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Control of ergot in pearl millet through pollen management*

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SUMMARY

Four pearl millet F_1 hybrids, ICH-118, ICH-220, BJ-104, and ICH-206, which are highly susceptible to ergot, were grown one/season in isolation plots and in a demonstration plot during the four rainy seasons of 1978–81, respectively, alone and mixed with an early flowering variety SC-2(M)5-4, which is less susceptible to ergot (less than 10% severity) to test the hypothesis that increased pollen availability at the early stages of flowering in hybrids protects the hybrids from ergot infection. In 1978, the hybrid was grown with the pollen donor in a seed mixture (4 parts hybrid and 1 part pollen donor) and in other years one row of the pollen donor was planted between two, four, or eight rows of the hybrid. Ergot inoculations were made 3–4 times at protogyny flowering stage of the hybrids. Significant reductions in ergot infection and considerable increase in grain yields occurred in the hybrids when grown with the pollen donor line. The possible application of this control measure in farmers' fields is discussed.

INTRODUCTION

Ergot of pearl millet (*Pennisetum americanum* (L.) Leeke), induced by *Claviceps fusiformis* Loveless, is a major disease problem in commercial and experimental F_1 hybrids in India (Arya & Kumar, 1976; Sundaram 1975; Rachie & Majmudar, 1980). The disease not only reduces grain yields considerably but also constitutes a health hazard to humans and animals that eat pearl millet products contaminated with the alkaloid-containing sclerotia of the causal fungus (Bhat, Roy & Tulpule, 1976; Kannaiyan, Vidhyasekaran & Kandaswamy, 1971; Krishnamachari & Bhat, 1976; Patel, Boman & Dallal, 1958). Thakur & Williams (1980) described the effects of pollination in reducing ergot infection in male-sterile lines, and suggested that ergot might be controlled in pearl millet hybrids if more pollen could be made available during the early flowering period of this highly protogynous crop. Reduced ergot infection due to *Claviceps purpurea* (Fr.) following rapid pollination has also been reported in male-sterile wheat and barley (Cunfer, Mathre & Hockett, 1975; Darlington & Mathre, 1976; Puranik & Mathre, 1971; Watkins & Littlefield, 1976). Pearl millet being a highly cross-pollinated species, possibilities of ergot control through pollen management appear to have better promise than in normally self-pollinated species. During the four rainy seasons of 1978–81 we tested this hypothesis in field trials at the International Crops Research Institute for the Semi-Arid Tropics, (ICRISAT) and the results are reported in this paper.

MATERIALS AND METHODS

Test hybrids, pollen donor, and planting details

Three ICRISAT experimental hybrids, ICH-118, ICH-220, and ICH-206 and a commercial Indian hybrid, BJ-104, which are highly susceptible to ergot (more than 80% severity) and which

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flower within 45–50 days of planting were used as the test cultivars. A selection from an East African variety SC-2(M)5-4 which is significantly more resistant to ergot (<10% severity) and flowers within 40–45 days, was used as the pollen donor.

Experiments were conducted in the rainy seasons at ICRISAT Centre farm. In 1978, the hybrid ICH-118 was sown on 5 July singly in two isolation plots and in a seed mixture (four parts hybrid + one part pollen donor) in two more isolation plots. The isolation plots (16, 10-m rows) were located at least 500 m from any other pearl millet fields. Rows within plots were 75 cm apart and plants were 10–15 cm apart within rows.

In 1979, the hybrid ICH-220 was sown on 11 July singly in six isolation plots (32, 20-m rows) and with the pollen donor planted in every third row in six other isolation plots.

In 1980, the hybrid BJ-104 was planted on 29 July, singly in three isolation plots (32, 20-m rows), with one row of the pollen donor between every four rows of the hybrid in three other plots, and one row of the pollen donor between every eight rows of the hybrid in a further three plots.

In 1981, the hybrid ICH-206 was sown on 2 July, singly in two plots (32, 20-m rows), and with one row of pollen donor after every four rows of hybrid also in two plots. These were planted in the ergot nursery and no isolation distance was maintained. The two 'hybrid-alone' plots were planted 10 days before the hybrid + pollen-donor plots.

Treatments and ergot inoculation

Details of 50% stigma emergence in hybrids, pollen-donor line and dates of ergot inoculation are provided in Table 1. In three seasons all the plots were inoculated, in 1978 only two plots

Table 1. *Dates of 50% stigma emergence (SE) of pearl millet hybrids and the pollen donor line (PD) and ergot inoculations in four rainy seasons (1978–81)*

		Dates	
Year	Hybrids/PD	50% S.E.	Ergot inoculations
1978	ICH 118	29 Aug.	29, 31 Aug., 4 Sep.
	PD	24 Aug.	
1979	ICH 220	1 Sep.	29, 31 Aug., 4 Sep.
	PD	29 Aug.	
1980	BJ 104	13 Sep.	13, 16, 19 Sep.
	PD	9 Sep.	
1981	ICH 206	2 Sep.	1, 2, 3, 5 Sep.
	PD	25 Aug.	

