one of the ms-lines which showed <10% ergot, probably an escape. With ergot resistant lines supplied from ICRISAT efforts are underway in the Indian program to develop ergot resistant hybrids and varieties.

3.3.3.ICRISAT Center breeding lines. More than 300 lines in 9 trials (IPMAT-7, PMHT, PMHT(P), PMHT-2, PMIST, PMST-1, ELVT, APVT and DSC bulk) were screened during the 1981 and 1982 rainy seasons. Most of the lines (98%) showed high susceptibility

(>50% severity) to ergot (Table 3.3.3). All the hybrids, synthetics and varieties were equally susceptible under individual plant inoculation.

With the development of high resistant ergot lines major efforts are underway to breed ergot resistant hybrids and synthetics.

3.3.4. Selected Lines. About 500 lines which were selected from the 1980 and 1981 screens and entries from IPMDMN were screened. The results are summari sed in Table 3.3.4.

All 45 IPMDMN entries showed >30% ergot severity. In PMEN selections several entries showed less ergot and 70 ergot-free heads were selected for further evaluation. Among the other selections, only selections from germplasm lines (700,000 series) provided some ergot resistant segregants and 43 ergot free heads were selected.

Of 247 ergot inbreds and multiple disease resistant inbreds (MDI) most were highly susceptible and few inoculated heads which, though developed less ergot, could not be selected because of poor seed set under selfing.

3.3.5. Pearl Millet Ergot Nursery (PMEN) 1981. The 34-entry trial consisting of advanced generation ergot resistant lines was evaluated in 2 replications. Two rows (4m) per entry per replication were grown and 10 plants were inoculated per row. Data were recorded on days to 75% flowering, and mean and range of ergot severity. Twentysix of the 34 entries had mean ergot severities of not more than 1% and not more than 5% on any of the

40 inoculated heads/entry. The other eight entries had mean severities between 1 and 5% with severity range of 0-35% on individual heads, while the check BJ-104 had the mean severity of 79% with range of 50 to 98% (Table 3.3.5).

Days to 75% flowering in test entries varied between 44 (ICMPE 134-6-6) to 69 (ICMPE 13-6-25) whereas it was 42 days in BJ-104. Nine entries which looked good agronomically were selected for further evaluation.

3.3.6. International Pearl Millet Ergot Nursery (IPMEN).

The 1981 IPMEN. The 29-entry IPMEN was evaluated at 10 locations in India and 2 in Nigeria. Although no entry was ergot free at all the locations, five entries developed at ICRISAT Center (ICMPE F7 lines, 134-6-9, -134-6-11, -134-6-41, -134-6-34 and -134-6-25) were highly resistant at all Indian locations with across locations mean ergot severities of not more than 2%. Another eight entries had across location mean ergot severities of not more than 10% compared with 41% on the susceptible check. A report on this has already been published (Progress Report PM Path. 67).

The 1982 IPMEN. The 29-entry IPMEN was tested at 7 locations in India and 1 in Nigeria. Although no entry was ergot free at all the locations 13 entries were highly resistant with across locations mean severities of not more than 1% and the maximum severity of not more than 5% at any location. Several entries showed high ergot resistance even at Samaru. Some of the promising entries were ICMPE 134-6-9, ICMPES-2, ICMPE 134-6-34, ICMPE 134-6-25, ICMPE 247-6, ICMPE 134-6-6, ICMPE 134-6-41,

ICMPES-27 and ICMPE 134-6-11. Some of the common entries which showed high ergot resistance in 1981 and 1982 are presented in Table 3.3.6. A report on the 1982 IPMEN has already been published (Progress Report: PM Path.78).

3.4.Resistance development:

3.4.1.Resistance development I. The first set of crosses, made in 1977 involving 20 ergot-low-susceptible lines, were screened and ergot resistant pedigree-selected each generation provided many lines with high levels of ergot resistance at F6 generation. Of 53 crosses, only two crosses (J2238 x J2210-2 and J606-2 x J703-1) have provided most of the surviving resistant lines. During the 1981 rainy season 538 F8 lines were screened and 97% of the lines showed high levels of ergot resistance (≤10% severity). The results are summarised in Table 3.4.1a.

From F6 generation and beyond, line-bulks were made of resistant progenies and at F8 most of the progenies were in line-bulks. About 150 line-bulks (sibbed and selfed) were evaluated for ergot reactions at ICRISAT Center and Aurangabad during the 1982 rainy season. Sixtysix and 86% of the lines showed high ergot resistance (≤ 5% severity) at ICRISAT Center and Aurangabad, respectively (Table 3.4.1b). Attempts have been made to combine phenotypically similar sister lines with stable high levels of resistance by sib-mating and these lines are designated as ICMPES Nos. Some of these have been and will be grown in isolation plots to increase the seed for distribution. Combining similar lines at F8 generation has helped us reduce the

number of ergot resistant progenies to a manageable level.

Several crosses were made between F3 x F5 involving different ergot-low- susceptible parents to diversify the genetic base in the resistant progenies.

Some of the F8 lines have been identified as maintainers on ms-lines 5141A, 5054A and ICM ms 81 by breeders and these are being used in the backcross program to develop ergot resistant seed parent.

Several of the advanced generation (F6-F8) lines and ICMPES lines were evaluated in the multilocational testing through IPMEN and have shown very high levels of ergot resistance across locations in India.

3.4.2.Resistance development II. Seventyone F1s generated involving six ergot low susceptible lines (700708-1-E-2, 700526-E-1, 700626-E-1, J797-1-E-1-1, J2238-E-4-1, ExBouchi 700638-3-2-E-1-DM-1) and their selections, were screened during the 1979 rainy season. The mean ergot severities ranged from 1 to 62% (Progress Report PMP E/S 8004 Appendix XI p. 136) and 29 lines were selected for further evaluation as F2 population during the 1979-80 post-rainy season. The mean severities varied between 6 and 44% compared with 80% on ICH 105 (Progress Report PMP E/S 8004, Appendix XX p.186). Ergot resistant individual plants (226) selected from F2 pops. were screened during the 1980-81 post-rainy season as F3 lines and 200 ergot-free single heads selected from 27 F3 lines (Progress Report PM Path 61, Appendix XVIII, p.82) were screened as F4 lines during the 1981

rainy season and 310 ergot-free single heads were selected from 50 F4 lines. These were screened as F5 lines during the 1981-82 post-rainy season and 483 ergot-free single heads selected from 76 F5 lines were evaluated as F6 lines during the 1982 rainy season. Finally, 159 ergot-free heads were selected from 25 F6 lines (1 cross) for further evaluation (Tables 3.4.2a; 3.4.2b).Twelve F5 line-bulks were evaluated in a replicated trial for ergot reaction during the 1981-82 post-rainy season at ICRISAT Center. Ten of these showed $\leq$ 10% mean severity compared with 93% on the check ICH-206 (Table 3.4.2c).

3.4.3.Resistance development III. To further increase the levels of resistance, eight ergot resistant F5 lines (derivatives of crosses among 6 ergot-low-susceptible lines) were intermated during summer 1980, progenies screened, and resistant plants selected at each generation upto F4. Ergot reactions of parents and progenies are summarised in Tables 3.4.3a and 3.4.3b. During the 1982 rainy season 685 F4 progeny-lines were screened and 77% of these showed high levels of ergot resistance ($\leq$10% severity).

Data presented in Table 3.4.3a indicate that F1s from crosses between resistant parents showed more ergot than the parents, F2 plants showed still higher ergot levels but with many individual ergot resistant segregants. From 8 F2 populations (500 plants inoculated in each), 181 ergot-free heads (4.5%) were selected for evaluation as F3 lines. At F3, 40 plants were inoculated in each F3 line and 685 ergot-free heads (9.5%) were selected for evaluation as F4 lines. These results clearly indicate the very low frequency of resistance genes that are

available in these lines.

Sixteen F4 line-bulks were evaluated during the 1981-82 post-rainy season. The mean ergot severities ranged from 1 to 8% compared with 88% on BJ-104 (Table 3.4.3c).

3.4.4.Resistance development IV. Five crosses made between new ergot-low-susceptible F5 lines were evaluated as F2 populations during the 1981 rainy season. A total of 167 ergot resistant (<5% severity) single heads were selected and screened as F3 lines during 1981-82 post-rainy season. Many of F3 lines showed high levels of ergot resistance (<10% severity) coupled with good agronomic traits (Table 3.4.4a). Fortyone lines which showed high levels of ergot resistance had agronomic scores of 5 or less [on a 1(best)-9(worst) scale] and the plant height varied between 180 and 220 cm. From these 41 F3 lines 199 single plants were selected for further evaluation. The details of ergot reactions of parents, F2 and F3 progenies, and selections are provided in Table 3.4.4b.

3.4.5.Ergot resistant sib-bulks. During the 1982 summer, more than 300 F5, F7 and F8 lines were grown in the downy mildew nursery. Phenotically similar sister lines were sib-mated to generate 32 sib-bulks. Pollen collected from 10-15 good-looking plants was mixed together to pollinate 2-3 plants in each line. Equal quantity seed from the same number of pollinated plants from each line were bulked to constitute a sib-bulk. Number of sister lines involved in each sib-bulk varied from 2 to 11. These 32 lines designated as ICMPES were evaluated for ergot reactions at

ICRISAT Center and Aurangabad during the 1982 rainy season. Ten of these were also evaluated for their yield potential at Hissar and ICRISAT Center in a replicated trial.

Twenty-two lines which were evaluated only for ergot reactions at ICRISAT Center and Aurangabad were all highly resistant at Aurangabad with mean severities varying between <1 and 4% and all except 4 entries (which had mean severities between 18 and 47%) were resistant at ICRISAT Center also (Table 3.4.5a). The three checks WC-C75, ICMS 7703 and BK-560 developed ergot severities of 64, 72 and 90%, respectively.

Eight of the 10 ICMPES lines showed high levels of ergot resistance (≤ 5% severity) both at ICRISAT Center and Aurangabad. However, the yield potential of the lines were not comparable to those of WC-C75 and BK-560. One of the lines, ICMPES-3 which had the highest yield of 1.8 kg/plot was 63% of BK-560 and 75% of WC-C75 at Hissar under ergot-free situation. At ICRISAT Center under very high ergot pressure, the highest yielding entry (ICMPES 28) was 106% of BK-560 and 94% of WC-C75. Under heavy ergot pressure (95% severity on BK-560) it is apparent that ergot resistant lines can yield as well as hybrids (Table 3.4.5b).

Comparison of yields of BK-560 with the average yield of the ergot resistant entries under two conditions (ergot free at Hissar and high ergot-pressure at ICRISAT Center) indicates 61% grain-yield loss due to ergot. This assumes that yield potential of BK-560 is the same relative to the ergot resistant entries at the two locations.

3.5.Resistance utilization

3.5.1.Ergot resistant pollinators. Using 30 ergot-low susceptible (ELS) F5 lines as pollinators on 3 ms lines (111-A, 5054-A, and 5141-A), 642 F1 test hybrids were generated (by BST) during the summer 1980. These were screened during the 1980 rainy season and all the hybrids showed high ergot susceptibility (>50% severity). By 1980 rainy season several ergot resistant lines were identified where the period of protogyny within a head was reduced from the normal 3 days to 1 day or even less. Our breeders identified four lines in the cross [111A x (111Bx3/4 souna-39-2-2)] which had short protogyny (about 2 days). To test whether hybrids made with parents exhibiting short protogyny, differed in ergot resistance these four lines were used as female parents with ergot resistant lines as pollinators and 34 F1 test hybrids were generated during summer 1981. These hybrids were screened in the 1981 rainy season and all the 34 hybrids were found highly susceptible (>50% ergot severity)(Table 3.5.1) indicating that short protogyny in one or both parents of a hybrid does not appear to contribute to ergot low susceptibility.

Maharashtra Hybrid Seed Co.(MAHYCO) produced 37 hybrids using our ergot resistant lines as pollinators on 8 of their ms-lines, and again all were highly susceptible (Table 3.5.1).

In 1982 summer our breeders made hybrids between ergot resistant lines (both parents) and ELS lines (seed parent) with ergot resistant lines as pollinators. These hybrids were evaluated during the 1982 rainy season. All 49 hybrids between ergot resistant lines were highly resistant while the other 55

hybrids between ELS (SC-2(M)5-4-Sels) and ergot resistant lines showed variable reactions, with 26% of these showing more than 20% ergot severity (Table 3.5.1). These results show that to obtain ergot resistant F1 hybrids both parents should have resistance.

3.5.2. Breeding ergot resistant seed parents. By 1978 Rabi ELS F3 lines were developed and 25 lines with desirable agronomic traits were identified by our breeders. In February 1979 'action-plan' was prepared to utilise these ELS lines in a breeding program particularly to produce ergot resistant hybrids.

Some of the ELS lines at F4 were crossed to 5054B and 5141B and 14 F1 crosses were generated during the 1979 rainy season. F2 populations were screened during the Rabi 1981 and ergot resistant individual heads were selected. The process was repeated at each generation upto F5 (1982 rainy season), where only 37 heads from original 8 crosses were selected (Tables 3.5.2a; 3.5.2b). The frequency of ergot resistant plants selected varied from 1.3% in F2 to 9.4% in F4 and 7.5% in F5. At each generation 10 random plants were crossed to 'A' lines to test their maintaining ability. Once high levels of ergot resistance with stable reactions are obtained these will be converted into seed parent by backcrossing using ER 'B' lines as recurrent parent.

The other set of crosses were made using two of the ergot resistant F7 lines (ICMPE 134-6-9 and ICMPE 134-6-18) on 5141B, 5054B, 111B and 81B during the 1981 summer season and 22 F1s were generated. F2 pops. were screened during the 1981-82 post-rainy

season and ergot resistant plants were selected for screening as F3 lines during the 1982 rainy season. Frequency of selection of ergot resistant plants varied from 2.9% in F2 to 12.1% in F3 (Tables 3.5.2a; 3.5.2c). Sixtyseven ergot resistant plants have been selected for further evaluation.

3.5.3. Identification of ergot resistant maintainers. Several of the ergot resistant F7 and F8 lines were identified as maintainers on 111A, 5141A, 5054A and ICM ms81. Some of these are in the process of being converted into ms-line through back-crossing. Most of the maintainers have been selected from ICMPE 134-6-9, ICMPE 134-6-18, ICMPE 13-6-8, ICMPE 13-6-9 and ICMPE 13-6-28 (Table 3.5.3).

3.5.4. Attempt to transfer ergot resistance in 'R' and 'B' lines. During the summer 1982 crosses were made (by BST) between ICP-220 (pollinator) and ER-110-2 (ergot resistant R line) and between 5054B x ER 126-1 (ergot resistant B line) and the resulting F1s and parents were evaluated in the 1982 rainy season ergot nursery.

Three of the four F1s between RxER or BxER developed much less ergot (mean severity 25 to 45%) compared with their susceptible parents, the R and B lines, which had the severities of 88 and 68%, respectively (Table 3.5.4). This provides an assumption that the transfer of ergot resistance may be easier in some parental lines than others. Backcrosses will be attempted to transfer ergot resistance from ergot B and ergot R lines to 5054B and ICP 220, respectively.

3.5.5. Effect of cytoplasm on ergot susceptibility. To determine the effects of cytoplasm on ergot susceptibility/resistance, a ms line 5054-A, (with sterile cytoplasm), its maintainer 5054B (both ergot susceptible) were both crossed with (i) an ergot resistant line ER 110-2 and (ii) a normal (ergot susceptible) pollen parent (R line) ICP 220. Both these act as restorers on 5054A. The combinations were additionally made using the restorers as females and 5054B as the male. The hybrids and the parents were evaluated during the 1982 rainy season.

