

DEVELOPMENT OF OPEN-POLLINATED VARIETIES,
NON-CONVENTIONAL HYBRIDS AND INBRED LINES
OF TROPICAL MAIZE WITH RESISTANCE TO
FALL ARMYWORM, *SPODOPTERA FRUGIPERDA*
(LEPIDOPTERA:NOCTUIDAE), AT CIMMYT

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ABSTRACT

As part of the overall improvement of maize, *Zea mays* L., the International Maize and Wheat Improvement Center (CIMMYT) has been working to develop tropical maize materials with improved levels of resistance to fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), and good agronomic qualities. Efficient mass rearing and infestation techniques have been developed, many of which have been adopted or adapted by other FAW host plant resistance workers. Our initial efforts to develop FAW resistance consisted of a population improvement approach. Recently, CIMMYT's maize insect resistance improvement program has been amplified to include screening and development of new sources of resistance, international testing of these sources, and inbred line and 'non-conventional' hybrid development, in addition to the continuing development of open-pollinated varieties.

RESUMEN

Como parte del programa de mejoramiento de maíz, el Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) ha trabajado para desarrollar el germoplasma de maíz con niveles de resistencia de la planta huésped contra al "cogollero", *Spodoptera frugiperda* (J. E. Smith). Se han desarrollado técnicas eficientes de crianza masiva e infestación artificial al nivel de campo. Muchas de esas técnicas han sido adoptadas por otros trabajadores en resistencia de la planta huésped para facilitar sus trabajos y estudios. Nuestros trabajos iniciales fueron sobre el mejoramiento de resistencia al nivel de poblaciones de maíz. Recientemente, el programa de entomología sobre la resistencia de las plantas huéspedes ha sido ampliado para incluir la evaluación y desarrollo de fuentes de resistencia nuevas, ensayos internacionales para probar dicha resistencia, y la formación de variedades de polinización libre, líneas endocriadas e híbridos 'no-convencionales' con resistencia al cogollero.

For more than a decade, the maize improvement program of the International Maize and Wheat Improvement Center (CIMMYT) has included improvement of host plant resistance (HPR) to the fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), as an integral part of its selection and improvement process in maize materials of tropical lowland and subtropical adaptation (Mihm 1985). The FAW is a major destructive field pest of maize in tropical and subtropical areas of the Americas, and in favorable years even damages fields in temperate production areas. Enhanced levels of resistance to

TABLE 1. INTERMEDIATE GERMLASM PRODUCTS OF THE CIMMYT MAIZE IMPROVEMENT PROGRAM.

Category	Composition	Number
Pools	± 500 Half-sibs	± 50
Populations	± 250 Full-sibs	± 40
Experimental varieties	± 10 Full-sibs	± 600
Inbred lines	S ₃ -S ₅ level	± 5000
'Non-conventional' hybrids	Variety & Topcross	± 500

FAW in maize cultivars is highly desirable and would have great utility to CIMMYT's clientele, the National Agricultural Research Systems (NARS) and their farmers. In many developing countries, where low input agriculture predominates, HPR is the only practical means of managing pest populations and minimizing production losses resulting from pest attack.

Because of its facilities for insect mass rearing, its personnel (breeders, entomologists, and pathologists), its resource commitment to the improvement of maize germplasm, and its well established ties to NARS for testing and production research, CIMMYT is uniquely qualified to conduct FAW HPR research (Mihm 1983).

Before 1984, HPR improvement to FAW was carried out in selected CIMMYT germplasm 'pools' and 'populations' (Table 1) of lowland tropical adaptation (Ortega et al. 1980). The goal was gradual improvement of resistance on a population level, and extract superior progenies to form open-pollinated experimental varieties with improved resistance (Mihm 1985). When the work was begun in the late 1970s, such varieties were the most appropriate intermediate product for CIMMYT to produce because of the ease of maintenance, seed production, and distribution for most client countries.

