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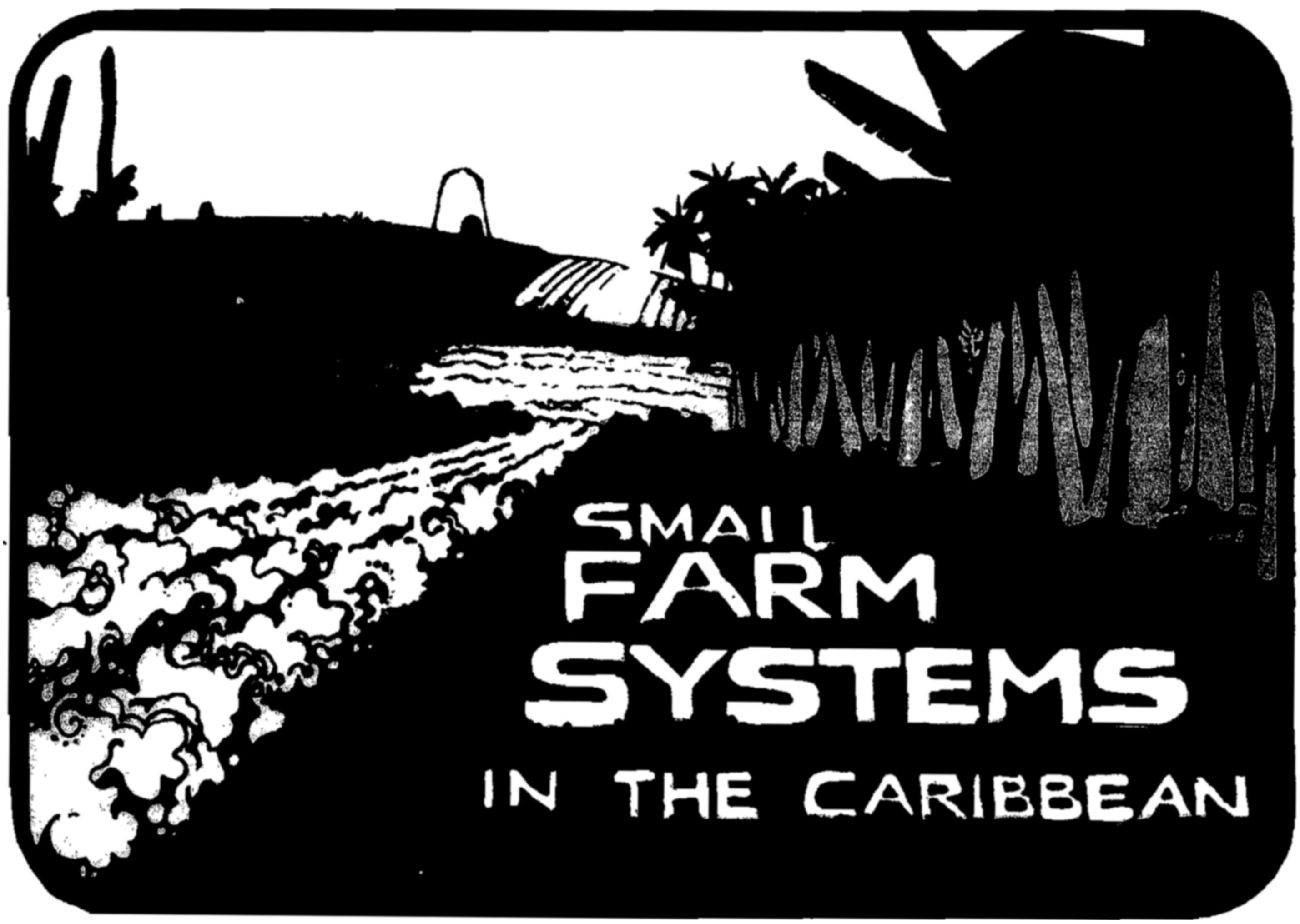

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Adaptation of CIMMYT's High Protein Quality Corn Varieties to Puerto Rico

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Six modified endosperm *opaque-2* corn varieties from CIMMYT were evaluated at Lajas and Isabela, Puerto Rico in 1983. Two Puerto Rican varieires, Mayorbela and Diente de Caballo, were used as checks. Opaque-2 (o2) corn normally has soft endospoerms, while modified varieties approach the appearance of normal corn. The subplots of each variety were a check, benomyl treatmenr, and *Fusarium moniliforme* silk inoculation. Traits measured included incidence of seedborne fungi, planr and ear heights, visual ear infection, ear lengths and diameter, yield and 500 kernel weight, and modification. Yields and modification of the CIMMYT varieties were similar ro that of the traditional (non o2) varieties. *F. moniliforme* was found to be the most important seedborne fungus. The inoculation technique was found to increase incidence of *F. monoliforme* and should be useful for evaluating large numbers of families in a selection program. Improvement of yield and adaptability of CIMMYT's materials is needed for viable commercial production of these varieties. On the basis of this evaluation, S1 recurrent selection has begun in two modified o2 varieties.