Results presented in Table 3.5.5 indicate that F1s between AxER and AxR (in sterile cytoplasm) were more susceptible (mean ergot severities between 76 and 82%) than F1s between BxER or ERxB and BxR or RxB (all in fertile cytoplasm- mean severities between 48 and 70%). The F1s between ER lines were, however, resistant (mean severities <1-3%). The results although preliminary, suggest that sterile cytoplasm might be a cause of increased susceptibility in commercial F1 hybrids. We need to make more detailed investigations to substantiate this effect.

3.5.6. Development of ergot resistant synthetics. Using 12 ergot resistant F5 progenies from two crosses (J2238 x J2210-2; J606-2 x J703-1) 3 synthetics ICMS 8031, ICMS 8032, and ICMS 8034 were constituted (by SBC) during the summer 1980. These were evaluated for ergot reactions in the ergot nursery and for yield (by SBC) at three locations (PHF, PLF and Bhavanisagar) during the 1980 rainy season.

All the three synthetics had mean ergot severities in the range of 12 to 15% compared with 24% on WC-C75 and 54% on BJ-104

under open-spray inoculation (Table 3.5.6). One of the three synthetics ICMS 8034 produced grain yields 5% more than WC-C75 and 10% more than BJ-104 across 3 locations.

In 1981, another synthetics ICMS 8102 was constituted involving 2 ergot resistant lines and 3 agronomic elite (ergot susceptible) inbreds with a view to increase the yield level of the synthetic while maintaining ergot resistance. But this synthetic developed 49% ergot severity in the 1981 rainy season ergot nursery.

Efforts are now being made to produce synthetics using highly ergot resistant F8 lines with desirable agronomic traits.

3.5.7. Observations of hybrids and varieties for ergot susceptibility. The degree of ergot incidence and severity under natural conditions depends on the weather conditions during flowering period of a pearl millet crop. On an isolation plot basis, hybrid crops have been observed to succumb to ergot infection more than open- pollinated varieties where pollen is available earlier and for much longer time than in hybrids. During the 1981 rainy season we recorded ergot incidence and severities in the three F1 hybrids and two varieties at two locations on the ICRISAT farm. Hybrids developed more ergot (both incidence and severities) than varieties (Table 3.5.7). Although both hybrids and varieties would had similar amounts of pollen interference in these trials, the hybrids showed more ergot than varieties.

3.6. Alternative control measure

3.6.1. Control of ergot through pollen management. In continuation with the experiments for 3 yr in isolation plots, in the 1982 rainy season a demonstration experiment was planted in the ergot nursery without maintaining any isolation distance. Two treatments, hybrid ICH-206 alone and 4 rows of ICH-206 alternated with 1 row of the pollen-donor line SC-2(M)5-4, with 2 replications were tested. Plot size was 16 rows x 10 m with rows spaced at 75 cm and plants within row at 20 cm. Ergot inoculations were made with honeydew conidial suspension using knapsack power sprayer, four times, every alternate day beginning at 50% flowering in the hybrid. All the four plots were inoculated and overhead sprinkler irrigation was provided to maintain high humidity.

Ergot scoring was done for incidence (%) and severity (%) for each of the 16 rows/plot. Grain yields, 1000-grain weight, yield/plot were also measured.

Ergot incidence (%) and severity (%) in the hybrid grown with the pollen-donor line were significantly less than the hybrid grown alone (Table 3.6.1). A significant increase in 1000-grain weight and yield/plot were also recorded in the hybrid grown with the pollen-donor line over the hybrid-alone plot.

The results thus confirmed our earlier findings of the isolation plot experiments and indicate that the pollen management system can effectively be employed to control ergot in farmers' fields.

Table 3.2.2. Ergot severity (%) in pearl millet male-sterile line 5141-A following exposure of the inflorescences to germinating or non-germinating sclerotia of Claviceps fusiformis for 72 and 96 hours

Inflorescence No.	Time (hr) exposed to germinating sclerotia[a]		Time (hr) exposed to non-germinating sclerotia[a]	
	72	96	72	96
1	30	40	0	0
2	10	40	0	0
3	5	10	0	0
4	5	20	0	0
5	20	10	0	0
6	5	60	0	0

[a] Same sets of germinating or non-germinating sclerotia in the pot soil were used for both exposures.

Table 3.3.1. Screening of germplasm lines for ergot resistance during 1981-82 at ICRISAT Center

Year & Season	Origin	No. of lines	Percentage of lines in sev.[a] class				No. of heads selected
			<10%	11-20%	21-50%	>50%	
1981-82 post-rainy	Tanzania	129 (S_1)	0	0	6	94	26
1982 summer	Togo	178 (S_1)	17	27	50	6	127
1982 Summer	Ex-Bornu	45 (S_1)	22	25	53	0	18
1982 rainy	Togo	127 (S_2)	4	1	27	68	41
1982 rainy	Ex-Bornu	18 (S_2)	11	6	44	39	16
1982 rainy	Ghana	123 (S_1)	2	3	51	44	19

[a] Based on 10-20 inoculated inflorescences/line.

Table 3.3.2. Summary of ergot reactions of entries in All India Coordinated Millets Improvement Project trials at ICRISAT Center during the 1981 and 1982 rainy seasons

Trial	No. of entries		No. of entries in ergot severity[a] (%) class							
			≤10		11-20		21-50		>50	
	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982
IPMHT-I	17	21	0	0	0	0	0	0	17	21
APMHT-II	21	19	0	0	0	0	0	0	21	19
IPMPT-IV	17	15	0	0	0	0	1	1	16	14
APMPT-V	19	17	0	0	0	0	1	1	18	16
MS Lines	54	106	0	1	0	1	4	16	50	88
Others	17	18	0	0	0	0	1	2	16	16
Total	145	196	0	0	0	1	7	20	138	174
% of entries			0	0	0	<1	5	10	95	89

[a] Based on 10-20 inoculated inflorescences/entry

ble 3.3.3. Summary of ergot reactions of ICRISAT Center breeding lines in 10 trials during the 1981 and 1982 rainy seasons at ICRISAT Center

Trial	No. of entries		No. of entries in ergot sev.[a] (%) class							
			≤10		11-20		21-50		> 50	
	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982
IPMAT-7	21	-	0	-	0	-	0	-	21	-
PMHT	25	25	0	0	0	0	0	0	25	25
PMHT (P)	25	25	1	0	0	0	0	2	24	23
PMHT-2	36	-	0	-	0	-	1	-	35	-
PMST	25	25	0	0	0	0	1	1	24	24
PMIST-1	36	-	0	-	0	-	0	-	36	-
ELVT	20	-	0	-	0	-	0	-	20	-
APVT	-	24	-	0	-	0	-	1	-	23
D SC bulk	-	16	-	0	-	0	-	0	-	16

[a]Based on 10-20 inoculated inflorescences/entry

- Entries not screened.

Table 3.3.4. Summary of ergot screening of advanced generation selections made during 1980 and 1981 screens

Material	Year & Season	No. of entries	No. of entries in ergot sev.[a] (%) class				No. of ergot free heads selected
			<10	11-20	21-30	>30	
IPMDMN	1981 rainy	45	0	0	0	45	-
PMEN Sels.	1981 rainy	16	4	8	2	2	70
Ergot-Smut F_7 lines	1981 rainy	15	10	3	0	2	-
Germplasm-I	1981 rainy	57	11	10	14	22	43
Germplasm-II	1981-82 post-rainy	60	18	11	10	21	-
Ergot inbreds (BST)	1982 rainy	43	2	6	3	32	-
SC-2(M)5-4 Sels.	1982 rainy	15	0	1	3	11	-
MDI (BST)[b]	1982 rainy	247	9	13	35	190	-

[a] Ergot severity based on 10-20 inoculated inflorescences/entry.

[b] Screened in multiple disease nursery.

- Selections not made.

Table 3.3.5. Ergot reactions and days to 75 percent flowering (DTF) of 34 entry Pearl Millet Ergot Nursery (PMEN) during the 1981 rainy season

Pedigree	DTF	Ergot severity (%)	
		Mean[a]	Range
ICMPE 140-7-8	59	<1	0-1
ICMPE 247-6-2	52	<1	0-1
ICMPE 140-6-8	48	<1	0-2
ICMPE 247-8-5*	54	<1	0-1
ICMPE 13-6-15-2	59	<1	0-1
ICMPE 247-16-2	54	<1	0-1
ICMPE 13-6-1-2	57	<1	0-1
ICMPE 13-6-29-1	54	<1	0-1
ICMPE 140-6-38	49	<1	0-2
ICMPE 13-6-28-5	57	<1	0-1
ICMPE 134-6-6*	44	<1	0-1
ICMPE 13-4-29	69	<1	0-1
ICMPE 13-6-28	58	<1	0-1
ICMPE 262-4-9	50	<1	0-1
ICMPE 262-4-1	52	<1	0-1
ICMPE 261-2-5*	48	<1	0-5
ICMPE 13-6-22-1	58	<1	0-1
ICMPE 247-2-4*	54	<1	0-2
ICMPE 13-6-10-2	59	<1	0-1
ICMPE 13-6-26*	54	<1	0-2
ICMPE 13-6-25	69	1	0-2
ICMPE 13-6-29*	59	1	0-5
ICMPE 247-2-3	54	1	0-1
ICMPE 13-6-13	61	1	0-10
ICMPE 13-6-9-1	58	1	0-2
ICMPE 13-6-24*	61	1	0-2
ICMPE 134-6-31*	44	1	0-10
ICMPE 13-6-27-10*	58	1	0-20
ICMPE 13-6-23	61	1	0-5
ICMPE 134-6-38	47	1	0-10
ICMPE 140-7-12	57	1	0-20
ICMPE 13-6-27	59	2	0-25
ICMPE 248-10-1	50	3	0-35
ICMPE 248-10-2	49	5	0-25
BJ-104 Check	42	79	50-98

[a] Mean of 40 bagged-inoculated heads from 2 reps.
* 9 entries were selected for further evaluation.

Table 3.36. Percent ergot severities[a] of eight common entries in 1981 and 1982 IPMENs at three Indian and one West African locations

Entry[b]	ICRISAT Center		Jamnagar		Aurangabad		Samaru	
	1981	1982	1981	1982	1981	1982	1981	1982
ICMPE 134-6-9	<1	<1	<1	<1	8	1	46	<1
ICMPE 134-6-11	<1	1	<1	<1	8	5	43	<1
ICMPE 134-6-41	<1	1	<1	<1	9	5	35	<1
ICMPE 134-6-34	<1	1	1	<1	8	2	35	<1
ICMPE 134-6-25	<1	<1	<1	0	10	1	44	1
ICMPE 13-6-27	5	1	7	1	20	1	18	6
ICMPE 13-6-30	3	2	4	1	28	1	33	1
ICMPE 34-1-10	4	13	4	7	12	4	13	2
Susceptible check	99	98	41	58	60	97	68	83

[a] Based on 20-40 inoculated inflorescences per entry in two replications.

[b] ICMPE-ICRISAT Millet Pathology Ergot lines.

Table 3.4.1a. Progress made in developing ergot resistance in pearl millet (1978-1981) following pedigree selection in the first set of crosses[a]

Year and season	Generation	No. of lines	No. of plants screened/line	Percentage of lines in ergot severity (%) class					
				<1	1-10	11-20	21-30	31-40	>40
1978 rainy	F_2	33 pop	>200	0	0	0	6	9	85
1978-79 post-rainy	F_3	657	40	0	2	6	11	16	65
1979 rainy	F_4	472	40	0	15	20	28	22	15
1979-80 post-rainy	F_5	220	180	1	14	19	16	20	31
1980 rainy	F_6	572	80-160	14	56	18	9	2	<1
1980-81 post-rainy	F_7	373	20	7	47	21	12	8	5
1981 rainy	F_8	538	20	59	38	3	<1	<1	0

[a]crosses which provided most resistant progenies upto F_8 generation

J2238 x J2210-2
J606-2 x J703-1

Table 3.4.1b. Summary of ergot reactions of 159 F_8 line bulks (selfed and sibbed in 3 trials at two locations during the 1982 rainy season

Trials	Locations	No. of lines in ergot sev. (%) class			
		0-5	6-10	11-20	>20
46 selfed	IC	35	3	5	3
	A'bad	36	5	5	0
47 sibbed	IC	27	7	6	7
	A'bad	40	2	1	4
66 seed mix.	IC	43	6	10	7
	A'bad	61	3	1	1
Total 159	IC	105	16	21	17
	A'bad	137	10	7	5
% of lines	IC	66	10	13	11
	A'bad	86	6	4	4

IC = ICRISAT

A'bad = Aurangabad

Table 3.4.2a. Selection for increased levels of ergot resistance in the progenies of crosses[a] between ergot low-susceptible lines (1979-1982)

Year and Season	Gene-ration	No. of lines/ crosses	No. of plants screened/ lined	Percentage of lines in ergot sev. (%) class					
				<1	1-10	11-20	21-30	31-40	>40
1979 rainy	F_1	71	10	0	30	31	14	11	14
1979-80 post-rainy	F_2	29 pop.	>200	0	10	10	38	28	14
1980-81 post-rainy	F_3	226 ($16F_2$)	40	2	40	23	18	7	10
1981 rainy	F_4	200(($27F_3$)	40	36	42	13	3	3	3
1981-82 post-rainy	F_5	310 ($50F_4$)	40	10	63	13	11	3	0
1982 rainy	F_6	483 ($76F_5$)[b]	40	32	58	5	2	1	2

[a] From 26 crosses involving ergot low-susceptible individual plants from 6 lines (700708-1-E-2; 700626-E-1; 700526-E-1; J797-1-E-1; J2238-E-4-1; ExBouchi 700638-3-2-E-1-DM-2) 71 F_1s were generated. One of the 26 crosses (700708-1-E-1 x J797-1-E-1-2) provided maximum number of ergot-free plant upto F_6 generation.

[b] From 25 F_6 159 ergot-free heads were selected for further evaluation.

Table 3.4.2b. Details of crosses made and progenies screened and selected at each generation from F_1 to F_6 in 4 years (1979-1982)

Cross No.	Pedigree	No. of progenies at each generation					
		F_1	F_2	F_3	F_4	F_5	F_6
1	700708-1-E-2 x 700626-E-1	3	4	-	-	-	-
2	700626-E-1x700708-1-E-2	1	-	-	-	-	-
3	700626-E-1-DM-1x700708-1-E-1	2	-	-	-	-	-
4	J797-1-E-1-2x700626-E-1	3	-	-	-	-	-
5	700626-E-1xJ797-1-E-1-2	3	-	-	-	-	-
6	700626-E-1-DM-1xJ797-1-E-3-4	1	-	-	-	-	-
7	J797-1-E-3-4x700626-E-1-DM-1	1	-	-	-	-	-
8	J797-1-E-1-2x700708-1-E-1	2	-	-	-	-	-
9	700708-1-E-1xJ797-1-E-1-2	3	4	93	118	229	483[a]
10	700708-1-E-1xJ797-1-E-1-1	1	-	-	-	-	-
11	700708-1-E-3xJ797-1-E-1-1	4	9	118	82	81	-
12	J2238-E-4-1xJ797-1-E-1-2	3	2	-	-	-	-
13	J797-1-E-1-2xJ2238-E-2-1	2	2	-	-	-	-
14	J797-1-E-3-4xJ2238-E-4-1	2	2	-	-	-	-
15	700626-E-1-DM-1xJ2238-E-4-1	4	5	11	-	-	-
16	J2238-E-4-1x700626-E-1	2	-	-	-	-	-
17	700708-1-E-1-DM-1xJ2238-E-4-1	4	-	-	-	-	-
18	J2238-E-4-1x700708-1-E-1-DM-1	5	-	-	-	-	-
19	J2238-E-4-1x700526-E-1	4	-	-	-	-	-
20	700526-E-1xJ2238-E-4-1	4	-	-	-	-	-
21	J797-1-E-3-4x700526-E-1	2	-	-	-	-	-
22	700526-E-1xJ797-1-E-3-4	3	-	-	-	-	-
23	Ex Bouchi 700638-3-2-E-1-1xJ797-1-E-1-3	3	-	-	-	-	-
24	J797-1-E-1-3xEx Bouchi 700638-3-2-E-1-DM-2	3	-	-	-	-	-
25	Ex Bouchi 700638-3-2-E-1-DM-2xJ2238-E-4-1	3	-	-	-	-	-
26	J2238-E-4-1xEx Bouchi 700638-3-2-E-1-DM-2	3	1	4	-	-	-
	Total	71	29	226	200	310	483

a From 25 F_6 lines 159 ergot-free heads were selected for further evaluation at F_7.

