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Effects of pollination on smut development in pearl millet*

R. P. THAKUR, K. V. SUBBA RAO *and* R. J. WILLIAMS
Pearl Millet Improvement Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), P.O. Patancheru, A.P. 502324, India

In field and screenhouse experiments, pollination of inflorescences of three pearl millet F_1 hybrids and two male-sterile (ms) lines with fresh viable pollen 5–8 days after inoculation with a *Tolyposporium penicillariae* sporidial suspension reduced smut severities significantly compared with inoculated, non-pollinated control plants. Smut development was not significantly reduced in a ms line following pollination of inoculated inflorescences with pollen of low viability. The implications of these findings in developing an effective screening technique for smut resistance and in controlling this disease in pearl millet are discussed.

INTRODUCTION

Pearl millet (*Pennisetum americanum* (L.) Leeke) is the staple cereal of the hot, drought-prone arid and semi-arid regions of Africa and the Indian sub-continent. The estimated average grain yields of pearl millet are 543 kg/ha in India and 595 kg/ha in Africa (Anon., 1980). In India, with the commercial cultivation of semi-dwarf, high-tillering, early-maturing and management-responsive F_1 hybrids, a substantial increase in grain yields over the traditional varieties has been demonstrated (Rachie & Majmudar, 1980). Several of the F_1 hybrids, unfortunately, have been highly susceptible to three fungal diseases, viz. smut, induced by *Tolyposporium penicillariae* Bref., downy mildew (*Sclerospora graminicola* (Sacc.) Schroet.) and ergot (*Claviceps fusiformis* Loveless). Bhatt (1946) reported that smut infection in pearl millet is not systemic but occurs through young emerging stigmas and is drastically reduced at anthesis. Thakur & Williams (1980) demonstrated that ergot infection also occurs through stigmas and that pollination protects against infection by inducing rapid stigma withering. They presented evidence of a negative relationship between pollen availability and ergot severity in pearl millet. Understanding of the role of pollination in ergot escape contributed to the development of an effective field screening technique (Thakur *et al.*, 1982). Because of the similarities in infection process in the two diseases, it seemed possible that pollination would also affect smut development. In this paper we report the results of experiments conducted to determine the effects of pollination on smut development in pearl millet genotypes susceptible to smut.

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MATERIALS AND METHODS

The experiments were conducted in the fields and screenhouse at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) near Hyderabad, India, during the rainy and post-rainy seasons of 1980–81, with three pearl millet F_1 hybrids and two male-sterile (ms) lines. Two field experiments were conducted, one with ICH-220 and another with 5054-A (ms), and two screenhouse experiments, one with BJ-104, BK-560 and 5141-A (ms), and another with 5054-A.

Sporidial suspensions were prepared in distilled water from 10-day-old cultures on potato agar at 35°C. Inoculations were made by injecting sporidial suspension (*c.* 10^6 sporidia/ml) of *T. penicillariae* into the 'boots' (flag leaf sheaths) just before inflorescence emergence. Immediately after inoculation, emerging inflorescences were covered with white parchment bags in the field and with

polythene bags in the screenhouse. Water-injected and bagged inflorescences were maintained as controls. The standard pollination method (Thakur & Williams, 1980) was used to pollinate the inoculated and non-inoculated inflorescences at the maximum stigma emergence stage (>75% stigma emergence), 5–8 days after inoculation in different genotypes. The ms lines were pollinated with pollen harvested from their corresponding B (maintainer) lines and the hybrids were pollinated with pollen either from the corresponding B line or from other lines growing nearby.

To determine the influence of the effectiveness of pollination on smut development, ms line 5054-A was pollinated with pollen of low and high viability from its B-line in a field experiment. Pollen harvested and stored for 6 days at 25°C which produced less than 10% seed-set on 5054-A was classed as low-viability pollen (LVP) and the freshly harvested pollen which produced more than 80% seed-set on 5054-A was classed as viable pollen (VP). Six treatment combinations of inoculation and pollination were made (Table 2).

The levels of smut development were determined, at crop maturity, by removing the bags and estimating the percentage of florets converted to smut sori on individual inflorescences. The mean smut severities of individual treatments were then calculated, based on the total number of inflorescences observed. The mean percentage seed-set for individual treatments was determined in the same way.

RESULTS

In the field and screenhouse experiments, pollination with viable pollen following inoculation reduced smut severities significantly in all the three hybrids and the two ms lines (Table 1). Pollination of ms line 5054-A with LVP following inoculation did not reduce smut severity significantly (Table 2).

Inoculation prior to pollination usually resulted in reduced seed set, compared with pollination alone, especially for ms line 5141-A (Table 1). Pollination with LVP resulted in poor seed-set.

DISCUSSION

The results clearly indicate that pollination with VP reduced smut development in pearl millet plants that had been inoculated with *T. penicillariae*. Since smut infection in pearl millet occurs through stigmas in young florets before anthesis (Bhatt, 1946; Thakur *et al.*, unpublished), withering of stigmas either due to ageing in the absence of pollen (in ms lines) or following pollination might be expected to affect smut infection. Pollination in pearl millet has been shown to induce rapid stigma withering resulting in reduced ergot infection (Thakur & Williams, 1980). Histopathological studies, however, are needed to determine the reasons for the reduced smut infection following pollination.

The result of this investigation is of considerable importance in developing effective screening technique for smut resistance in pearl millet. In order to obtain high infection levels the inoculated inflorescences must be protected from pollination by covering with bags.

In nature, smut infection occurs through airborne sporidia produced from germinating teliospores in the soil from a previous infected crop (Bhatt, 1946). The extent of germination of teliospores in the soil and therefore the degree of smut infection in a crop depends on weather conditions during flowering. As the period between inoculation and disease development is about 2 weeks the chances of secondary spread within a crop are limited to only the late nodal tillers which contribute little to grain yield.

In India all commercial F_1 hybrids and their ms lines are highly susceptible to smut. Our experiments suggest that lack of their own fertile pollen may partly account for the susceptibility of ms lines. F_1 hybrids, because of their characteristically more synchronous tillering and flowering, have reduced pollen availability at the initial flowering stages. They also flower earlier than open-pollinated varieties and thus more often encounter rains during flowering; this not only stimulates the release of sporidia but also further reduces the availability of pollen. Thus F_1 hybrids have the physiological characteristics for higher susceptibility to smut in addition to their genetic susceptibility (Thakur *et al.*, unpublished) compared with open-pollinated varieties.

Table 1. 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[d]			
	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 ($P = 0{\cdot}05$)	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 2. Effects of inoculation (inoc.) and pollination (poll.) using low-viability pollen (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.

The results indicate the possibility of smut control in a commercial F_1 hybrid through the provision of enough pollen at flowering, from a strategically planted smut-resistant pollen donor line.

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