In 1984, it was apparent that the progress made was slow because of low gene frequency and competitive selection concerns. Also, several NARS were developing capabilities of viable hybrid seed production systems, especially for utilizing varietal or topcross hybrids (termed 'non-conventional' by the CIMMYT maize program) (Table 2). Nearly all the maize grown in developed countries is produced from single-, three-way, or double-cross hybrids, which are formed from crosses of highly inbred maize lines, and growers purchase new seed for each planting. In developing countries, it is difficult to maintain inbred line purity, to produce good quality seed of hybrids, to get high enough seed yields, and to get seed distributed on time to farmers at a price they can afford. Many of these problems are minimized in the production of 'non-conventional' hybrids. Although these are less uniform for many characteristics than conventional

TABLE 2. CONVENTIONAL HYBRIDS, MADE BY CROSSING HIGHLY INBRED LINES, CONTRASTED TO 'NON-CONVENTIONAL' HYBRIDS, WHERE AT LEAST ONE PARENT IS NON-INBRED.

Conventional	Components	'Non-conventional'	Components
Single cross	A x B	Topcross:	Commercial hybrid x Line
Three-way	(A x B) x C		Family (half-, full-sib) x Line
Double cross	(A x B) x (C x D)		Variety x Line
		Varietal:	Family (half-, full-sib) x Family
			Variety x Family
			Variety x Variety

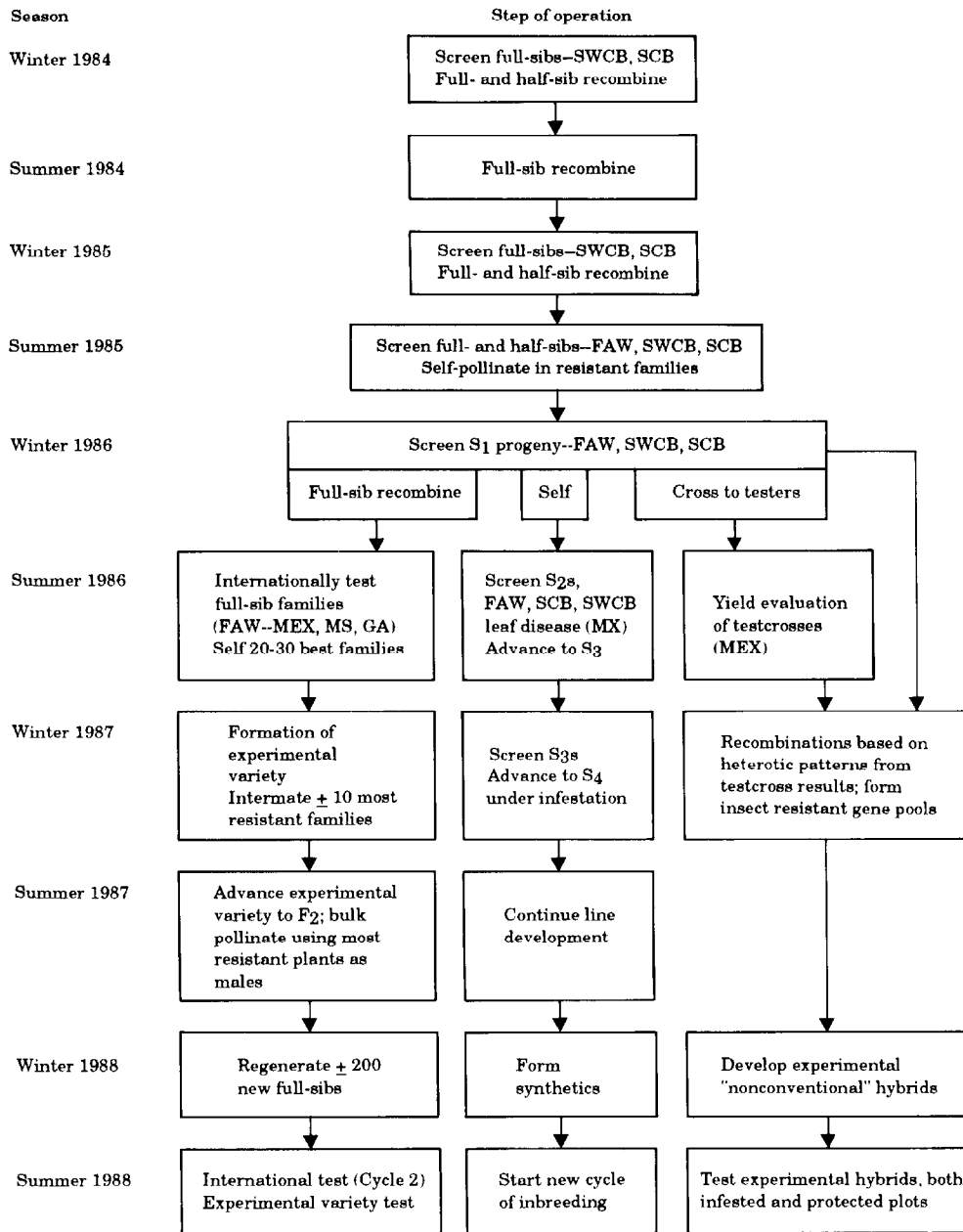


Fig. 1. Flow-chart showing operations and breeding methodology used in developing the Multiple Borer Resistance (MBR) population, inbred line extraction, and the formation of experimental varieties and 'non-conventional' hybrids.