Table 3.4.2c. Ergot reactions of 12 F_5 line-bulks during the 1981-82 post-rainy season at ICRISAT Center

Entry No.	Sl.No.	Identity	Ergot severity (%)	
			Mean[a]	Range
4	1	ICMPE (8-1-4)-14-1	<1	0-1
6	2	" (8-1-4)-14-4	<1	0-2
7	3	" (8-1-4)-14-6	<1	0-5
9	4	" (10-2-2)-6-2	<1	0-5
5	5	" (8-1-4)-14-2	2	0-25
3	6	" (7-1-3)-22-5	3	0-25
12	7	" (10-2-2)-6-6	6	0-50
11	8	" (10-2-2)-6-5	8	0-90
10	9	" (10-2-2)-6-3	8	0-75
1	10	" (6-1-2)-3-3	10	0-65
8	11	" (9-2-1)-9-5	17	0-75
2	12	" (7-1-3)-17-1	19	0-90
		ICH 206 check	93	70-100

[a] Mean of 40 inoculated inflorescences from 2 reps.

ICMPE(8-1-4) - (700708-1-E-1 x J 797-1-E-1-2)-1-4
ICMPE(10-2-2) - (700708-1-E-3 x J 797-1-E-1-1)-2-2
ICMPE(7-1-3) - (700708-1-E-1 x J 797-1-E-1-2)-1-3
ICMPE(6-1-2) - (700708-1-E-1 x J 797-1-E-1-2)-1-2
ICMPE(9-2-1) - (700708-1-E-3 x J 797-1-E-1-1)-2-1

Table 3.4.3a. Ergot reactions and selections made for ergot resistant plants in the progenies of 8 crosses between ergot-low-susceptible F_5 lines

Cross	Generation					
	F_1	F_2	F_3		F_4	
	Erg. sev. (%)	Erg. sev. (%)	lines screened	mean erg. sev. (%) range	lines screened	mean erg. sev. (%) range
P_1xP_2	3	22	30	<1-37	146	<1-47
P_2xP_1	13	32	42	<1-48	150	0-39
P_1xP_4	5	35	5	<1-24	45	<1-26
P_4xP_1	11	40	25	<1-18	15	<1-10
P_2xP_4	12	34	14	<1-19	0	-
P_4xP_2	6	35	25	<1-32	152	0-43
P_3xP_4	18	57	34	<1-30	150	<1-39
P_5xP_3	14	59	6	<1-21	27	<1-42

Ergot sev. mean based on F_1-40 heads; F_2-100 of the 500 inoculated heads; F_3-40 heads in 2 reps; F_4-40 heads in 2 reps.

Parents	Erg. sev. (%)	
	X	range
P_1 = (J606-2 x J703-1)-4-4-5-6(F_5)	<1	0-5
P_2 = (J2238 x J2210-2)-3-3-4-6(F_5)	<1	0-2
P_3 = (J2238 x J2210-2)-3-3-10-7(F_5)	<1	0-5
P_4 = (700619 x 700599)-3-2-11-5(F_5)	2	0-10
P_5 = (700619 x 700599)-3-2-11-2(F_5)	3	0-10

Erg. sev. based on 30 heads in 3 reps.

Table 3.4.3b. Summary of the progress made in increasing levels of ergot resistance in the progenies of crosses between ergot low susceptible F_5 lines during 1980-82

Year & Season	Gene-ration	No. of lines screened	No. of plants screened/ line	Percentage of lines in ergot sev. (%) class			
				≤10	11-20	21-30	>30
1980-81 post-rainy	F_1	8	40	37	63	0	0
1981 rainy	F_2	8 pop.	500	0	0	12	88
1981-82 post-rainy	F_3	181	40	75	16	7	2
1982 rainy	F_4	685	40	77	14	8	1

Table 3.4.3c. Ergot reactions of 16 F_4 bulks ($ERF_5 x ERF_5$) during the 1981-82 post-rainy season at ICRISAT Center

Sl. No.	Identity	Ergot severity (%)	
		Mean[a]	Range
1	2-39	1	0-5
2	1-22	1	0-2
3	7-32	2	0-5
4	7-10	2	0-10
5	4-9	2	0-5
6	1-13	3	0-10
7	2-20	3	0-35
8	6-8	3	0-30
9	7-25	3	0-20
10	2-15	3	0-25
11	2-5	4	0-25
12	3-4	5	0-25
13	1-1	5	0-40
14	2-11	6	0-55
15	7-12	8	0-80
16	6-2	8	0-40
	BJ-104 Check	88	50-100

[a] Mean of 40 inoculated-inflorescences from 2 reps.

Table 3.4.4a. Performance of 167 F_3 lines (ER F_5xER F_5)by SBC) for ergot resistance during the 1981-82 post-rainy season at ICRISAT Center

Ergot severity (%) class	No. of lines	Percentage of lines
0-<1	2[a]	1
1-10	69[a]	41
11-20	56	33
21-30	17	10
31-40	15	9
41-50	4	2
>50	4	2

[a] 41 of these lines had agronomic scores of 5 or less on 1-9 scale

Table 3.4.4b. Ergot reactions and selections made for ergot resistance (ER) plants in 5 crosses involving ER F_5 lines during 1981-82 at ICRISAT Center

Cross No.	Pedigree	F_2 Erg. sev.%		F_3		
		x	Range	Lines screened	Mean ergot sev. range	ER plants selected
1	(J2238xJ797-1)-2-2-6-1x(J606-2xJ703-1)-4-4-5-2	7	0-80	48	1-68	58
2	(Ex-Bouchi 700638-3-2xSC-1(S_4)27-2)-1-10-19-6x(J606-2xJ703-1)-4-4-5-2	3	0-65	23	<1-37	30
3	(Ex-Bouchi 700638-3-2xSC-1(S_4)-27-2)-1-10-19-6x(J2238xJ797-1)-2-2-6-1	7	0-50	27	2-50	35
4	(J606-2xJ703-1)-4-4-5-2x(J2238xJ797-1)-2-2-6-1	8	0-75	41	1-39	57
5	(J606-2xJ703-1)-4-4-5-2x(Ex-Bouchi 700638-3-2xSC-1(S_4)-27-2)-1-10-19-6	6	0-80	28	1-46	19

Ergot severity(%) based on 100-160 heads in F_2 and 20 heads in F_3

Ergot reactions of F_5 lines involved in crosses(post-rainy season 1979-80)

Pedigree	Mean[a] of ergot severity (%)
(J2238xJ797-1)-2-2-6-1	15
(J606-2xJ703-1)-4-4-5-2	3
(Ex-Bouchi 700638-3-2xSC-1(S_4)27-2)-1-10-19-6	21

[a] Based on 30 heads in 3 replications

Table 3.4.5a. Ergot reactions and days to 75 percent flowering (DTF) of 22 F_8/F_9 bulks during the 1982 rainy season at ICRISAT Center and Aurangabad

Sl No.	Entry	DTF ICRISAT	Mean[a] ergot sev. (%) ICRISAT	Aurangabad
1.	ICMPES- 4	59	1	1
2.	ICMPES- 5	52	2	1
3.	ICMPES- 6*	58	43	4
4.	ICMPES- 7*	65	18	<1
5.	ICMPES- 8*	58	47	1
6.	ICMPES- 9*	62	44	2
7.	ICMPES-12	65	<1	<1
8.	ICMPES-13	59	3	1
9.	ICMPES-14	65	3	<1
10	ICMPES-15*	60	1	<1
11	ICMPES-16*	57	1	<1
12	ICMPES-17*	62	4	<1
13	ICMPES-18	58	9	3
14	ICMPES-19	67	4	<1
15	ICMPES-20	64	9	4
16	ICMPES-21	59	6	2
17	ICMPES-22	59	2	1
18	ICMPES-25	59	7	<1
19	ICMPES-26	57	1	<1
20	ICMPES-29*	55	4	1
21	ICMPES-30	62	7	1
22	ICMPES-31*	60	1	<1
	WC-C-75 (Check)	47	58	70
	ICMS 7703 (Check)	49	65	80
	BK-560 (Check)	39	95	86

[a]Based on 20-40 inoculated heads in 2 replications.

*Agronomically good entries at Aurangabad.

Table 3.4.5b Evaluation of ergot resistant sib-bulks for ergot reactions and grain yields during the 1982 rainy season

Entry	Mean ergot severity[a] (%)		Yield/plot[b] (g)	
	ICRISAT Center	Aurangabad	ICRISAT Center	Hissar
ICMPES - 1	1	1	725	809
ICMPES - 2	1	<1	1072	971
ICMPES - 3	22	17	807	1846
ICMPES -10	10	1	920	577
ICMPES -11	1	<1	851	259
ICMPES -23	3	<1	742	361
ICMPES -24	2	<1	740	430
ICMPES -27	1	<1	748	390
ICMPES -28	4	1	1385	644
ICMPES -32	2	2	744	494
WC-C-75 (Check)	58	70	1468	2469
BK-560 (Check)	95	86	1311	2924

[a] Based on 60-120 inoculated heads in 3 replications.

[b] Mean of 3 replications, plot size 2rows x 4m.

Table 3.5.2a. Screening of progenies of B lines x ER lines 1980-82

Year & season	Generation	No. of lines	No. of plants screened	Percentage of lines in ergot sev. range				ER plants selected	
				≤10	11-20	21-50	>50	No.	%
Phase I									
1980-81 post-rainy	F_2	14	5,600	-	-	-	-	73	1.3
1981 rainy	F_3	73	730	0	4	30	66	52	7.1
1981-82 post-rainy	F_4	51	510	10	14	28	48	49	9.6
1982 rainy	F_5	49	490	25	17	37	21	37	7.5
Phase II									
1981-82 post-rainy	F_2	22	3,779	17	9	27	47	111	3
1982 rainy	F_3	111	555	58	16	25	1	67	12

- data not available

Table 3.51 Ergot reactions of test-cross hybrids using ergot resistant (ER) lin as pollinators

Year	Female parent	No. of F_1 hybrids	Percentage of hybrids in Ergot severity (%) range			
			<10	11-20	21-50	> 50
1980	111A	189	0	0	0	100
	5054A	216	0	0	0	100
	5141A	237	0	0	0	100
1981	SP 1588 SP 1590 SP 1592 SP 1594	34	0	0	0	100
1981	MAHAYCO	37	0	0	0	100
1982	ER F_6-F_8	49	92	8	0	0
	SC-2(M)5-4 Sels	55	45	29	20	6

SP = short protogyny

1588 = [111A x (111B x 3/4 Souna-39-2-2]-2

1590 = ["]-3

1592 = ["]-4

1594 = ["]-6

Table 3.5.2b. Ergot reactions and selection made of ergot resistant plants in the progenies of crosses between B lines x ergot-low-susceptible F_4 lines

Cross No.	Pedigree	F_2 (1980-81 post-rainy)	F_3 (1981 rainy)		F_4 (1981-82 post-rainy)		F_5 (1982 rainy)	
		ER plants sel.	Erg. sev. range	ER plants sel.	Erg. sev. range	ER plants sel.	Erg. sev. range	No. of plants selected
1.	S054B x (J606-2 x J703-1)2-2-1	9	13-78	8	46-88	7	23-94	1
2.	" " J703-1)4-4-2P_2	4	33-42	5	51-91	3	9-60	2
3.	" " J703-1)4-7-9	10	24-75	13	1-78	9	1-35	14
4.	" " J703-1)4-8-2P_2	15	35-84	8	7-77	6	1-32	5
5.	" " " 4-8-2P_3	5	53-85	1	52	0	-	-
6.	" (J606-2 x J703-1)5-3-5	2	27-75	2	28-48	1	60	0
7.	" " J703-1)5-3-7P_1	1	57	2	12-34	4	21-63	2
8.	" " " 5-3-7P_2	2	52-57	3	20-39	3	13-32	4
9.	" " J703-1)6-2-1	2	67-73	1	52	1	54	0
10	" (J703-1 x J797-1)3-1-8	7	19-94	3	8-22	7	9-50	5
11	" (J797-1 x J703-1)6-7-2	3	17-37	1	15	0	-	-
12	" (" J703-1)6-8-8	3	47-65	3	16-33	8	16-53	4
13	" (J2238 x J1553)-1-5-32	3	66-79	0	-	0	-	-
14	5141B x (J606-2 x J703-1)6-2-11)	7	48-81	2	70	0	-	-
	Total plants selected	73		52		49		37
	No. of plants screened	5600		730		520		490
	Frequency of selection (%)	1.3		7.12		9.42		7.5

Table 3.5.2c. Selection of ergot resistant (ER) plants in the progenies of crosses between B lines x ER F_7 lines 1981-82

Cross No.	Pedigree	Erg. sev.	F_2 ER plants selected	Mean Erg. sev. range	F_3 ER plants selected
1.	(5141B x ICMPE 134-6-9)-3	58	14	0-49	13
2.	" " 134-6-9)-11	64	8	1-47	6
3.	" " 134-6-9)-10	59	5	1-37	6
4.	" " 134-6-9)-8	53	4	1-30	2
5.	" " 134-6-9)-5	69	5	1-21	6
6.	" " 134-6-18)-6	52	9	1-14	7
7.	" " 134-6-18)-3	69	4	1-18	4
8.	" " 134-6-18)-1	61	5	<1-32	2
9.	(5054B x ICMPE 134-6-9)-9	65	1	41	0
	" " 134-6-9)-1	55	5	<1-32	1
11	" " 134-6-18)-4	61	2	31-40	0
12	(111B x ICMPE 134-6-9)-12	45	4	<1-20	0
13	" " 134-6-9)-13	43	4	1-19	2
14	" " 134-6-9)-6	48	2	0-34	1
15	" " 134-6-9)-1	49	0	-	-
16	" " 134-6-18)-7	50	3	1-21	1
17	(81B x ICMPE 134-6-9)-14	35	5	1-30	3
18	" " 134-6-9)-15	50	6	2-49	2
19	" " 134-6-9)-7	36	8	2-14	4
20	" " 134-6-18)-5	35	5	2-30	0
21	" " 134-6-18)-8	31	7	0-25	6
22	" " 134-6-18)-2	49	5	4-32	1
	Total ER plants selected		111		67
	No. of plants screened		3779		555
	Frequency of sel. (%)		2.9		12.1

Table 3.5.3. Promising ergot resistant maintainers on 5054A, 5141A, and ICM MS 81

Pedigree	No. of sels.	No. of sels. with ≤5% ergot sev.[a]
ICMPE 134-6-9	23	22
ICMPE 134-6-18	13	13
ICMPE 13-6-8 ICMPE 13-6-9 ICMPE 13-6-28	28[b]	27

[a]Based on 10 inoculated inflorescences/line.

[b]112 single plant maintainers were selected for further utilization.

Table 3.5.4. Attempt to transfer ergot resistance in 'R' and 'B' lines (K-'82)

Cross/Parents (F_1)	Ergot severity (%)[a] Mean	Range
ICP 220 P_2 x ER 110-2 P_2	45	1-85
ER 110-2 P_2 x ICP 220 P_2	70	1-95
ER 126-1 P_2 x 5054 B P_3	25	0-75
5054 B P_3 x ER 126-1 P_2	25	0-75
5054 B P_3	68	50-85
ICP 220 P_2	88	80-95
ER 126-1 P_2	<1	0-1
ER 110-2 P_2	<1	0-1

[a]Based on 10 head obs. for crosses and 5 head obs. for parents.