PD = SC 2 (M) 5-4 selection.

were inoculated. The treatments in 1978 were not replicated while in the other 3 yr there were at least two replications/treatment.

Ergot inoculations were made three to four times during the protogyny stage of flowering with a motorised knapsack sprayer with aqueous honeydew conidial suspensions (*c.* 1×10^6 conidia/ml) obtained from infected inflorescences in the ergot resistance screening nursery. In the 1981 experiment high humidity was maintained by providing overhead sprinkler irrigation twice/day for 30 min each throughout the inoculation and disease development period.

Ergot incidence and severity assessment

At crop maturity ergot incidence (%) was calculated from the numbers of infected and non-infected inflorescences. Ergot severity (%) was determined by estimating the % florets

infected on individual inflorescences using the standard ergot severity assessment key (Thakur & Williams, 1980).

In 1980, the central 8 m of the centre 11 rows were used for observation, while in other years the central 10 m of the centre 16 rows were used. In 1978, 100 inflorescences of ICH-118 from each row were assessed for ergot incidence and 20 randomly-selected ICH-118 inflorescences per plot were used to estimate ergot severity. In 1979, 200 randomly-selected inflorescences of ICH-220 were assessed for ergot severity in each replication. In 1980 ergot severity was determined on 50 randomly-selected inflorescences of BJ-104/plot. In 1981 all the inflorescences of 16 individual rows of ICH-206/plot were assessed for incidence and severity.

Grain yield measurement

Fully-matured earheads, harvested from each plot marked for ergot severity assessment, were sun-dried and hand-threshed. Thousand-grain-weight measurements were taken for the replicated experiments in 1979–1981 and the grain yield/plot (16, 10-m rows) was measured only for the 1981 demonstration experiment.

RESULTS

Rainfall, humidity and temperature

The details of rainfall, relative humidity (max. and min.) and temperature (max. and min.) during the period between inoculation and disease development in the 1981 rainy season are provided in Table 2. There were 222·7 mm rainfall within 20 days, distributed over 12 days with 16 periods of rain, in addition to the sprinkler irrigations provided twice/day. Relative humidity remained between 44–95% with more than 80% r.h. for 13 h or more/day, and temperature ranged between 18 and 31 °C throughout the period between inoculation and disease development.

Ergot infection

All the four hybrids grown with the pollen-donor line developed significantly less ergot (both incidence and severity) than when grown without the pollen donor (Table 3).

Grain yield

A considerable increase in 1000-grain weight occurred when the hybrids were grown with the pollen donor line compared to when they were grown without the pollen-donor line (Table 4). In the 1981 demonstration experiment the grain yield/plot of ICH-206 grown with the pollen donor was almost double the yield of the ICH-206 plots without the pollen donor (Table 4).

DISCUSSION

The results obtained indicate clearly the potential of positive control of ergot in pearl millet through provision of pollen at the critical flowering stage of the hybrids. Even under high relative humidity (80% or more) for more than 13 h/day with sprinkler irrigations and heavy rainfall, the control measure was quite effective in reducing ergot levels and increasing grain yield of the hybrid.

The reduced ergot infection (both incidence and severity) in plots with the pollen-donor line is almost certainly due to rapid pollination of the protogynous inflorescences of the hybrids by the pollen-donor line. It is important that the pollen-donor line should flower earlier than the hybrid or the planting be adjusted such that when the hybrid begins to flower, enough pollen from the pollen-donor line is available to effect rapid pollination of the hybrid.

Wet conditions such as those experienced during our studies (sprinkler irrigation twice/day +

Table 2. *Weather data for the period between inoculation and disease development in the 1981 rainy season*