hybrids, this usually does not detract from their acceptability. Many developing country farmers actually benefit from some heterogeneity in their cultivars, as their production fields are often not uniform, and harvest is done by hand labor, not machines. Suitable cultivars for most subsistence farmers need only be fairly uniform in grain color and texture, maturity, yield, and postharvest storability (Deutsch 1988).

In order to make greater and faster progress in developing FAW resistance, and to produce an array of germplasm products with greater utility to a wider range of maize

improvement programs in both developing and developed countries, CIMMYT formed a new maize population and began improving it for resistance to several maize field pests. This population was named the Multiple Borer Resistance (MBR) population (Fig. 1). It was formed from predominantly subtropical and temperate materials that were reported to have high or intermediate levels of resistance to FAW and the following subtropical or temperate region maize stem borers: *Ostrinia nubilalis* (Hubner), *Diatraea grandiosella* (Dyar), *D. saccharalis* Fabricius, and *Chilo partellus* (Swinhoe) (Benson 1986, Mihm 1986, Smith et al. 1988).

Progenies from this population were evaluated internationally for resistance in 1986. Two hundred full sib families were sent to interested cooperators who had the capability to artificially infest at least 10 plants per progeny row with FAW or one of the maize stem borers to assess resistance to first and/or second generation damage by that pest (Smith et al. 1988). Each cooperator infested 10-15 plants per row with 30-40 newly hatched FAW larvae (Mihm 1983). Leaf feeding ratings were taken 14-21 days after infestation using a 1 to 9 scale (1 = highly resistant, 9 = highly susceptible). These, and other data of interest were reported to CIMMYT. The number of families in each resistance category from the Mississippi, Georgia, and Mexico FAW evaluations are presented in Fig. 2. The results indicated fairly high frequencies of FAW resistance, with most of the families showing high (1-3 ratings) or intermediate (4-6 ratings) levels of resistance. Only a few families were classified in the susceptible category. These results indicate this population is an excellent source of FAW resistance; most breeding materials and commercial cultivars are found to be susceptible when artificially infested with FAW.

In addition to taking resistance ratings, each cooperator selected the 20 to 30 most resistant families (equal or superior to the best resistant check entry) with good agronomic characters and self pollinated the best plants in these families. The majority of the seed harvested from these plants remained with the cooperators for use in their HPR program. Most of the cooperators sent 50-100 seeds of each selected ear to CIMMYT, where they are being used to regenerate a new set of progenies for testing in 1988, and for line and variety development. For each test site that successfully evaluated the population, there is the potential to develop an experimental variety and/or extract inbred lines with potentially superior resistance. If the population was tested for the same species at more than one site, there is the potential to develop an across site experimental variety, using the 8-10 most resistant families across sites as progenitors. Based on the results from the 1986 MBR international test, CIMMYT decided to develop only Across 86 MBR-FAW for the following reasons: (1) the cooperators from Mississippi and Georgia have the production of resistant inbred lines as their goal; (2) both sites are similar in latitude and general adaptation to the Mexican test site; and (3) most of the selected families were common across sites, therefore site specific experimental varieties would not differ greatly.

Seed of selected S1's returned to CIMMYT from these and other sites which evaluated for stem borer resistance was used to continue inbred line development and to regenerate a new set of full sib progeny for international testing in 1988 (Fig. 1). Some of the initial S1 lines used in developing the full sib families for the 1986 international progeny testing trial (IPTT) were also testcrossed to a set of testers to determine combining ability groups. These testcrosses were grown in a subsequent season under both infested and protected conditions to identify their resistance reaction and yield performance. The results were used to help form two insect resistant pools with good potential combining ability. Information from the testcross performance also will be used to identify lines for forming synthetics and experimental 'non-conventional' hybrids with high yield potential and good resistance, primarily for developing country NARS, but of possible value in developed country programs as well.