ER 126-1 = ICMPE 13-6-9-1 - maintainer on 5054A.

ER 110-2 = (EC-298-3 x SC-2(M)5-4-3-4-1)-2 -restorer on 5054A.

Table 3.5.5. Effect of cytoplasm on ergot resistance (K-82)

Parents and Cross (F_1)	Mean[a] ergot severity (%)
5054-A	89
5054-B	68
ICP-220	88
ER 126-1	<1
ER 110-2	<1
5054-A x ICP 220 P_1	76
5054-B x ICP 220 P_1	70
ICP 220 P_1 x 5054-B	56
5054-A x ER 110-2	82
5054-B x ER 110-2	48
ER 110-2 x 5054-B	52
ER 126-1 x ER 110-2	<1
ER 110-2 x ER 126-1	3

[a] Based on 15 inflorescences in 3 replications.

Table 3.5.6. Ergot reactions and grain yields of ergot resistant synthetics (1980-1981)

Year	Synthetic	Ergot severity[a] (%)	Yield[b] (Kg/ha)
1980	ICMS 8031	12	1865
	ICMS 8032	15	1827
	ICMS 8034	14	2035
	WC-C75	24	1928
	BJ-104	54	1846
1981	ICMS 8102	49	-[c]

[a] Mean of 10-20 open inoculated inflorescences.

[b] Mean of 3 locations PHF, PLF and Bhavanisagar.

[c] Data not available.

Table 3.5.7. Ergot susceptibility of some released and improved hybrids and varieties under natural conditions during the 1981 rainy season at ICRISAT Center farm

Hybrid/variety	Ergot infection (%)	
	Incidence	Severity
BJ 104[a]	95	4
ICH 220[a]	100	13
ICH 412[b]	99	39
WC-C75[a]	31	0.3
ICMS 7703[a]	39	1

[a] Incidence and severity based on 100 heads from the central 2 rows in the ICRISAT demonstration plot.

[b] Incidence and severity based on 400 heads in 4 replications-Physiology expt.

Table 3.6.1. Pollen management to control ergot in a pearl millet hybrid

Treatment	Ergot infection[a]		Grain yield[a]	
	Inc. (%)	Sev.(%)	1000 grain wt (g)	Yield/plot[b] (kg)
ICH-206	100	62	6.5	6.4
ICH-206 + SC-2(M)5-4[c] (4+1)	57	5	7.1	12.7
SE (m)±	1.9	1.5	0.2	0.04

[a]Mean of 2 replications.

[b]Plot size 16 rows x 10m.

[c]Ergot-low susceptible pollen-donor line which flowers earlier than the hybrid.

4. SMUT

4.1. Summary

Biology and Epidemiology

- Studies were made on morphological and cultural characters of the smut pathogen, Tolyposporium penicillariae and a method to obtain inoculum in large quantities for field screening was developed.
  -Trans Br.Mycol.Soc (in press).

- Pollination of smut inoculated inflorescences reduced smut development significantly compared with inoculated non-pollinated inflorescences. This had implications in developing the smut-screening technique.
  -Plant Pathology (in press).

- The smut screening technique developed in 1980 has successfully been used during the 1981 and 1982 rainy seasons on a large scale at ICRISAT Center.
  -Phytopathology (in press).

Resistance identification, development and utilization

- About 500 smut resistant single plant selections (S4) from the 1980 germplasms (S3) in the advanced screen, were screened as plant-to-row progeny in the 1981 rainy season at Hissar; 94% of the lines showed high levels of resistance (< 5% mean severity). Similarly, 340 (S5) selections from 79 S4 selected in 1981 screen and grouped into dwarf, medium-tall, and tall, were screened in the 1982 rainy season at ICRISAT Center; 93% of these showed high resistance.

- AICMIP trial entries - 78 hybrids and 68 populations in four trials were screened and only 8 hybrids and 16 populations showed < 10% smut severity.

- PMSN entries - in 2 years (1981 and 1982) 73 smut resistant entries were evaluated in replicated trials at Hissar and ICRISAT Center; about 95% of the entries showed high levels of resistance (< 5%) across two locations.

- Multilocational testing of smut resistant lines was continued and several lines with high levels of smut resistance were identified (IPMSN reports - P.M. Path. 65 and 77). Two lines (SSC FS-252-S-4 and ICI 7517-S-1) have shown stability of resistance across locations in India and West Africa over 3-5 years.

- From the first set of crosses between smut resistant lines, 514 F4 lines representing 28 crosses were screened in the 1981 rainy season at Hissar and 98% of the lines showed high levels of resistance (< 5% severity). Five hundred and thirteen selections from these lines were grouped into tall, medium tall and dwarf with varying maturity periods. Many of these F5 lines (91%) screened in the 1982 rainy season were highly resistant and in

each group smut resistant lines with good agronomic traits were identified. A similar approach is being followed in other sets of crosses with major emphasis on selecting high smut resistant plants in agronomically elite progenies.

- Crosses between smut resistant and agronomic elite lines provided smut resistant good agronomic lines at F4 and F5 generations.

- Attempt to incorporate smut resistance in ICM ms 81 through crosses between 23D2B (I) x smut resistant lines continued to provide many smut resistant plants at F4 and F5 stages and 88 F5 lines were identified as maintainers on ICM ms 81. These lines are being utilized in a backcross program to convert them into smut resistant ms lines.

- All the F1 hybrids, produced using nine smut resistant lines as pollinators on three ms lines (111A, 5054A and 5141A) showed high susceptibility to smut (>20% severity) indicating resistance is recessive.

- The smut resistant composite (SRC), made using 37 smut resistant lines in 1978, its C2, C3 progenies, and several experimental varieties were screened. The percentage of progenies showing high levels of smut resistance increased at each cycle and 4 of 9 experimental varieties showed $\leq$ 10% smut severity.

- Two synthetics constituted using 13 smut resistant lines, showed very high resistance to smut (<1% severity) and looked agronomically impressive during the 1982 rainy season.

4.2. Biology and Epidemiology

4.2.1. Studies on biology of Tolyposporium penicillariae. Sporeballs of Tolyposporium penicillariae Bref. varied in shape from circular to near- polyhedral and measured 42-325 µm x 50-175 µm. (Fig.1). The number of teliospores aggregated in balls varied from 200 to 1400. Teliospores were mostly circular and measured 7-12 µm in diameter. Different patterns of germination were observed (Fig.2). Maximum germination of teliospores aggregated in balls occurred at 30 C (Fig.3). Much variability was observed in cultural characters of the pathogen grown on different media (Table 4.2.1a; Figs.4-7). The fungus grew well within 3-5 days on potato/carrot agar at 35 C (Table 4.2.1b). Growth of the

Fig. 1. Sporeballs of *Tolyposporium penicillariae*.

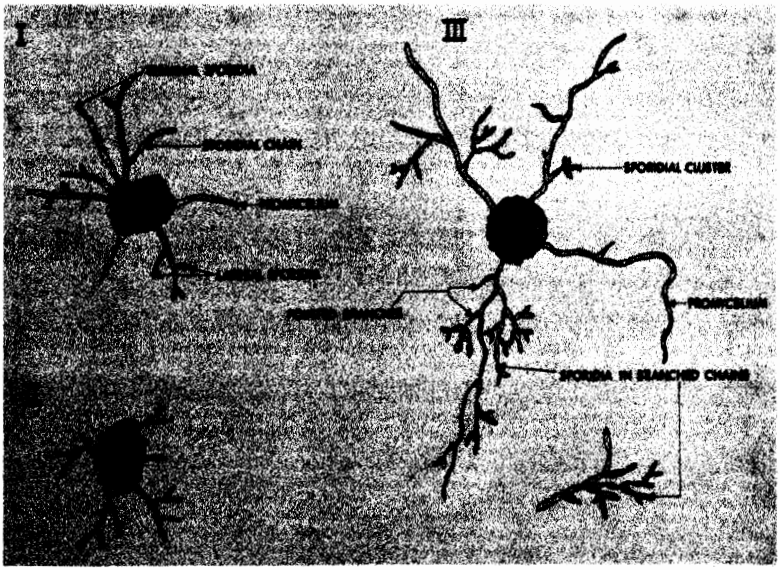

Fig. 2. Patterns of teliospore germination in *Tolyposporium penicillariae*

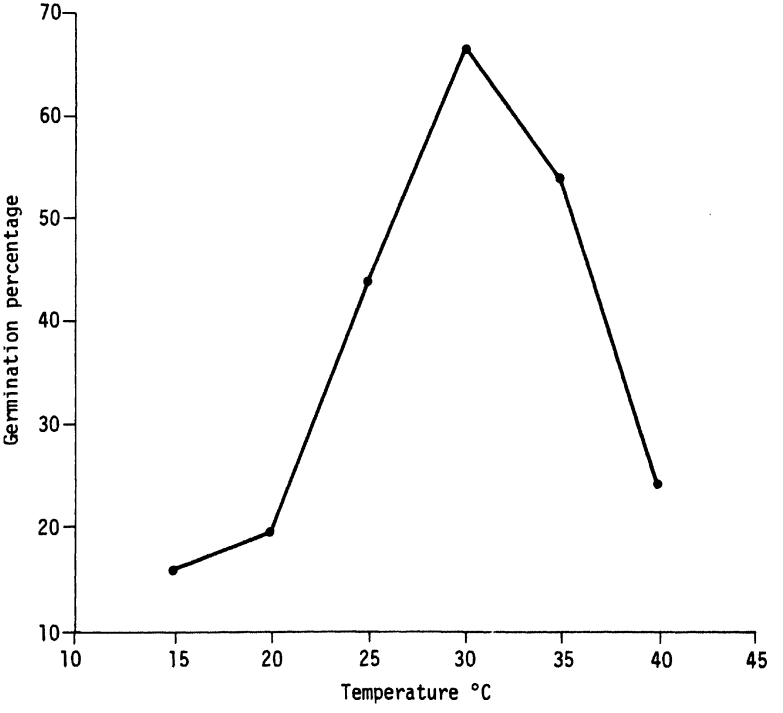

Fig. 3. The percentage germination of sporeballs of *Tolypocystis penicillariae* incubated for 13 h in water at 6 temperatures.

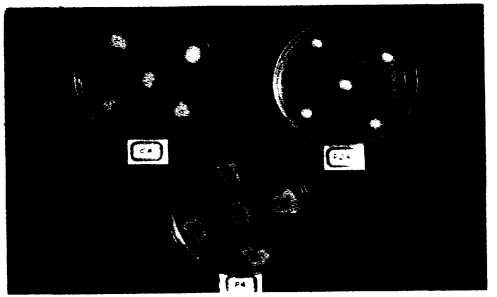

Fig.4. Growth of *Tolyposporium penicillariae* on carrot agar (CA), potato dextrose agar (PDA) and potago agar (PA) after 5 days incubation at 35°C.

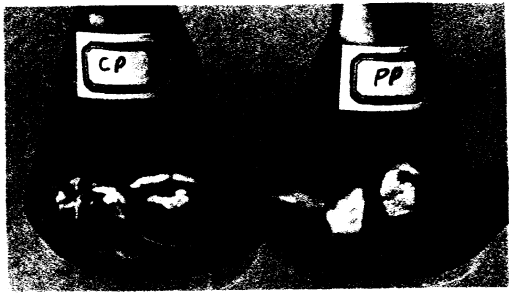

Fig. 5. Growth of *Tolyposporium penicillariae* on carrot pieces (CP) and potato pieces (PP) after 5 days incubation at 35°C.

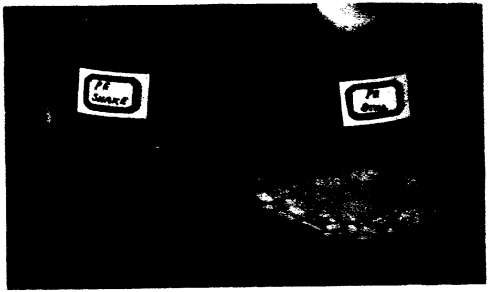

Fig.6. Growth of *Tolyposporium penicillariae* in potato extract (PE) shake and still-cultures after 5 days incubation at 35°C.

Fig. 7. Shake-culture of *Tolyposporium penicillariae* as compared to still-culture in carrot extract (CE) after 5 days incubation at 35°C.

fungus remained purely sporidial even after repeated subculturing. Sporidia were borne on promycelia, laterally and/or terminally, and these reproduced by budding in chains (Fig.2). Sporidia were spindle-shaped and varied in length from 8-25 µm. Individual separated teliospores seldom germinated (Fig.8). Cultures stored for 90 days at 10 C produced chlamydospores (Fig.9). In inoculation test, sporidial inoculum proved most infective for use in large-scale field screening.

4.2.2. Effects of pollination on smut development. In field and screenhouse experiments, pollination of inflorescences of three pearl millet F1 hybrids and two ms-lines with fresh viable pollen, 5-8 days after inoculation with a *T. penicillariae* sporidial suspension, reduced smut severities significantly compared with inoculated, non-pollinated control plants (Table 4.2.2a). Smut development was not significantly reduced in a ms line following pollination of inoculated inflorescences with pollen of low viability (Table 4.2.2b). The findings showed that it is essential to prevent pollination for screening to be effective to detect smut resistance in pearl millet.

4.2.3. Development of field screening technique for smut resistance. To develop an effective field screening technique the following factors were studied.

i) Sporeball longevity in vitro. Freshly collected sporeballs from the infected inflorescences produced more than 80% germination in sterile distilled water at 25 C while those stored at 10 C for various time period (1-61 months) had reduced

germination percentage with increased storage time (Fig. 10).

ii) Effect of inoculum sources: Sporidia grown on potato agar for 3-20 days at 35 C were most infective compared with other inoculum sources (Table 4.2.3a).

iii) Effect of flowering stage at inoculation: Inoculations made at the boot-leaf stage produced significantly higher smut than at the other stages of flowering (Table 4.2.3b).

iv) Effect of inoculum concentrations. Sporidial concentratipns of 3.2×10^6 sporidia/ml and above produced significantly more smut than lower concentrations (Table 4.2.3c).

v) Effect of types of bags. Covering the inoculated "boot" with parchment bag produced significatnly more smut than polythene bags in the field but opposite results were obtained in the screenhouse (Table 4.2.3d).

vi) Effects of humidity. Maintaining high relative humidity (>80%) for about 16 h every day during the period from inoculation to disease development, with sprinkler irrigation, provided 92% smut compared with only 19% when the same humidity was maintained for about 7 h (Table 4.2.3e).