Keywords: *Zea mays* L., maize, *opaque-2*, modified *opaque-2, Fusarium monoliforme*.

Since the discovery of opaque-2 (o2) endosperm mutant by Mertz et al. (1964), many directions of research have been tried in order to efficiently utilize the gene's ability to increase lysine and tryptophan levels, thus improving corn protein quality. Early on, some researchers were discouraged by undesirable characteristics such as lower grain yield, poor consumer acceptance, and susceptibility to machine harvest damage, insects and ear rots (Díaz, 1972; Gulya et al., 1979; Lambert et al., 1969; Pinstrup-Andetson, 1971; and Warren, 1978). Since the 1970's much work has been directed rowards the use of genetic modifiers that improve the endosperm texrure of o2 corn, giving it a more normal appearance and hardness. CIMMYT (Centro Internacional de Mejoramienro de Maiz y Trigo) has used this approach to develop its "quality protein maize" (QPM) populations (Vasal et al., 1980).

Although once a widely grown crop, very little corn is presently grown in Puerto Rico. Nevertheless, large quantiries of corn are imported as feed for the livestock, pork, and poulrry industries (Puerto Rico Department of Agriculture, 1979-80). Furthermore, as fewer acres are planted ro sugarcane, alternate crops and rotations of crops must be considered. Local production of corn varieties with improved protein quality could reduce the amount of corn and protein supplements thar are presently imported for monogastric animals such as swine and poultry.

The primary objective of this research was to compare the adaptation of six modified endosperm o2 corn varieties ro two traditional varieties in Puerto Rico. Other objectives were ro:

1. Determine the susceptibility of modified o2 and traditional varieties to ear infection by *Fusarium moniliforme*, comparing natural and artificial inocularion;
2. Select the best modified o2 varieties for use in a S1 family recurrent selection program; and
3. Determine which agronomic characteristics should be included in a selecrion program.

MATERIALS AND METHODS

Six modified (hard and vitreous) endosperm o2 corn varieties from CIMMYT, and two Puerto Rican varieties (Mayorbela and Diente de Caballo) were evaluated in trials planted in March and May 1983, in Lajas and Isabela, Puerto Rico, respectively. Diente de Caballo is a tall, lare, floury type, while Mayorbela is earlier and shorter with a flint kernel type. A split plot design, with eight varieties arranged in a randomized complete block design and three subtreatments, was used. The subplots were:

1. A check not sprayed or inoculated;
2. A rreatment with the fungicide Benomyl, but uninoculated; and
3. Artificial inoculation with *Fusarium moniliforme*.

The whole plots were randomized except for the normal varieties which were either placed downwind from o2 varieties and/or were surrounded by an o2 bulk to minimize normal contamination of the o2 varieties.

The twelve row whole plots were divided into four rows per subplot. Row length was 5.1 m with plants spaced 26 cm apart (about 43,200 plants per hectare). Fertilizer was preplant incorporated at a rate of 56 kg ha^{-1} of 15-5-10 with 175 kg ha^{-1} of nitrogen sidedressed at five weeks after planting in the form of urea. Furadan (1.7 kg ha^{-1} of actual ingredient) was preplant incorporated and insecticides (Lannate and Sevin) applied weekly or biweekly as needed. Trials were irrigated as needed. Lasso and Round-up were used for weed control. The center two rows (excluding end plants) in each subplot were hand harvested.

At Lajas, the fungicide Benomyl was sprayed on the ears and silks when the first varieties began to flower and ten days later. At Isabela one application of Benomyl was used at ten days after first flowering (when all varieties were flowering). Inoculation of *F. moniliforme* was carried out by a modification of a technique used by Warren (1978). A suspension of spores was brushed onto silks cut with a scissors ro a length of about 2.5 cm. The silks were then covered with a pollination shoot bag. In Lajas a total of 20 plants in two rows were inoculated at 10 and 20 days after first flowering (the average of the two dates is used in this report). In Isabela only one inoculation was made.