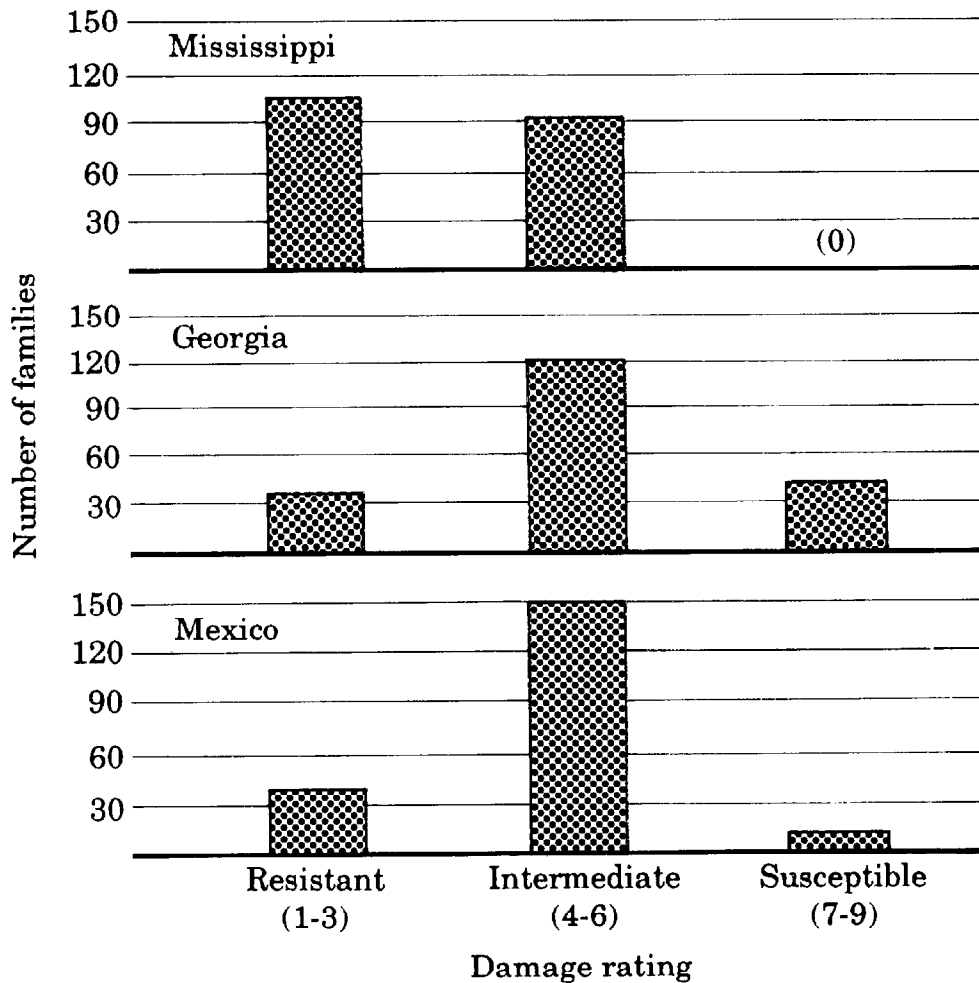


Fig. 2. Fall armyworm leaf-feeding ratings of 200 full-sib families of MBR population at three locations.

In developing the MBR population and monitoring the sites where it was internationally tested, two things were observed. First, although there was notable expression of daylength sensitivity in this germplasm, cooperators were able to obtain viable seed from testing sites more than 40° North latitude to 30° South latitude, indicating broad general adaptation of the population. Second, there was variability for resistance to common foliar diseases within the population. As we are aware of the importance of resistance to plant pathogens as well as insect pests, and know that varieties will not be acceptable to farmers unless they are resistant to both, we also screen and select for resistance to leaf diseases, and ear and stalk rots.

Lines from the MBR population that are selected for insect resistance are being screened for reaction to common rust, *Puccinia sorghii* Schw. and *Helminthosporium* sp. leaf blights. The most resistant disease selections are then re-screened for insect reaction and re-incorporated into the population.