Based on the results reported above an effective field screening technique was developed which involves inoculation of tillers at the boot-leaf stage by injecting a sporidial suspension (ca 1×10^6 sporidia/ml) from viable sporeballs of *I. penicillariae* grown in potato/carrot agar at 35 C into the space around the inflorescence within the flag leaf sheath followed by covering the tiller "boots" with parchment bags to prevent pollination and to assist in maintaining humidity. High humidity was maintained with frequent overhead sprinkler irrigation throughout the period

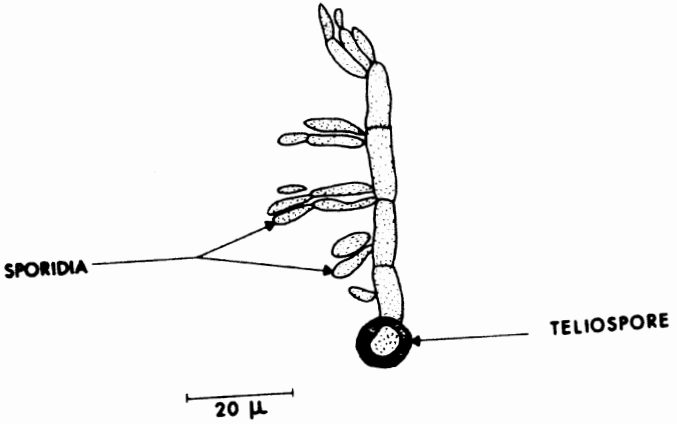

Fig. 8. A germinated teliospore of *Tolyposporium penicillariae*

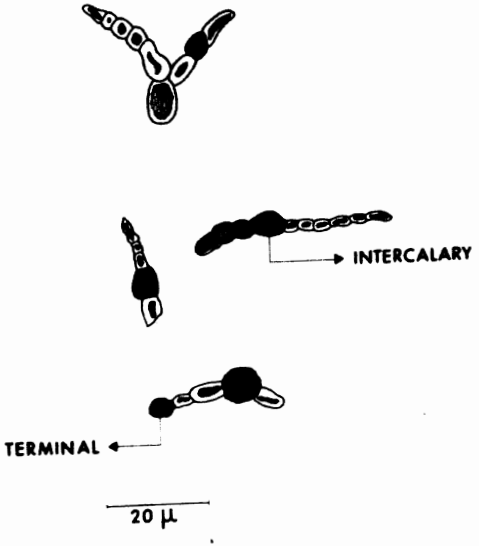

Fig. 9. Chlamydospores of *Tolyposporium penicillariae* in culture

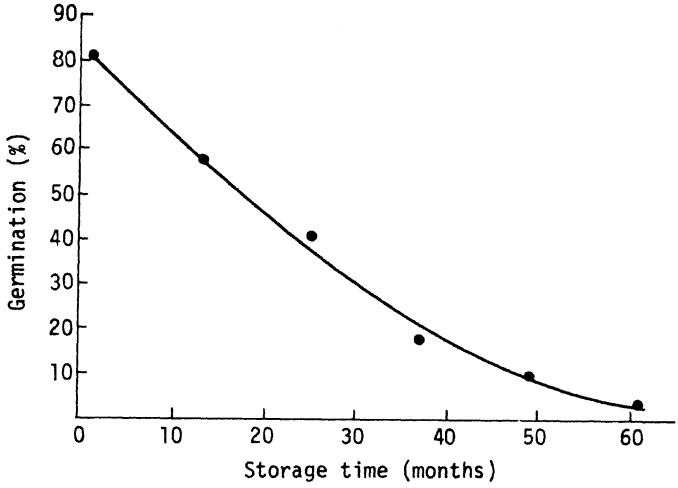

Fig. 10. Germination of *Tolyposporium penicillariae* sporeballs after storage for different time periods at 10°C

of inoculation, flowering and grain development (Table 4.2.3e). Inflorescences were scored for smut reaction 20-25 days after inoculation with the aid of a standard key developed to estimate percent severity (Fig.11). This technique was used in the field during the 1981 rainy season to screen more than 200 pearl millet lines. Resistance was confirmed in a few lines and many resistant plants with selfed seeds were selected (Table 4.2.3f). During the 1982 rainy season, the nursery was operated on a large scale and about 3,000 entries were screened the details of which are described below.

4.3. Resistance identification

4.3.1. Selections from the 1980 screens. i) Germplasm lines. About 500 smut resistant individual plant selections from germplasm lines (S3) originating from Nigeria, Mali, and Senegal were screened as S4 lines in the 1981 rainy season at Hissar. Ten plants in each line were inject-inoculated with 24 hr water-soaked sporeballs of *T. penicillariae* and bagged with parchment bags. A large number of lines (94%) showed high levels of resistance (≤5%) and 340 single plants from 79 S4 lines were selected for evaluation as S5 lines (Table 4.3.1). During the 1982 rainy season these lines were grouped into dwarf, medium-tall, and tall, with other F4 and F5 lines derived from resistance development sub-project and screened at ICRISAT Center following the improved screening technique.

ii) 1981 PMSN selections. - 306 smut resistant selections from

the 1981 PMSN, were screened at ICRISAT Center during the 1982 rainy season and 85% of these showed <5% smut severity (Table 4.3.1). We selected 212 smut-free plants fom 47 lines for further evaluation.

iii) IPMSN selections. - Of 111 selections screened in the 1982 rainy season at ICRISAT Center, 91% of lines showed <5% smut severity and 78 plants from 18 lines were selected.

iv) 1981 IPMDMN selections. Of 9 selections screened, although 7 showed <5% smut no selection was made because of poor selfed seed set.

v) Smut Resistant Composite Selections. Of the 50 selections screened, only 8 plants from 2 lines were selected.

4.3.2. AICMIP trial entries. During the rainy seasons of 1981 and 1982, 78 hybrids and 68 populations (varieties) in four trials were screened at ICRISAT Center. Only 8 hybrids and 16 varieties showed resistance to smut with mean smut severities of not more than 10% (Table 4.3.2). In 1981 screening was done in smut nursery where disease pressure was adequate (91% severity on BJ-104). In 1982, screening was done in MDN where inoculations were made on late tillers, but without sprinkler irrigation, resulting in only 48% smut severity on BJ-104. In 1981 most of the hybrids showed > 50% mean smut severities but varieties in general, developed less smut. Since the number of hybrids and varieties with high smut resistance is low and smut resistant

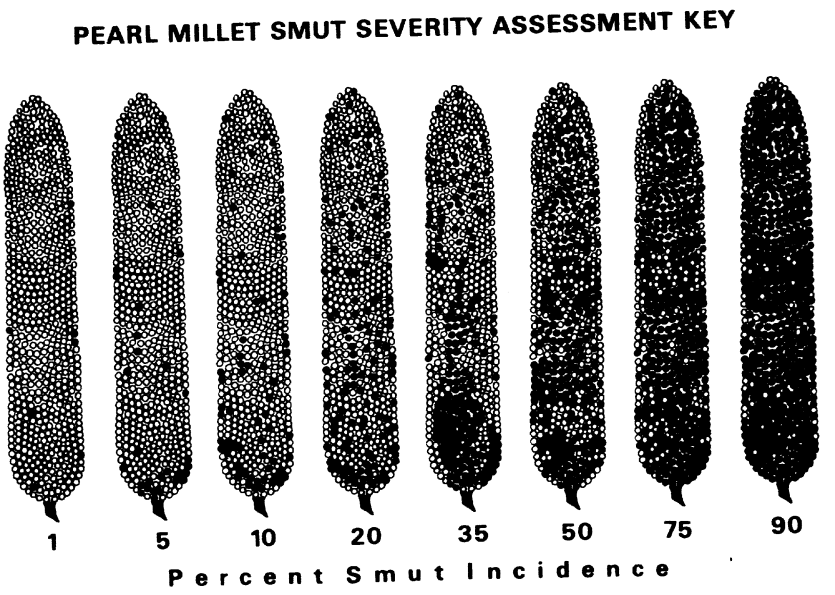

Fig. 11. Standard drawings used to aid estimation of smut severity in pearl millet inflorescences.

lines are being supplied from ICRISAT, major efforts are needed to breed for smut resistance in the Indian Millet Program.

4.3.3. ICRISAT Center entries. During the 1981 rainy season 109 entries in 4 trials (PMIST-2, IPMAT-7, IPMEN and IPMDMN) were screened at Hissar. Smut inoculations were made by injecting 24 hr water-soaked sporeballs into the "boot" and then covering with parchment bags. Because of dry weather at flowering, smut development was not adequate (<40% severity on the susceptible check), and therefore most of the entries showed ≤ 10% mean smut severity (Table 4.3.3).

4.3.4. Pearl Millet Smut Nursery(PMSN). Promising smut resistant lines which were not included in the IPMSN for multilocational testing were evaluated in a replicated trial. There were 39 entries in 1981 and 34 in 1982. Screening was done in both the years at two locations - ICRISAT Center and Hissar. Results summarised in Table 4.3.4 show that most of the entries were highly resistant (≤ 5% mean smut severities) compared with 37-80% and 15-26% on the susceptible check, at ICRISAT and Hissar, respectively. Some of these lines will be included in the 1983 IPMSN for multilocation evaluation.

4.3.5. International Pearl Millet Smut Nursery (IPMSN). The 1981 IPMSN with 29 test entries was evaluated at 4 West African and 3 Indian locations. Seven entires were highly resistant with across locations mean smut severities of 2 to 5% except at Kano (Nigeria) where the mean severities ranged from 8 to 32% (IPMSN

Report 1981. PM Path. 65). The 1982 IPMSN consisted 28 test entries and was evaluated at 2 locations in West Africa and 3 locations in India. The mean smut severities of test entries across locations varied between < 1 and 7% compared with 43% on the susceptible check (ICH-220). Fifteen entries showed mean smut severity of < 1% across locations with maximum severity of not more than 2% at any one location (IPMSN Report 1982. PM Path. 77). Two entries (SSC FS 252-S-4 and ICI 7517-S-1) have shown stability of resistance across locations over 3 to 5 years of testing (Table 4.3.5).

4.4. Resistance development

Unlike ergot resistance, we were able to identify several plants from some germplasm lines which within 3-4 cycles of selection in the smut nursery provided high levels of smut resistance. A few of these lines like SSC-FS-252-S-4, ICI 7517-S-1, EB 132-2-8-5-2-DM-1, P-489-S-3, and several others have shown high levels of resistance over 3-5 yr of multilocational testing. Most of these lines, however, are agronomically unacceptable. We therefore directed our efforts, on a limited scale, to select smut resistant plants with desirable agronomic traits in the progenies of crosses between smut resistant lines. By the 1982 rainy season we could select many F4 lines which have good agronomic traits in addition to high smut resistance. These lines are being preferred for utilization by our breeders.

4.4.1 Resistance development I. The first set of crosses (plant x

plant) were attempted during summer 1978 involving 14 smut resistant lines at ICRISAT Center and 118 F1s were generated. Progeny lines (F1-F4) were screened at Hissar and at each generation smut resistant plants were selected (Table 4.4.1). During the 1981 rainy season 514 F4 lines from 28 crosses were screened and 508 of these showed high levels of smut resistance (<5% mean severity). These lines have been grouped to represent tall, medium tall and dwarf lines and F5 progeny lines were evaluated at ICRISAT Center during the 1982 rainy season. Many of these lines possess good agronomic traits besides high smut resistance (Table 4.4.4).

4.4.2. Resistance development II. In summer 1979, crosses were made between four smut resistant lines which had shown high levels of resistance (<1% mean severity) in the 1978 IPMSN. These lines are SSC FS-252, EB 24-1, EB 137-1-1, and WC FS 148. Five F2 populations were screened during the 1980 rainy season at Hissar and 123 smut-free single heads with selfed seed were selected. F3 lines were screened in the 1981 rainy season and 90 smut-free heads were selected which were screened as F4 progeny lines at ICRISAT Center in the 1982 rainy season. From 25 F4 lines 127 smut-free plants have been selected for further evaluation (Table 4.4.2). A large number of lines have shown high levels of smut resistance at each generation. Many of the F4 lines have shown good levels of resistance to downy mildew and possess good agronomic traits also.

4.4.3. Resistance Development III. The third set of crosses were

made during summer 1980 at ICRISAT Center between the smut resistant progenies identified in the 1979 multilocational testing. Five smut resistant lines (ICI 7517-S-1, SSC FS 252-S-4, P-10-S-1, WC FS 151-S-1-1 EB 229-4-1-S-6-1) were involved which had undergone several cycles of selection for smut resistance at Hissar. Four F1s and 4F2 populations generated from 5 lines were screened at Hissar during the 1980 and 1981 rainy seasons, respectively. In F1 a minimum of 20 plants/cross were inoculated and in F2, 200 plants/cross and resistant plants with good selfed-seed were selected. One hundred thirty-three F3 lines were screened at ICRISAT Center during the 1982 rainy season, following the development of field-screening technique in 1981. At F3, 10 plants/line were screened and 157 smut-free plants were selected for evaluation as F4 lines (Table 4.4.3). Most of the lines showed high levels of resistance (≤5% severity) at F3 stage combined with good agronomic traits.

4.4.4. Evaluation of promising smut resistant F3 lines. During the 1981 rainy season selected F3 lines from crosses involving 14 smut resistant lines were screened at 3 locations Hissar, ICRISAT Center and Bambey in a 2-replicate trial. Screening was done by inoculations at ICRISAT Center and Hissar and simply by bagging (without inoculation) at Bambey. Smut reactions of 43 F3 lines and their 5 parents are presented in (Table 4.4.4). Eight of the 43 F3 lines remained smut-free at all 3 locations, 17 entries showed mean severities of not more than 1% and the remaining lines had mean severities between 2 and 11% compared with 43% severity on the susceptible check (ICH-220) (Table 4.4.4). Among

5 parents only SSC-FS-252-S-4 remained smut-free while the remaining 4 had mean smut severities between 7 and 16%.

4.4.5. Smut resistant agronomic elite lines: In the smut nurseries at Hissar and ICRISAT Center, during the 1981 rainy season, in cooperation with breeders smut resistant lines were evaluated for their agronomic worth. Of about 1900 entries at Hissar we (RPT, SBC and KVSR) selected 49 entries which had desirable agronomic traits in addition to their high smut resistance and there were 11 common entries good at both locations (Table 4.4.5). Some of these lines are direct selection (S4 or S5) from germplasm lines and others from crosses between smut resistant lines at F4 or F5 stage. Several of these lines were included in the 1982 IPMSN for multilocational testing.

4.4.6. Evaluation of advanced smut resistant lines (F5 and S5): Smut resistant selections from the 1981 screen were grouped into three height groups -tall, medium-tall, and dwarf and were screened during the 1982 rainy season at ICRISAT Center following the improved screening technique. A minimum of 10 plants were inoculated in each line. Of 1065 lines screened more than 90% of the lines showed very high levels of smut resistance (Table 4.4.6). Among the tall entries, which are mainly selections from germplasm lines, 89% of 487 entries, 96% of 486 medium tall entries, and 94% of 63 dwarf entries showed $\leq$ 5% smut severity. Most of the medium-tall and dwarf entries are the progenies selected from crosses involving smut resistant lines. The basis of grouping into three height groups is the height of

BJ-104 which we considered a medium tall entry.

This has been an interesting exercise in selecting smut resistant lines in various height classes which will be useful to breeders.

4.5. Resistance utilization

4.5.1. Improvement for agronomic traits: Two germplasm lines, EB 237-3-1 and EB 132-2 which remained smut-free during the 1977 screening at Hissar, were crossed to 5 agronomic elite inbreds [(B282 x J804-1-21-2), (J25-1 x 700797-1-5-2), (J934-7 x 700797-19-1-5), (J104 x 700441-6-1), (70-1 x 700594-5-1)] developed in the breeding program. Crosses were made during the summer 1978 (by BST) and 50 F1s were generated. Progenies (F1 to F4) were screened during the rainy seasons 1978 to 1981 at Hissar and selections for smut resistance were made at each generation following pedigree selection method. Starting with 50 crosses at F1 and F2 generations, only 8 crosses provided most resistant plants upto F4 generations. All 158 F4 progeny lines screened during the 1981 rainy season, showed high levels of smut resistance (≤5% mean severity) and 166 smut-free plants were selected from 47 F4 lines for further evaluation (Table 4.5.1a). These were grouped into tall, medium tall and dwarf entries and screened alongwith other entries during the 1982 rainy season at ICRISAT Center (Table 4.4.6). Several of these lines which showed good agronomic traits were included in the IPMSN for multilocational testing in 1982. Some of these lines were also used by breeders in developing synthetics and as resistance

sources in the hybrid program.