Traits measured were days to 50% anthesis, plant and ear height, ear length and diameter, number of moldy kernels, percent of ear area damaged by insects (primarily ear worm), grain yield, 500 kernel weight, percent endosperm modification, degree of endosperm modification (reference 10 with technique modified to a 0 to 5, opaque to normal, scale), percent germination and seedborne fungi.

Data were subjected to analyses of variance separately and over locarions. Treatment means were compared using a protecred LSD (F-LSD) (Carmer and Swanson, 1971).

RESULTS AND DISCUSSION

Significant differences due to location were found for most ttaits except for 500 ketnel weight and modification (not shown) (Table 1). Isabela was the more productive environment.

Very few differences among varieties were found (Tables 2 and 3). Number of moldy kernels varied significantly among varieties with White H.E. o2 being most susceptible ro infection and local variety Diente de Caballo the least susceptible. Although the Puerto Rican varieties were less ear ror susceptible and taller than modified o2 varieties, in general the modified varieties perfotmed well. Petcent and degree of modification did not vary among varieties, with all varieties showing excellent levels of edosperm modification (Table 3). It appears that the o2 modifiers are relatively stable over different envitonments. Our tesults show that those varieties with a high percent modification also have individual kernels with a high degree of modification. It will not be necessary to select directly for endosperm modification in a selection program aimed at improving adaptation of rhese materials in Puerto Rico. Very poorly modified families should nevertheless be eliminated in a selection program.

No variety by location (*i.e.*, genotype by environment) interactions were found for any trait (not shown). This means that varieties responded similarly at both locations for all traits although location means were often different. This would normally suggest that testing at one location would be sufficient when testing these traits and varieties. However, lack of a variety by location interaction may be due in part to lack of sufficient precision in determining possible differences between varieties.

Table 1: Location means of agronomic traits averaged over seven corn varieties planted in March (Lajas) and May (Isabela), 1983.

Trait	Location: Lajas	Location: Isabela	$\bar{X}$	LSD
Earworm (percent of ear damaged)[1]	6.3	0.1	3.2	0.99
No. of moldy kernels per ear[1]	3.8	8.3	6.1	1.12
Plant height (cm)	150	189	170	6.54
Ear height (cm)	67	83	75	3.09
Ear length (cm)[1]	12.6	14.1	13.3	.54
Ear diameter (cm)[1]	4.2	5.1	4.6	0.55
Days to 50% anthesis	61	55	57.6	1.03
Yield ($kg\ ha^{-1}$)[2]	3054	3888	3472	427.6
500 kernel weight (g)[1]	122.6	132.9	126.9	4.65 (n.s.)

[1]Averaged over all subplot treatments.

[2]Averaged over check and benomyl treated subplots.

n.s. = No significant differences among locations according to F-test.

LSD = Least significant difference at α = 0.05.

Table 3: Percent and degree of endosperm modification in two normal and six modified o2 corn varieties averaged over two locations[1].

Variety	Percent Modification	Degree of Modification[3]
Diente de Caballo[2]	96.7	3.7
Mayorbela	100	5.0
White H.E. O2	95.8	4.1
Amarillo Dentado	99.5	3.9
Tuxpeño-1 QPM	98.1	4.0
Pool 23	99.4	4.1
Amarillo Dentado QPM	98.4	4.0
Amarillo Cristalino	100	4.2
Mean	98.7	4.2

[1]Values are means over two locations (Lajas and Isabela) and three subplot treatments.

[2]Mean over three treatments at Lajas only.

[3]Ratings from 0 to 5 (opaque to normal).

Table 2: Means of various agronomic traits over two locations for six modified o2 and two normal corn varieties[1].

Variety	Moldy kernels (no.)	Insect damage (%)	Days to 50% anthesis	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Grain yield (kg/ha)	500 kernel weight (g)
Diente de caballo[2]	2.4	6.1	64	194	100	13.3	4.6	3030	172.3
Mayorbela	4.6	3.5	56	182	91	14.4	3.9	3963	137.6
White HE-o2	10.5	3.5	59	177	79	14.3	5.3	3652	124.9
Amarillo Dentado	5.2	2.9	58	173	76	13.4	4.9	3583	125.7
Tuxpeño-1 QPM	6.9	3.0	58	158	64	13.2	4.6	3372	130.6
Pool-23-QPM	4.8	2.5	58	165	71	12.9	4.8	3139	122.6
Amarillo Dentado QPM	3.5	2.8	58	165	70	12.4	4.7	3378	125.3
Amarillo Cristalino QPM	7.0	4.1	57	168	71	12.8	4.3	3215	121.7
$\bar{X}$	6.1	3.2	58	170	75	13.3	4.6	3472	126.9
LSD	1.8	2.1 (n.s.)	1.9 (n.s.)	12.2	4.5	.98	1.0 (n.s.)	800.0 (n.s.)	8.7

[1]Values are means from Lajas and Isabela, Puerto Rico with the exception of Diente de Caballo. Averaged over subplots as indicated in Table 1.
[2]Mean from Lajas only. These menas are not included in the overall mean.
n.s. = No significant differences among varieties according to F-test.
LSD = Least significant difference at α = 0.05.