Testing of the MBR indicated a more complex approach was needed for developing resistant germplasm for lowland humid tropical areas, especially where the downy mildew disease complex or maize streak virus diseases occur (although there were apparent differences for streak reaction at the Kenya testing site). In order to develop insect

TABLE 3. EXPERIMENTAL VARIETIES, FAMILIES, AND INBRED LINES SELECTED FOR RESISTANCE TO FALL ARMYWORM AT CIMMYT.

Material	Selections available	Adaptation
Tuxpeno	PR 8321, Exp'l. variety	Tropical/subtropical
Antig.-Ver. 181	PR 8424, Exp'l. variety	Tropical/subtropical
Pools 24, 26	Half- & full-sib families, S ₁ lines	Tropical/subtropical
MBR	Across 86-FAW, Exp'l. var.	Subtropical/temperate
Varios x Mp lines	Full-sibs, S ₁ & S ₂ lines	Tropical/subtropical
MIRT	Population development	Tropical/subtropical

resistant germplasm to serve in such areas, another population is being developed. It is named the Multiple Insect Resistant, Tropical (MIRT) population (Mihm 1986, Smith et al. 1988). The germplasm incorporated into this population is predominantly of lowland tropical adaptation. Crosses with sources of downy mildew resistance from Thailand and streak resistance from the CIMMYT/IITA program in Nigeria were included. Selections of FAW and stem borer resistance from CIMMYT pools and populations, from 'Antigua' collections from the CIMMYT maize germplasm bank, and Mississippi resistant lines and hybrids were added.

The MIRT population is still being formed, but we expect to have a set of full-sib progenies ready for international testing in 1989. We hope to send it for insect resistance screening to cooperators in countries with lowland humid tropical climates, where FAW and other armyworms and borer pest complexes occur. Additional evaluation for disease reaction will be useful though not essential at this time.

The best sources of FAW and stem-borer resistance available to the present, the Mississippi-released inbred lines, are deficient in many agronomic characteristics (Williams & Davis 1988). However, Overman (1988) was able to use them to develop new hybrids with multiple resistance to leaf-feeding and stalk-boring lepidopterous pests by crossing them with susceptible, agronomically superior U.S. Corn Belt lines, then extracting new resistant lines. These lines, in hybrid combinations, are competitive in yield with current commercial hybrids in the absence of pest attack, yet superior in yield under insect infestation (Overman 1988). Some of the recently extracted CIMMYT 'Antigua' lines are equal to the Mississippi lines in FAW and stem borer resistance, and superior to them in standability and leaf blight, stalk and ear rot resistance under Mexican growing conditions. Their combining ability and yield performance are yet to be tested.

Table 3 lists various materials that have been selected for FAW resistance at CIMMYT that are presently available in small quantities for testing. In the near future, we expect to develop and have available new materials, in the form of open-pollinated varieties, synthetics, inbred lines, and experimental non-conventional hybrids with potential resistance to FAW and other insect and disease pests of maize from temperate to tropical growing areas.

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FALL ARMYWORM (LEPIDOPTERA: NOCTUIDAE) INFESTATIONS IN NO-TILLAGE CROPPING SYSTEMS

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ABSTRACT

Field experiments comparing no-tillage and plow-tillage practices demonstrated that infestations by the fall armyworm, *Spodoptera frugiperda* (J. E. Smith), ultimately become similar in either cropping system. However, in certain no-tillage situations where high mulch concentrations were present on the soil surface, oviposition and damage were reduced. Significantly fewer egg masses and damage were sampled on corn, *Zea mays* L., (3-leaf stage) while seedlings remained within no-tillage mulch. Oviposition quickly became similar to that observed in plow-tillage systems when the plants grew above the mulch canopy of no-tillage. The number of egg masses on corn older than 4 leaves was similar in either cropping system, and leaf injury at plant silking was the same. In a comparison of corn, sorghum (*Sorghum bicolor* [L.] Moench.), and soybeans (*Glycine max* L.), the latter crop had no damage in either tillage system while corn and sorghum were heavily infested. Efficacy of chlorpyrifos (0.56 kg [AI]/ha) for controlling fall armyworm leaf damage was similar in corn and sorghum in either cropping system.

RESUMEN

Experimentos donde se comparó el no labrar y el labrar con arado demostró que las infestaciones por el gusano cogollero, *Spodoptera frugiperda* (J. E. Smith), al final, son igual en cualquiera de los dos sistemas. Sin embargo, en ciertas situaciones donde no