Another attempt was made (by KAK) to cross smut resistant lines to EC-298-3, a high tillering, early maturing line. Seven smut resistant lines with smut severity range of 0 to 8% were crossed with EC-298-3 during the summer 1979 and 7 F1s were generated. Progeny lines (F1 to F3) were screened at Hissar during the 1979-'81 rainy seasons and F4 lines were screened at ICRISAT Center during the 1982 rainy season. At each generation smut-free, high-tillering plants were selected. At F4, 25 of the 26 lines showed high levels of smut resistance (≤ 5% severity) but only 2 plants with desired agronomic traits could be selected (Table 4.5.1b).

4.5.2. Transfer of smut resistance in ICM ms 81. Progenies derived from the mutagen treated 23 D2A and B showed high susceptibility to smut during the 1977 rainy season at Hissar. To incorporate smut resistance into downy mildew resistant version of 23 D2B, crosses were made between 23 D2B (Improved) X smut resistant lines in summer 1978. Five smut resistant lines (EB 24-1, EB 74-3, EB 137-1-1, WC FS 148 and SSC FS 252) which showed < 1% smut severity were used to generate 18 F1s (plant x plant). F1s were grown in the 1979 rainy season at Hissar and F2 (10 rows of 4m each) in the 1980 rainy season. Screening was done by inoculating only dwarf plants in each population. Sixty seven smut resistant plants (≤ 10% smut) were selected and these were grown as F3 lines during the 1981 summer season at ICRISAT Center to make test crosses onto ICM ms 81 primarily to evaluate the maintenance ability. In the 1981 rainy season, test crosses (57

only) and the F4 progenies (66) were evaluated in the smut nursery at Hissar.

Test crosses showed higher susceptibility to smut than F4 progenies where 57 of 66 F4 lines had ≤ 10% smut severity compared with only 1 of the 57 test crosses with < 10% severity (Table 4.5.2). Test crosses were evaluated for their sterile/fertile reactions at ICRISAT Center. Of 57 test crosses, 23 were sterile, 19 fertile, 10 sterile/fertile and 5 fertile/sterile depending on the frequency of sterile plants in the entry. The mean smut severity on sterile test crosses was more (47%) than on fertile test crosses (34%) with range varying from 10 to 85% for steriles and 16 to 53% for fertiles.

From 66 F4 lines screened at Hissar in the 1981 rainy season, 95 smut resistant plants were selected which were screened as F5 lines at ICRISAT Center in the 1982 rainy season. Fifty of 95 F5 lines showed ≤ 10% smut severity and 62 smut free heads were selected for further testing.

During summer 1982, 88 F5 lines (23 D2B(I) X SR) were identified as maintainers on 81 A and these were evaluated in the 1982 rainy season. Results of smut reactions are summarised in Table 4.5.2. Fortythree (49%) of 88 lines showed ≤ 10% smut and these are being used as recurrent parents in a backcross program with 81 A to convert them to ms lines.

4.5.3. Smut resistant lines as pollinators. Nine smut resistant

lines were used as pollinators on three ms lines (111A,5054A and 5141A) and 12 hybrids were produced during the summer 1982 (by BST). These hybrids and pollinators were evaluated for smut reactions in the 1982 rainy season.

Eight of the nine pollinators remained smut-free while one (P-10-S-1-2) developed 25% smut severity. All the hybrids showed susceptibility with mean smut severity ranging from 21 to 65% compared with 52% on BJ-104 and 79% on ICH-220 (Table 4.5.3). All the three ms lines were highly susceptible (mean severity range 53-84%). The two established pollinators J-104 and ICP-220-2 developed smut severities of 8 and 45%, respectively. The results thus indicate resistance to smut is recessive and therefore to obtain smut resistant F1 hybrid, both parents should have adequate resistance.

4.5.4. Smut resistant synthetics. Using 13 smut resistant F4 lines, (derived from crosses between smut resistant lines) selected during the 1981 rainy season in the smut nursery for high smut resistance coupled with good agronomic traits at Hissar, 2 synthetics were constituted (by SBC) in the 1981 summer at ICRISAT Center. These synthetics, ICMS-4 and ICMS-5 were evaluated for smut reactions in the 1982 rainy season in a replicated trial. Both synthetics showed high smut resistance with mean severity of < 1% compared with 52 and 79% severities on BJ-104 and ICH-220, respectively (Table 4.5.4). These also appeared promising for grain yields.

4.5.5. Smut resistant composite. A smut resistant composite was

constituted using 37 smut-low-susceptible lines in 1978 (By SCG) and its Co progenies (562) were screened in the 1980 rainy season at Hissar. C1 progenies (244) were screened during the 1981 rainy season at Hissar and C2 (712) at ICRISAT Center in the 1982 rainy season. Screening and selecting progeny lines for high levels of smut resistance continued. A large proportion of progenies at each generation (Co-78%, C1-97%, C2-86%) showed adequate levels of smut resistance (≤10%) (Table 4.5.5a).

From the C1 progenies nine experimental varieties were produced which had mean smut severities between 4 and 23% and 4 of these showed not more than 10% mean smut severity (Table 4.5.5b). These varieties, however, did not show high grain yield potential.

Table 4.2.1a. Growth and culture characteristics of *Tolyposporium penicillariae* grown on different media at 35°C

Medium	Topography	Colour	Margin	Consistency
Potato extract	Thin colonies floating on the surface of the medium	Dull white	Wavy	Membranous
Potato pieces	Raised, finely ridged	Dull white-white	Lobate	Leathery
Potato agar	Thick, flat, broadly ridged appearing like a frilled structure	Dull White	Wavy & Lobate	Yeastoid
Potato dextrose agar	Raised shiny colonies	Dull White	Entire	Yeastoid
Carrot extract	Thin layer covering the entire surface of the medium	Creamy	Entire	Membranous
Carrot pieces	Raised, finely ridged	White & Creamy	Wavy	Leathery
Carrot agar	Shiny colonies, raised in the centre, thin at periphery	Yellowish White	Entire	Yeastoid

Table 4.2.1b. Culture characteristics of Tolyposporium penicillariae on potato agar at five temperatures of incubation

Parameter	Temperature of incubation (°C)				
	20	25	30	35	40
Mean colony size[a] (mm)	9.7x6.8	10.0x7.5	11.5x8.6	12.6x9.4	1.9x1.1
Type of growth	Sporidial	Sporidial	Sporidial	Sporidial	Sporidial
Colour of colony	Dull white-white	Dull white-white	Dull white	Dull white	Dull white

[a] Mean of 12-88 colonies in 5 replications.

Table 4.2.2a. Smut severity and seed set in five pearl millet lines following various inoculation (inoc.) and pollination (poll.) treatments in field and screenhouse experiments

Treatment[a]	Smut severity (%)						Seed set (%)					
	Field experiments		Screenhouse experiments[d]				Field experiments		Screenhouse experiments			
	ICH-220[b]	5054-A[c]	BJ-104	BK-560	5141-A	5054-A[e]	ICH-220[b]	5054-A[c]	BJ-104	BK-560	5141-A	5054-A[e]
Inoc., no poll.	25	43	88	77	74	43	<1	<1	<1	<1	0	5
Inoc., poll.	1	4	8	21	32	2	82	76	74	71	45	84
No inoc., no poll.	0	0	0	0	1	0	0	<1	15	22	1	0
No. inoc., poll.	0	0	0	0	<1	0	85	83	91	86	86	90
LSD (P=0.05)	7.6	3.6	3.5	10.1	9.2	5.8	6.5	2.9	11.7	14.4	12.4	6.3

[a] In each treatment inoculations were made at the boot-leaf stage and pollinations were made at the maximum stigma-emergence stage, 5-8 days after inoculation.

[b] Based on observations of 20 inflorescences/treatment.

[c] Based on observations of 100 inflorescences/treatment.

[d] Based on observations of 10 inflorescences/treatment.

[e] A separate experiment was conducted without the provision of high humidity.

Table 4.2.2b. Effects of inoculation (inoc.) and pollination (poll.) using low-viability (LVP) and viable pollen (VP) on smut development and seed set in a pearl millet male-sterile line (5054-A)

Treatment[a]	Smut severity (%)[b]	Seed set (%)[b]
Inoc., no poll.	81	0
Inoc., poll. with VP	2	84
Inoc., poll. with LVP	68	4
No. inoc., no poll.	0	<1
No. inoc., poll. with VP	0	83
No inoc., poll. with LVP	0	10
LSD (P=0.05)	15.3	21.2

[a]In each treatment inoculation was done at the boot-leaf stage and pollination was done at the maximum stigma-emergence stage, 5-8 days after inoculation.

[b]Mean of 10 inflorescences/treatment.

Table 4.2.3a. Effect of different sources of Tolyposporium penicillariae inoculum on percent smutted florets in pearl millet male-sterile lines and hybrids

Inoculum source[a]	Experiment location and pearl millet line[b]					
	Screenhouse			Field		
	5054-A	5141-A	BJ-104	BJ-104 I	BJ-104 II	ICH-105
Sterile distilled water (check)	<1	0	0	0	<1	0
3-5 day culture[c]	73	74	86	54	-[d]	68
15-20 day culture[c]	80	73	75	39	29	56
>60 day culture[c]	71	43	41	-[d]	-	-
Sporeballs soaked in water for 24 hr	35	10	15	18	13	16
L.S.D. ($P<0.05$)	13.3	12.3	14.5	20.1	5.3	14.7

[a] Sporidial suspens on (ca $1x10^6$ sporidia/ml) was used to inoculate the tillers at the 'boot' stage.

[b] Mean of 10-20 inflorescences/treatment.

[c] Growth at 35 C on potato agar.

[d] Treatment not included.

Table 4.2.3b. Effect of flowering stage at time of inoculation on percent smutted florets in a pearl millet hybrid and male-sterile line

Flowering stage at inoculation	Inoculation method	Expt. location and pearl millet line		
		Screenhouse expt.[b]		Field expt.[c]
		BJ-104	5054-A	BJ-104
Boot leaf	Injection	63	95	29
Early stigma-emergence	Spray	41	55	<1
Full stigma-emergence	Spray	6	30	<1
Anthesis	Spray	0	0	0
L.S.D. ($P<0.05$)		13.9	3.2	9.5

[a] Mean of 10-15 inflorescences per treatment.

[b] Polythene bags were used to cover the inoculated boots.

[c] Conducted at Hissar without sprinkler irrigation.

Table 4.2.3c. Effect of concentration of Tolyposporium penicillariae sporidial suspensions on smut development in two pearl millet hybrids

Sporidial conc.[a] (sporidia/ml)	Smutted florets (%)	
	Field expt.[b]	Screenhouse expt.[c]
	BJ-104	ICH-220
Sterile distilled water (check)	<1	2
0.7×10^5	78	54
0.5×10^6	79	55
3.2×10^6	87	54
2.4×10^7	87	57
L.S.D. ($P<0.05$)	6.7	25.4

[a] Obtained as water dilution from 10-day growth on potato agar at 35 C.

[b] Mean of 20 inflorescences per treatment.

[c] Mean of 10 inflorescences per treatment.

Table 4.2.3d. Effect of type of bags on smut development in a pearl millet hybrid and two male-sterile lines

Treatment	Smutted florets (%)[a]					
	Screenhouse experiment			Field experiment		
	BJ-104	5141-A	5054-A	BJ-104		5141-A
				I[b]	II	
Non-inoculated check	0	0	0	0	1	0
Inoculated[c], no bag	<1	<1	0	0	3	<1
Inoculated, Parchment bag	26	34	2	54	78	79
Inoculated, Polythene bag	82	83	73	23	57	11
L.S.D. ($P < 0.05$)	10.9	12.9	7.0	13.5	5.5	6.5

[a] Mean of 10-15 inflorescences per treatment.

[b] Conducted during summer (March) 1980 without sprinklers.

[c] *T. penicillariae* sporidial suspensions (ca $1x10^6$ sporidia/ml) from 10-day growth on potato/carrot agar was used for inoculating tillers at the boot leaf-stage.

Table 4.2.3e. Relative humidity and temperature during the period from inoculation to smut assessment, and smut development in a pearl millet hybrid and a male-sterile line

Season	Inoc. to disease assessment period	Average Temp.C		Average RH (%)		No. of hours RH	Smut severity (%)	
		Min.	Max.	Min.	Max.	>80%	ICH-220	5054-A
Rainy'81	21 Aug.-9 Sep.	20.4	24.5	73.0	87.4	16.2	92[a]	92[b]
Post-rainy '81-'82	3 - 22 Feb.	19.8	26.7	52.1	85.5	7.6	19[b]	17[b]

[a] Mean of 40 inflorescences.

[b] Mean of 10 inflorescences.

Table 4.2.3f. Screening of pearl millet lines for smut resistance at ICRISAT Center during the 1981 rainy season

Nursery or plant material evaluated	No. of entries	Smut severity (%)[a]		No. of plants inoculated	Smut-free plants selected (%)
		Mean	Range		
F_1 hybrids[b]	38	72	10-92	760	0
Populations[b]	36	46	8-82	720	0
Local Collections[b]	17	23	8-47	340	0
PMSN[c]	39	4	0-20	1560	11
IPMSN[d]	29	4	0-28	1160	9.5
F_3 Smut Res. Bulks[e]	43	1	0-22	1720	15
Susc. Check (ICH-220)	1	85	80-91	40	0

[a] Overall mean and range of entry means based on 20-40 inoculated plants per entry.

[b] Entries from All India Coordinated Millet Improvement Projects (AICMIP).

[c] Pearl Millet Smut Nursery.

[d] International Pearl Millet Smut Nursery.

[e] Smut resistant F_3 lines developed at ICRISAT-Hissar sub-center.

Table 4.3.1. Summary of the smut reactions[a] of Advanced Smut germplasm selections in different trials and selections from Smut Resistant Composite

Season screened	Trial	No. of[b] entries screened	No. of entries in smut severity(%) class				No. of plants selected
			0-5	6-10	11-20	>20	
Rainy '81	ASS(S_4)	499	470 (94)	19 (4)	9 (2)	1 (<1)	340 [79]
Rainy '82	1981 PMSN Sel[c]	306	259 (85)	23 (7)	11 (4)	13 (4)	212 [47]
Rainy '82	1981 IPMSN Sel[c]	111	101 (91)	6 (5)	4 (4)	0 (0)	78 [18]
Rainy '82	1981 IPMDMN Sel[c]	9	7 (78)	1 (11)	1 (11)	0 (0)	0
Rainy '82	1981 SRC Sel[c]	50	37 (74)	5 (10)	7 (14)	1 (2)	8 [2]

[a] Mean of 10 inoculated heads.

Figures in the parentheses are percentage of entries.

[b] Lines representing Ex-Bornu, NW, (700713 x SC-2(M)-3-7-4), F_4FC P lines, 3/4 Ex-Bornu, ND, ICI, WC FS, SSC FS, IP, SDN etc.

Figures in the square brackets represent the no. of entries selected.

[c] Selections from screens in the 1981 rainy season at ICRISAT Center.

Table 4.3.2. Summary of smut reactions[a] of 74 and 72 entries in four AICMIP trials at ICRISAT Center during 1981 and 1982[b] rainy seasons respectively

Trial	No.of entries		No.of entries in severity (%) class							
	1981	1982	0-10		11-20		21-50		>50	
			1981	1982	1981	1982	1981	1982	1981	1982
IPMHT-I	17	21	1	3	0	1	2	12	14	5
APMHT-II	21	19	0	4	1	6	1	7	19	2
IPMPT-IV	17	15	1	9	2	3	9	2	5	1
APMPT-V	19	17	0	6	0	8	8	3	11	0
Percentage of entries			3	31	4	25	27	33	66	11

[a] Mean of 10-20 inoculated heads.

[b] Screened without sprinkler irrigation.