Date (September)	Rainfall*		Relative humidity			Temperature (°C)	
	Amount (mm)	Times	Max. (%)	Min. (%)	Period >80% (h)	Max.	Min.
1	0		92	60	14	27	19
2	8	0130–0300	90	76	20	24	19
3	18·8	2330–0020	90	66	16	26	19
4	0·9	1500–1510	95	64	16	27	19
5	0		90	54	15	30	19
6	0		90	58	17	28	20
7	2·4	2100–2130	92	56	17	30	20
8	1·5	2330–0100	92	52	16	31	20
9	1·6	1500–1510	92	46	15	31	18
10	9·5	1800–2230	95	48	16	29	18
11	93·4	2145–0715	90	56	15	30	18
12	0		90	52	14	31	19
13	0		92	48	13	30	19
14	0		92	44	13	31	19
15	0		92	46	14	31	19
16	0		92	56	18	29	20
17	1·6	—	90	54	15	31	19
18	29·2	2000–2100	88	64	16	29	19
19	15·0	1300–1315 1530–1545 0230–0315 0445–0830	90	64	17	27	20
20	40·8	1245–1315 2000–2020 2200–0300	90	64	19	27	20

* In addition sprinkler irrigation was provided between 1200–1230 and 1700–1730 every day.
— Information not available.

Table 3. *Ergot incidence (Inc.) and severity (Sev.) in four pearl millet F_1 hybrids inoculated with ergot and grown with and without the pollen donor (PD) line† during the four rainy seasons (1978–81)*

Treatment	1978 ICH-118		1979 ICH-220		1980 BJ-104		1981 ICH-206	
	Inc.†† (%)	Sev.†† (%)	Inc. (%)	Sev. (%)	Inc. (%)	Sev. (%)	Inc. (%)	Sev. (%)
Hybrid alone	59 (73)	15·3 (8)	76 (90)	25·1 (26)	70 (88)	61 (69)	90 (100)	53 (61)
Hybrid mix with PD (4 : 1)	35 (34)	2·4 (1)	—	—	—	—	—	—
Hybrid alternate with PD (2 : 1)	—	—	47 (55)	8·9 (12)	—	—	—	—
Hybrid alternate with PD (4 : 1)	—	—	—	—	56 (67)	11·5 (8)	49 (57)	7·9 (5)
Hybrid alternate with PD (8 : 1)	—	—	—	—	54 (62)	8·6 (6)	—	—
S.E. (M)±	1·49	1·13	2·42	0·6	34·96	1·87	1·19	0·37

† = A selection from variety, SC-2 (M)5-4, an early maturing ergot low-susceptible bristled line from Uganda.
†† = Arcsin transformed values of percentage incidence and severity with original percentage values in parentheses.
— = Treatment not included

Table 4. *Effects of the pollen donor (PD) line on 1000-grain weight in 3 yr and grain yield in 1 yr of pearl millet F_1 hybrids inoculated with ergot*

Treatment	1000-grain wt (g) 1979 ICH-220	1980 BJ-104	1981 ICH-206	Grain yield (kg/plot)† 1981 ICH-206
Hybrid alone	6·2	4·7	6·6	6·4
Hybrid alternate with PD (2 : 1)	7·8	—	—	—
Hybrid alternate with PD (4 : 1)	—	6·4	7·1	12·7
Hybrid alternate with PD (8 : 1)	—	5·1	—	—
S.E. (M)±	0·9	1·3	0·2	0·04

† Mean yield of 2 replications from a plot size of 16, 10-m rows.
— Treatment not included.

16 showers of rain in 12 days) normally cause pollen to be washed down resulting in poor seed set and heavy ergot infection; this did not occur. Evidently since pollen shedding (anthesis) in pearl millet continues throughout the day and night (Ayyangar, Vijiaraghavan & Pillai, 1933) only a few rain-free hours are necessary for pollination resulting in reduced ergot infection even under weather conditions highly favourable to ergot development.

Reduced ergot infection in hybrids was positively correlated with increased 1000-grain weight and grain yield/plot. This increase in grain yield can be attributed to the effects of rapid pollination from the pollen-donor line resulting in increased seed set which otherwise is lost to ergot, increased grain number due to improved pollination, and increased 1000-grain weight, apart from the fertility differences which might exist in different plots.

Before this technique is ready for use by farmers, efforts are needed to (i) identify and/or develop lines to be used as pollen donor to match with the flowering of the range of hybrids under cultivation, (ii) understand environmental effects on flowering time of the hybrid and the pollen-donor, particularly in relation to changes in latitude and day length in different millet growing areas; (iii) determine the ratio and ways of mixing hybrid to the pollen-donor in different environments; and (iv) examine the possible adulteration problem of the hybrid seed by the seed companies and acceptance by the farmers of the likely non-uniform hybrid crop. Successful exploitation of pollen management for ergot control will depend largely on whether seed companies and extension agencies can teach farmers to understand the principles involved and to accept the possible non-uniformity in hybrid crops.

In the absence of ergot resistant hybrids at the present time, the use of pollen management offers the only feasible means of control in the regions where the disease is considered a major problem in pearl millet.

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