Artificial inoculation with *F. moniliforme* was successful in increasing number of moldy kernels and incidence of seedborne *F. moniliforme* compared to the check (natural inoculation) (Table 4). Visual infection can perhaps be increased by increasing the number of inoculations, thus making this technique even more useful for selection purposes. The fungicide Benomyl was not effective in reducing visual nor seedborne *F. moniliforme* compared to the check, nor did it significantly increase grain yield (Table 4).

Table 5 shows that *F. moniliforme* was the most important seedborne fungus both in Isabela and Lajas. Incidence of most seedborne fungi was greater in Lajas. Conditions in Isabela were very dry in the 1983 growing season.

Significant subplot treatment by location interactions were found for moldy kernels, earworm damage, ear diameter, and grain yield (Table 6). Earworm damage was virtually nonexistent for all subplot treatments in Isabela, while there were significant differences among treatments at Lajas. In the combined analysis (Table 4) no differences among subtreatments were found. The artificial inoculation technique was much more effective in Isabela even though only one application was used, thus causing a significant interaction. Grain yields were not different among treatments at Lajas but varied sharply in Isabela. The reason for this interaction of treatment and location is not understood.

Based on the results of these trials two modified o2 varieties, Amarillo Cristalino QPM and Tuxpeño-1 QPM, have been chosen to undergo S1 family recurrent selection. Grain yield, early maturity and plant height will be used in an independent culling levels selection scheme. Poorly modified families will be eliminated.

Table 4: Means of subplot treatments averaged over seven corn varieties planted at two locations in March (Lajas) and May (Isabela), 1983.

Trait	Check (without fungicide) without inoculation)	Benomyl treated (without inoculation)	Inoculated (without Benomyl)	$\bar{x}$	LSD
No. of moldy kernels	5.0	4.4	8.8	6.1	2.04
Earworm (% of ear damaged)	3.0	4.4	2.1	3.2	1.06
Ear length (cm)	13.3	13.4	N/A	13.3	.35 (n.s.)
Ear diameter (cm)	5.0	4.3	N/A	4.6	0.65
Grain yield (kg ha)	3487	3533	N/A	3510	272.9 (n.s.)
Fusarium moniliforme (number of colonies per 50 seed)	35.7	35.4	51.1	40.7	6.01

[1] Only traits exhibiting significant differences among treatments are included, except for grain yield.

LSD = Least significant difference at = 0.05.

N/A = Treatment not included.

Table 5: Location means for seedborne fungi and percent germination averaged over all varieties[1].

	Lajas	Isabela	$\bar{x}$	LSD
Fusarium moniliforme	58.6	22.8	40.7	5.27
Penicillium spp. (green type)	22.5	18.8	20.6	7.6 (n.s.)
Penicillium spp. (yellow type)	8.8	6.0	7.4	3.06 (n.s.)
Aspergillus spp.	11.1	6.4	8.8	2.94
Trichoderma spp.	7.6	3.0	5.3	5.6 (n.s.)
Botryodiplodia theobromae	0.9	2.0	1.4	0.79
Total	123.4	97.5	110.4	33.4 (n.s.)
% Germination[2]	68.2	93.9	81.1	4.5

[1] Table includes only those fungi found at both locations. Means are average number of colonies per 50 seeds, over three subtreatments.

[2] Percent germination in laboratory.

LSD = Least significant difference at α = 0.05.

n.s. = No significant differences among locations.

Table 6: Location means for traits showing significant subplot treatment by location interaction.

Treatment	Location	Earworm Damage (%)	No. of moldy kernels	Ear diameter (cm)	Grain yield (kg ha^{-1})
Check	Lajas	5.7	3.5	4.2	3147
	Isabela	0.1	6.9	4.4	2728
Benomyl	Lajas	9.1	2.8	4.2	3097
	Isabela	0.1	6.0	5.1	[illegible]
Inoculation	Lajas	4.0	4.6	4.2	N/A
	Isabela	0.1	12.6	5.8	N/A

N/A = Not applicable

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