Table 4.3.3. Summary of the smut reactions[a] of 109 entries in four initial smut screening trials at Hissar during the 1981 rainy season

Trial	No. of entries	No. of entries in smut severity (%) class			
		0-10	11-20	21-50	>50
PMIST-2	25	23	2	0	0
IPMAT-7	21	16	3	1	1
IPMEN	20	19	1	0	0
IPMDMN	43	37	5	1	0

[a]Mean of 10 inoculated heads

In IPMEN, although there were 32 entries, only 20 were screened, so also in IPMDMN 2 entries were late and hence not screened.

Table 4.3.4. Summary of the smut reactions[a] of 39 and 34 entries in the Pearl Millet Smut Nursery during the 1981 and 1982 rainy seasons respectively

Smut severity (%) class	No. of entries in severity class			
	ICRISAT Center		Hissar	
	1981	1982	1981	1982
≤ 5	30	33	39	31
6-10	4	1	0	2
11-20	5	0	0	1
>20	0	0	0	0

[a]Mean of 40 inoculated heads in two replications at each location.

Table 4.3.5. Smut reactions of six common test entries for 5 years across four locations in India and West Africa

Entry	HISSAR					ICRISAT CENTER					JAMNAGAR					BAMBEY					Overall mean
	78	79	80	81	82	78	79	80	81	82	78	79	80	81	82	78	79	80	81	82	
SSC FS 252-S-4	0	0	0	-	0	-	-	0	0	0	1	1	0	0	0	<1	1	0	-	1	<1
ICI 7517-S-1	0	0	0	<1	<1	-	-	0	0	<1	<1	<1	0	<1	0	1	0	1	0	<1	<1
700130-S-1-DM-1	2	1	<1	-	0	-	-	1	2	1	1	<1	<1	1	0	16	5	1	0	1	2
EB 132-2-S-5-2-DM-1	6	2	<1	1	<1	-	-	<1	1	<1	2	1	<1	1	0	24	7	<1	2	<1	3
P-20-S-1	2	2	3	1	1	-	-	15	9	3	<1	<1	14	4	3	1	3	6	18	3	5
P-10-S-1	1	<1	<1	1	3	-	-	7	26	12	<1	0	1	10	10	<1	1	3	24	1	6
Susceptible check	15	25	30	11	36	-	-	61	91	72	4	11	31	18	58	17	11	31	84	24	34

(-) Trial not conducted/data not provided.

Table 4.4.1. Summary of the progress made in developing smut resistance in crosses involving low susceptible lines

Generation[a]	Season and year	No. of lines screened	No. of crosses represented	No. of plants screened		No. of plants selected	No. of lines in smut severity (%) class			
				Min./ line	Total/ generation		0-5	6-10	11-20	>20
F_1	Rainy '78	86[b]	86	10	860	85	85	1	0	0
F_2	Rainy '79	117	117	20	2340	167	93	15	7	2
F_3	Rainy '80	166(31 F_2)	31	20	3320	529	138	18	8	2
F_4	Rainy '81	514(87 F_3)	28	10	5140	514(112 F_4)	508	3	3	0
F_5	Rainy '82	513(112 F_4)	24	10	5130	599(115 F_5)	466	26	15	6

[a] All generations except F_5 were screened at Hissar and F_5 generation was screened at ICRISAT Center

[b] Only 86 of the 118 F_1s were screened.

One cross was discarded out of 86 at F_1 generation.

Table 4.4.2. Summary of the progress made in developing smut resistance in crosses involving smut low susceptible lines

Generation[a]	Season and year	No. of lines screened	No. of crosses represented	No. of plants screened		No. of plants selected	No.of lines in smut severity (%) class			
				Minimum per line	Total per generation		0-5	6-10	11-20	>20
F_1	Not screened		-	-	-	-	-	-	-	-
F_2	K'80	5	5	100	500	123	3	0	2	0
F_3	K'81	122(4 F_2)	4	10	1220	90(20 F_3)	121	1	0	0
F_4	K'82	90(20 F_3)	4	10	900	127(25 F_4)	81	4	4	1

[a] F_2 and F_3 screened at Hissar and F_4 at ICRISAT Center.

Parents	Smut severity(%) in K'78
SSC FS 252	0
EB 137-1-1	<1
WC FS 148	<1
EB 24-1	<1

Table 4.4.3. Summary of the progress made in increasing the levels of smut resistance from F_1 to F_3 generations in crosses involving smut low susceptible lines

Gene-ration[a]	Season and year	No. of lines screened	No. of crosses represented	No. of plants screened		No. of plants selected	No. of lines in smut severity (%) class			
				Minimum per line	Total per generation		0-5	6-10	11-20	>20
F_1	Rainy '80	4	4	20	80	4	4	0	0	0
F_2	Rainy '81	4	4	200	800	133(4)	4	0	0	0
F_3	Rainy '82	133	4	10	1330	157(34)	132	1	0	0

[a] F_1 and F_2 screened at Hissar and F_3 at ICRISAT Center

Parents	Smut reaction in K '79
ICI 7517-S-1	<1
SSC FS 252-S-4	<1
P-10-S-1	<1
WC FS 151-S-1-1	<1
EB 229-4-1-S-6-1	<1

Table 4.4.4. Summary of the smut reactions of 43 smut resistant F_3 (smut low susceptible x low susceptible) entries and their parents during the 1981 rainy season with across location entry means and across entry location means

Sl. No.	Entry	Smut severity(%) at Hissar	ICRISAT Center	Bambey	Mean[a]	Range
1	EBS 137-2 x (J1623 x WC6-3)	0	0	-	0	0-0
2	(EB 137-1-1 x SSC FS 252)-2	0	0	0	0	0-0
3	(EBS 137-2 x SSC FS 252)-4	0	0	0	0	0-0
4	(EB 117-2-1 x EBS 137-2)-3	0	0	0	0	0-0
5	(ExB132-2 S-'75 x J25-1x700797-1-5-2)-2	0	0	-	0	0-0
6	ExB132-2 S-'75x(J25-1xJ1623-21-4)	0	0	-	0	0-0
7	ExB237-3-1 S-'76x(J104x700441-6-1-1)	0	0	-	0	0-0
8	(EB237-3-1 x 111B)-2-9	0	0	-	0	0-0
9	(EB137-1-1 x WC FS 139)-4	<1	0	-	<1	0-1
10	(IP2253 x EB237-3-1)-1	0	0	<1	<1	0-1
11	(J1623xWC6-3)xEB237-3-1	<1	0	0	<1	0-1
12	(EB237-3-1 x SSC FS 252)-1	<1	0	-	<1	0-1
13	(EB 137-1-1 x EB 209-1-6)	<1	0	0	<1	0-1
14	(EB 137-1-1 x EB 117-2-1)-9	0	0	<1	<1	0-1
15	ExB237-3-1 S-'76x(B282xJ804-1-21-2-)	<1	0	1	<1	0-1
16	(EB 137-1-1 x SDS FS40)-4	<1	<1	-	<1	0-2
17	(EBS 137-2 x EB 137-1-1)-1	<1	<1	-	<1	0-2
18	(ExB132-2 S-'75x(J25-1x700797-1-5-2)-1	1	<1	-	<1	0-2
19	(EB 137-1-1 x EB 117-2-1)-3	<1	<1	<1	<1	0-3
20	(SDS FS 135xSSC FS 252)-5	<1	<1	1	<1	0-5
21	(ExB132-2 S-'75x70-1x700594-5-1)-3	-	0	1	<1	0-5
22	(EB 137-1-1 x SSC FS 252)-5	0	0	2	1	0-5
23	(EB 137-1-1 x EB 132-2)-5	<1	0	3	1	0-10
24	(WC FS 135 x SSC FS 252)-2	<1	2	1	1	0-20
25	(EB 137-1-1 x SDS FS 40)-1	1	<1	3	1	0-25
26	(EB 137-1-1- x EB 117-2-1)-2	0	<1	5	2	0-20
27	(IP 2253 x WC FS 139)-1	<1	0	5	2	0-30
28	ExB237-3-1 S-'76x(J934-7x700797-19-1-5)-7	1	2	7	3	0-35
29	(EB 137-1-1 x WC FS 139)-6	<1	0	10	3	0-40
30	(EB 117-2-1 x SDS FS 40)-2-1	2	3	3	3	0-50
31	(EB 132-2 x SSC FS 252)-1	<1	1	8	3	0-60
32	(IP 2253 x EB 237-3-1)-6	<1	0	9	3	0-70
33	ExB 132-2 S-'75x(70-1x700594-5-1)-4	-	3	5	3	0-80
34	(EB 137-1-1 x EB 132-2)-1	1	1	9	4	0-60
35	(EB 237-3-1 x SSC FS 252)-6	<1	8	10	6	0-70
36	(EB 117-2-1 x SSC FS 252)-11	9	5	3	6	0-80
37	(SDS FS 135 x SSC FS 252)-3	1	<1	17	6	0-85
38	(J 1623 x WC6-3)x(IP 2253)-3	0	0	19	6	0-90

39	(WC FS 135 x SSC FS 252)-3	1	<1	19	7	0-85
40	(EBS 137-2 x SDS FS 135)-2-5	1	1	18	7	0-90
41	ExB237-3-1 S-'76x(J104x700441-6-1)-6	15	1	-	8	0-60
42	(EB 137-1-1 x SDS FS 135)-1	<1	3	24	9	0-80
43	(EB 117-2-1 x WC FS 139)-1	2	22	9	11	0-40
	Location means	1	1	6	2	
	Trial check (ICH-220)	36	85	9	43	0-98
	Parents					
1	SSC FS 252-S-4	-	0	0	0	0-0
2	WC FS 139	<1	2	19	7	0-80
3	EB 209-1-6	2	4	31	12	0-80
4	EB 117-2-1	13	20	16	16	0-80
5	SDS FS 40	6	12	30	16	0-80

[a]Mean of 10-40 inoculated heads in 2 replications at each location.

Table 4.4.5. Smut resistant, agronomic elite entries identified during the 1981 rainy season screening at Hissar and ICRISAT Center.

S1 No.	1981 Ent. No.	Entry	Smut[a] Sev. (%)	Range
1	10	ND 2282-79-1-S-1-1-DM-1*	2	0-76
2	12	700479-S-6-1-DM-1*	1	0-35
3	13	EB 66-1-S-5-DM-1*	0	0-0
4	16	EB 137-2-S-2-2-DM-1*	1	0-2
5	17	EB 137-1-2-S-1-1-DM-1*	1	0-1
6	19	EB 188-2-3-S-1-DM-1*	2	0-25
7	20	EB 229-4-1-S-1-DM-1*	2	0-25
8	26	WC FS 346-S-2-2-DM-1*	8	0-75
9	32	F_4FC 1536-3-6-S-1*	1	0-25
10	34	F_4FC 1196-3-1-S-1*	3	0-50
11	37	(700713 x SC-2(M)3-7-4-2)-S-4-5*	1	0-20
12	220	(700713 x SC-2(M)3-7-4-2)-S-4-5-1*	0	0-0
13	357	P-489-S-2-10*	0	0-0
14	358	P-489-S-2-11*	0	0-0
15	360	P-489-S-2-13*	0	0-0
16	367	P-489-S-3-7*	0	0-0
17	93	SRC 252-1-1*	0	0-0
18	144	SRC 123-1-1*	0	0-0
19	20	(SSC FS 252 x EB 137-1-1)-20*	1	0-1
20	18	(WC FS 135 x SSC FS 252)-2-1*	1	0-5
21	32	(SDS FS 135 x SSC FS 252)-2-1*	0	0-0
22	33	(EB 137-1-1 x WC FS 139)-6-7*	0	0-0
23	104	(EB 137-1-1 x SDS FS 40)-4-2*	0	0-0
24	106	(EB 137-1-1 x SDS FS 40)-4-4*	0	0-0
25	109	(EB 137-1-1 x SDS FS 40)-4-7*	1	0-1
26	21	(J 1623 x WC 6-3) x (EB 237-3-1)-5-1**	0	0-0
27	22	(J 1623 x WC 6-3) x (EB 237-3-1)-5-2*	0	0-0
28	23	(J 1623 x WC 6-3) x (EB 237-3-1)-5-3*	0	0-0
29	26	(J 1623 x WC 6-3) x (EB 237-3-1)-5-6*	1	0-1
30	27	(J 1623 x WC 6-3) x (EB 237-3-1)-5-7*	0	0-0
31	99	(EB 137-1-1 x SSC FS 252)-1-3*	0	0-0
32	111	(EB 137-1-1 x SSC FS 252)-3-6*	0	0-0
33	123	(EB 137-1-1 x SSC FS 252)-5-7*	0	0-0
34	206	(EB 137-1-1 x EB 117-2-1)-1-4*	0	0-0
35	218	(EB 137-1-1 x EB 117-2-1)-3-1*	0	0-0

Sl No	1981 Ent. No.	Entry	Smut[a] Sev. (%)	Range
36	234	(EB 137-1-1 x EB 117-2-1)-5-4*	0	0-0
37	250	(EB 137-1-1 x EB 117-2-1)-9-1*	0	0-0
38	252	(EB 137-1-1 x EB 117-2-1)-9-3**	0	0-0
39	6	ExB 132-2 S-'75 x (70-1 x 700594-5-4)-2-1*	0	0-0
40	7	ExB 132-2 S-'75 x (70-1 x 700594-5-1)-2-2*	0	0-0
41	8	ExB 132-2 S-'75 x (70-1 x 700594-5-1)-2-3*	<1	0-1
42	24	ExB 132-2 S-'75 x (70-1 x 700594-5-1)-4-3*	0	0-0
43	73	ExB 132-2 S-'75 x (J25-1 x 700797-1-5-2)-5-5*	1	0-2
44	81	ExB 132-2 S-'75 x (J25-1 x J1623-21-4(P-1)-6*	<1	0-2
45	93	ExB 237-3-1 S-'76 x (B282 x J804-1-21-2)-1-6*	0	0-0
46	129	ExB 237-3-1 S-'76 x (J934-7 x 700797-19-1-5)-5-2*	0	0-0
47	131	ExB 237-3-1 S-'76 x (J934-7 x 700797-19-1-5)-5-4*	0	0-0
48	147	(ExB 237-3-1 x 111B)-2-4*	0	0-0
49	148	(ExB 237-3-1 x 111B)-2-5*	0	0-0
50	1	(IP 2253 x WC FS 139)-1	2	0-30
51	2	(WC FS 135 x SSC FS 252)-2	1	0-20
52	9	(EB 137-1-1 x SDS FS 40)-4	4	0-80
53	14	(IP 2253 x EB 237-3-1)-1	<1	0-1
54	20	(J1623 x WC 6-3) x (EB 237-3-1)	0	0-1
55	24	(EBS 137-2 x (J1623 x WC 6-3)	13	0-80
56	25	(EB 137-1-1 x SSC FS 252)-2	0	0-0
57	26	(EB 137-1-1 x SSC FS 252)-5	1	0-5
58	32	(EB 137-1-1 x EB 117-2-1)-9	<1	0-1
59	42	ExB 237-3-1 S-'76 x (J934-7 x 700797-19-1)-5-7	3	0-35
60	43	(EB 237-3-1 x 111B)-2-9	2	0-20
		ICH 220 (Check) at Center	85	40-98
		ICH 220 (Check) at Hissar	36	5-70

[a] Mean of 10-20 inoculated heads/entry.

* Agronomically elite lines at Hissar.

** Entries 50-60 were selected both at ICRISAT Center and Hissar.

Table 4.4.6. Summary of smut reactions[a] of smut resistant F_5 and S_5 lines in three height groups, screened during the 1982 rainy season at ICRISAT Center

Material	No. of entries	Number of entries in smut severity class			
		<5%	6-10%	11-20%	>20%
SR tall	487	435 (89)	27 (6)	20 (4)	5 (1)
SR med-tall	486	465 (96)	12 (2)	4 (1)	5 (1)
SR dwarf I	17	16 (94)	0 (0)	1 (6)	0 (0)
SR dwarf II	46	43 (94)	2 (4)	1 (2)	0 (0)
SR Ag.elite	29	12 (41)	16 (55)	1 (3)	0 (0)
Total	1065	971 (91.2)	57 (5.3)	27 (2.5)	10 (1.0)

[a] Based on the mean of 10 inoculated inflorescences/entry.

Figures in parenthses are the percentage values.

Table 4.5.1a. Summary of the progress made in increasing the levels of smut resistance from F_1 to F_4 generations in crosses involving smut low susceptible and agronomically elite lines

Gene-ration[a]	Season screened	Lines screened	Crosses repre-sented	Plants screened		No.of lines in smut severity (%) class			
				Minimum per line	Total per generation	0-5	6-10	11-20	>20
F_1	Rainy'78	50	50	10	500	48	2	0	0
F_2	Rainy'79	50	50	20	1000	32	13	4	1
F_3	Rainy'80	51(9 F_2)	9	20	1020	39	6	5	1
F_4	Rainy'81	158(25 F_3)	8	10	1580	158	0	0	0
F_5	Rainy'82	166(47 F_4)	7	10	1660[b]	159	4	2	1

[a]All generations were screened at Hissar except F_5 which was screened at ICRISAT Center.
[b]144 smut-free plants selected from 33 F_5 lines representing 7 crosses.

Parents	Smut severity (%) K'78
1. ExB 237-3-1	1
2. (B282xJ804-1-21-2)	2
3. ExB 132-2	3
4. (J25-1 x 700797-1-5-2)	4
5. (J934-7 x 700797-19-1-5)	7
6. (J104 x 700441-6-1)	18
7. (70-1 x 700594-5-1)	19

Table 4.5.1b. Summary of the smut reactions of the crosses between FC-298-3 and smut low susceptible lines at F_1, F_2 and F_3 generations at Hissar and F_4 generation at ICRISAT Center

Generation	Season screened	Lines screened	Crosses represented	Plants screened		No. of lines in smut severity (%) class			
				Minimum per line	Total per generation	0-5	6-10	11-20	>20
F_1	Rainy '79	7	7	10	70	6	1	0	0
F_2	Rainy '80	14	6	20	280	8	3	3	0
F_3	Rainy '81	81(9 F_2)	5	10	810	71	9	1	0
F_4	Rainy '82	26(8 F_3)	3	5	130[a]	25	0	1	0

[a]Only 2 plants were selected from 1 F_4 line

Parents	Smut severity(%) in K79
1. 700130-S-1	8
2. EB132-2-2-5-8	0
3. EB 116-1-1-S-7	0
4. EB 24-1-S-5	0
5. WC FS 148-S-1	<1
6. SSC FS 252-S-4	0
7. P-10-S-1	<1

Table 4.5.2. Summary of the smut reactions of F_4 ($23D_2B(I)xSR$) and test crosses on 81A at Hissar and F_5 ($23D_2B(I)xSR$) and maintainers on 81A at ICRISAT Center during the 1981 and 1982 rainy seasons respectively

Cross	No. of lines screened	No. of crosses represented	No of plants screened		No. of lines in the smut severity (%) class			
			Minimum per line	Total per generation/ season	0-10	11-20	21-50	>50
$F_4(23D_2B(I)xSR)$ [a]	66	8	10	660	57	4	3	2
$F_5(23D_2B(I)xSR)$ [a]	95(32 F_4)	8	5	475	50	12	28	5
$81AxF_4(23D_2BxSR)$	57	5	10	570	1	5	31	20
Maintainer $F_5(23D_2BxSR)$	88	4	10	880	43	13	21	11

a Parents

	Smut severity(%) in K78	
	Mean	Max.
1. SSC FS 252	0	0
2. EB 137-1-1	<1	5
3. EB 74-3	<1	2
4. EB 24-1-4	<1	2
5. WC FS 148	<1	5

Table 4.5.3. Smut reactions and days to boot leaf stage (DTBL) of the 12 hybrids, 9 pollinators and other lines during the '82 rainy season at ICRISAT Center

Sl.No.	Entry	DTBL	Smut severity (%)[a]			
			Rep 1	Rep 2	Mean	Range
1	111A x NEP 588-5690-S-8-4-1	40	32	10	21	1-75
2	111A x NEP 588-5690-S-8-4-2	43	19	25	22	1-50
3	111A x NEP 588-5690-S-8-4-3	43	29	17	23	1-75
4	5054A x ICI 7517-S-1-1	36	39	40	39	10-75
5	5054A x NEP 588-5690-S-8-4-3	33	54	26	40	10-80
6	5054A x NEP 588-5690-S-8-4-1	40	50	38	44	10-80
7	5054A x SSC FS 252-S-4-3	33	58	36	47	10-75
8	5054A x J 797-1-S-3-3	33	65	33	49	10-80
9	5054A x SSC FS 252-S-4-1	33	58	45	51	20-75
10	5054A x ICI 7517-S-1-2	36	66	57	61	40-75
11	5054A x P-10-S-1-2	33	79	52	65	30-90
12	5141A x J 797-1-S-3-3	40	74	56	65	40-85
	Pollinators					
13	SSC FS 252-S-4-1	48	-	-	0	0-0
14	SSC FS 252-S-4-3	48	-	-	0	0-0
15	ICI 7517-S-1-1	56	-	-	0	0-0
16	ICI 7517-S-1-2	43	-	-	0	0-0
17	J 797-1-S-3-3	37	-	-	0	0-0
18	NEP 588-5690-S-8-4-1	52	-	-	0	0-0
19	NEP 588-5690-S-8-4-2	48	-	-	0	0-0
20	NEP 588-5690-S-8-4-3	49	-	-	0	0-0
21	P-10-S-1-2	37	-	-	25	5-50
	Others					
22	5054A	50	-	-	62	30-90
23	5141A	62	-	-	84	50-95
24	111A	58	-	-	53	10-90
25	ICP 220-2	40	-	-	45	10-70
26	J-104-1	33	-	-	8	0-20
	BJ-104 (check)	34	-	-	52	30-75
	ICH-220 (check)	36	-	-	79	25-95

[a] Based on 5 inoculated heads/replication in hybrids and 5-10 inoculated heads/entry in pollinators and other lines.

(-) Data not available/planted in single rows.

Table 4.5.4. Smut reactions and days to boot leaf stage (DTBL) of 2 smut resistant synthetics during the 1982 rainy season at ICRISAT Center

Sl.No.	Synthetic	DTBL	Smut severity (%)			
			Rep 1	Rep 2	Mean	Range
1	ICMS-4	42	1	<1	<1	0-10
2	ICMS-5	37	1	<1	<1	0-20
3	BJ-104 (check)	34	50	54	52	30-75
4	ICH-220 (check)	36	88	70	79	25-95

[a]Mean of 40 heads in 2 replications.

Composition

(1) ICMS-4-(SSC FS 252xEB 137-1-1)-20
(WC FS 135 x SSC FS 252)-2-1
(EB 137-1-1 x WC FS 139)-6-7
(EB 137-1-1 x SDS FS 40)-4-2
(J 1623 x WC6-3)xEB237-3-1)-5-1
(EB 137-1-1 x SSC FS 252)-1-3
(EB 137-1-1 x SSC FS 252)-5-7
(EB 137-1-1 x EB 117-2-1)-9-3
(ExB132-2 S75x(70-1x700594-5-1)-2-1
(ExB132-2 S75x(J25-1x700797-1-5-2)-1-6
(ExB237-3-1 S76x(B282xJ804-1-21-2)-1-6
(ExB237-3-1 S76x(J934-7x700797-19-1-5)-5-2

(2) ICMS-5-(SSC FS 252 x EB 137-1-1)-20
(WC FS 135 x SSC FS 252)-2-1
(EB 137-1-1 x WC FS 139)-6-7
(EB 137-1-1 x SDS FS 40)-4-2
(J1623 xWC6-3)xEB237-3-1)-5-1
(EB 137-1-1 x EB 117-2-1)-9-3
(ExB132-2 S-75x(70-1x700594-5-1)2-
(ExB132-2 S-75x(J25-1x700797-1-5-2)-1-6
(ExB237-3-1 S76x(B282xJ804-1-21-2)-1-6
(ExB237-3-1 S76x(J934-7x700797-19-1-5)-5-2

Table 4.5.5a. Summary of the smut reactions[a/] of Smut Resistant Composite (SRC) progenies screened during 1980 and 1981 rainy seasons at Hissar and 1982 rainy season at ICRISAT Center

Composite	No. of progenies	No. of progenies in smut severity (%) class		
		0-10	11-20	>20
1980 SRC (C_0)	562	441 (78.5)	95 (16.9)	26 (4.6)
1981 SRC (C_1)	244	236 (96.7)	6 (2.4)	2 (0.8)
1982 SRC (C_2)	712	615 (86.4)	78 (10.9)	19 (2.7)

[a]Based on the mean of 10 inoculated heads in 1980 and 5 inoculated heads in 1981 and 1982.

Figures in the parentheses are the percentage of entries in each severity class.

Table 4.5.5b. Smut reactions and days to boot leaf stage (DTBL) of 9 SRC experimental varieties during the 1982 rainy season at ICRISAT Center

Sl.No.	Entry	DTBL	Smut severity (%)			
			Rep 1	Rep 2	Mean[a]	Range
1	SRC A81	37	7	2	4	0-40
2	SRC P8102	42	2	8	5	0-30
3	SRC P8101	39	14	1	7	0-60
4	SRC H8102	42	4	16	10	0-40
5	SRC P8104	36	6	26	16	0-75
6	SRC SREV	50	11	23	17	5-40
7	SRC P8103	36	21	17	19	1-60
8	SRC H8101	39	18	22	20	5-45
9	SRC P8105	42	36	10	23	1-75
	ICH-220 (check)	36	88	70	79	25-95

[a]mean of 5 inoculated heads.

5. SCREENING FOR MULTIPLE DISEASE RESISTANCE:

Summary

Screening for multiple disease resistance (downy mildew, ergot and smut) was initiated in summer 1982 and by the 1982 rainy season more than 1100 entries were screened. Downy mildew and smut resistance seem to be adequate in many entries while most entires were highly susceptible to ergot. Only ICRISAT Center-developed ergot resistant lines showed high levels of resistance to downy mildew, ergot, smut and also to rust in two seasons of screening.

Screening pearl millet germplasm lines and breeding materials simultaneously for resistance to downy mildew (DM), ergot, smut and rust (natural infection) was initiated during the summer 1982. The methodology involved space planting (20 cm between plants on 75 cm rows) of test lines in the DM-nursery which already had DM infector rows well-established. DM scores were taken 30 days after emergence (DAE) and the final scores at 45 DAE. In selected DM-free plants one tiller was inoculated with ergot and the second tiller of the same plant with smut. Observations for ergot and smut severities were recorded 20 days after inoculation and selfed seed of plants resistant to all three diseases were collected.

During the summer 1982, 303 entries, consisting of germplasm lines from Togo (178 S1), Ex Bornu (45 S1) and entries from IPMDMN, IPMEN, IPMSN and IPMRN were screened. Smut inoculations were not successful because of hot-dry weather during March-April but observations were recorded for DM, ergot, and natural rust incidence. Among the germplasm lines only 17% of Togo lines and 22% of Ex-Bornu showed <10% ergot severity while most entries (94-100%) were resistant to DM and rust. Again among the Disease Nursery entries except for IPMEN entries which had 85%, 100% and 100% of entries showing

resistance to DM, ergot and rust, respectively other nurseries had very few entries showing ergot resistance (Table 5.1).

During the 1982 rainy season 832 entries including AICMIP trial entries, Ghana germplasm lines, ICRISAT breeding lines and Disease Nursery entries (IPMDMN, IPMEN and IPMSN) were evaluated. DM and smut resistances were quite widespread in these lines but ergot resistance was rare except for the IPMEN entries which had combined resistance for DM and smut also (Table 5.2). Ergot, smut, DM and rust reactions of some of the ergot resistance entries in two years (1981 and 1982) are presented in Table 5.3.

The results of the two seasons of multiple disease screening indicate that because ergot resistance is most difficult to find and stabilise the strongest selection pressure should operate for ergot resistance first when this is required, and then for other diseases.

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Table 5.1. Summary of the results of screening pearl millet lines for multiple disease resistance at ICRISAT Center during the 1982 summer season (January-April)

Material	No. of entries	Percentage of entries resistant to		
		DM Inc.[a] (≤10%)	Ergot Sev.[b] (≤10%)	Rust Sev.[c] (≤10%)
IPMDMN	30	100	0	97
IPMRN	10	70	20	100
IPMEN	20	85	100	100
IPMSN	20	85	30	95
ExBornu(S_1)	45	100	22	100
Togo (S_1)	178	94	17	99

[a] Based on total and infected plant obs. in 2 replications 2 rows/entry/rep.

[b] Based on mean of 40 inoculated heads in two replications.

[c] Based on mean of two replications, 2 rows/entry/rep.

Table 5.2. Summary of results of screening pearl millet lines for multiple disease resistance at ICRISAT Center during the 1982 rainy season

Material	No. of entries	Percentage of entries resistant to		
		DM. Inc.[a] (≤10%)	Ergot[b] (≤10%)	Smut[c] (≤10%)
AICMIP:				
IPMHT- I	21	62	0	14
APMHT-II	19	74	0	21
IPMPT-IV	15	33	0	60
APMPT- V	17	64	0	35
Male Sterile lines	106	53	1	35
Others	18	50	0	44
Germplasm lines:				
Ghana	123	96	2	94
ICRISAT Breeding Trials				
PMST	25	88	0	84
PMHT	25	84	0	32
PMHT (P)	25	60	0	-
DSC Bulks	16	94	0	87
APVT	24	87	0	71
MDI	247	80	4	85
F5 Progenies (BxERL)	49	92	25	83
PATHOLOGY TRIALS				
IPMEN	29	93	79	100
IPMSN	28	86	3	100
IPMDMN	45	91	0	48

[a] Based on total and number of infected plants for each entry
[b] Mean of 10-20 bagged-inoculated heads.
[c] Mean of 5-20 inoculated-bagged heads of same plants inoculated earlier with ergot. Since inoculations were made in the later part of the dry season smut development was not adequate on test entries
(-) not inoculated.

Table 5.3. Ergot, smut, downy mildew (DM), and rust reactions of some of the ergot resistant entries during 1981 rainy (R) and 1982 Summer (S) and rainy seasons at ICRISAT Center

Entry[a]	Ergot sev. (%)			Smut sev. (%)		DM inc. (%)			Rust sev.(%)
	1981[b]	1982[d]		1981[b]	1982[d]	1981[c]	1982[d]		1982[d]
	R	S	R	R	R	R	S	R	S
ICMPE 134-6-25	<1	0	<1	0	0	0	0	0	0
ICMPE 134-6-41	<1	<1	<1	0	0	0	1	0	0
ICMPE 134-6-9	<1	1	0	0	-	0	1	0	0
ICMPE 134-6-11	<1	0	<1	0	0	0	0	5	0
ICMPE 140-3	1	<1	3	0	0	0	0	0	0
ICMPE 13-6-27	5	0	0	0	0	0	0	2	0
BJ-104 (Check)	83	67	94	54	48	32	5	51	40
WC-C 75 (Check)	74	-	66	3	2	2	-	5	-

[a] ICMPE-ICRISAT Millet Pathology Ergot, derived from crosses J2238xJ2210-2 and J606-2xJ2238.

[b] Based on 40 inoculated heads from two replications, both ergot and smut inoculations were made on tillers of the same plant.

[c] Based on DM reactions during the 1980/81 post-rainy season in ICRISAT Center DM nursery.

[d] Screening done in multiple disease nursery.

- data not recorded/entry not included.