Chapter 5

RECENT DEVELOPMENTS IN MAIZE BREEDING IN THE TROPICS

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According to the FAO, the total worldwide planted maize area in 1973 was 111 million ha, with a total production of 312 million tons (average yield 2010 kg/ha). Over half of the total world area planted is in Latin America, Africa, and South and Southwest Asia—in the tropics and semitropics south of 30°N latitude—but this vast region produces only about one fourth of the total world tonnage. The distribution of this acreage and tonnage among the different maize-growing areas is shown in Table 1. About 50% of all the maize produced in the tropics and semitropics is produced in Latin America.

With the exception of Argentina, parts of Brazil, South Africa, and Thailand, most of the maize in the tropics and subtropics is produced by small farmers as a subsistence food crop. It is grown under a wide range of temperature, soil fertility, and rainfall conditions. Little chemical fertilizer is used. Total rainfall varies from area to area and is often poorly distributed. Average yields per unit area are low. Most of the indigenous varieties that evolved under these conditions over the last 5000 years are low yielding but tough. They are well adapted to a primitive, traditional type of agriculture, but not well suited for the more productive, sophisticated agriculture that is now being promoted throughout the tropics.

TABLE 1. World maize production (1973)

Region	Area harvested (million ha)	Production (million metric tons)	Percentage of world total: Area	Percentage of world total: Production
United States	26.5	146.0	23.7	47.0
Europe-North Asia	25.6	85.8	22.8	27.3
Latin America	27.8	41.4	25.0	13.3
South and Southeast Asia	13.6	14.8	12.3	4.7
Africa minus South Africa	12.4	14.4	11.2	4.6
South Africa	5.6	9.6	5.0	3.1
Total	111.5	312.0		

As part of the overall effort in accelerating maize production in the tropics, the breeders are aiming at the development of higher yielding, widely adapted, fertilizer-responsive, biologically efficient varieties that are highly tolerant to the vagaries of weather, prevailing diseases, and insect pests and have more and better quality proteins—for a more modern scientific agriculture. One of the major problems is that most high-yielding varieties grow too tall under better fertility conditions and are susceptible to lodging. Reduction of plant height in most breeding programs has high priority.

In this chapter I try to briefly summarize the accomplishments and progress in maize improvement in the tropics and subtropics during the last 25 years. Although about 15% of the 80 million tons of maize produced in the tropics is produced in the cool highlands, I concentrate my remarks primarily on recent developments in the lowland tropics below 1000–1500 m elevation.

IDENTIFICATION OF SUPERIOR BREEDING MATERIALS

Maize improvement in the lowland tropics really began in the late 1940s and early 1950s with the systematic collection, classification and evaluation of indigenous varieties of maize in Latin America. There is a tremendous variation in varieties. Over 300 races have been described (Wellhausen, Roberts, et al. 1952; Brown, 1953; Wellhausen, Fuentes, et al. 1957; Roberts, Grant, et al. 1957; Brieger, Gurgel, et al. 1958; Brown, 1960; Ramirez, Timothy, et al. 1960; Grobman, Salhuana, et al. 1961; and Timothy, Pena, et al. 1961). These studies have provided an inventory of the kinds of germplasm available and in many cases have revealed the relationships and paths of its origin.

The first attempt at a systematic identification of elite racial complexes and heterosis patterns for the lowland tropics was made by Wellhausen in the early 1960s in collaboration with maize breeders in Mexico and Central and South America. In this study 10 dent or semident varieties were crossed with each of 10 flint or semiflint varieties, and the resulting crosses were tested in six locations in Latin America, along with local hybrids as checks. The results are summarized in Table 2.

These results, together with those obtained from subsequent studies, (Wellhausen, 1965), identified four outstanding basic racial complexes for the immediate improvement of maize in the tropics; namely, Tuxpeño and its related Caribbean and U. S. A. dents, Cuban Flint (CF), Coastal Tropical Flint (CTF), and ETO. These four complexes are highly resistant to the common maize diseases and possess excellent yield potential. They have become extremely attractive to breeders and provide the basic resources for the further improvement of maize throughout the tropics. Their origin and relationships have been adequately described in the series of publications on Races of Maize in Latin America. Origin of each is distinctly different and crosses among them exhibit considerable hybrid vigor, especially combinations of Tuxpeño with each of the others.

Tuxpeño, a pure dent type, is particularly outstanding. It originated on the gulf coast of Mexico, with a complex pedigree very distinct from the other three races. It possesses exceptional vigor and yield capacity and is one of the most productive of all maize races. It has influenced the development of the Cuban and West Indian dent races and is one of the putative parents of the U. S. A. Corn Belt dents. Crosses of Tuxpeño with ETO, CF, and CTF are strikingly vigorous, high-yielding, and exhibit an exceptionally strong heterosis pattern.

The three flint complexes, Cuban Flint, Coastal Tropical Flint, and ETO, although of diverse origin, are more closely related to each other than with Tuxpeño, yet crosses among them also exhibit considerable hybrid vigor.

According to Brown (1953, 1960) Cuban Flint is the only true flint found in the West Indies. Its distribution until recently was limited, primarily to the Oriente Province of Cuba, where it is commonly known as *Maiz Argentino.* Hatheway (1957) describes this race as Argentino and postulated that it originated from the accidental crossing of the Catetos of Argentina (imported during 1914–1930) with local *Criollo* Cuban varieties. Cuban Flint has contributed greatly, together with an introduced dent, to the development of the widely distributed *Maiz Criollo* (Cuban Yellow Flint) that Brown (1960) describes as one of the varieties of Coastal Tropical Flints. Hybrids and varieties developed by C. G. del Valle, one of the early corn breeders of Cuba, from the combinations of Cuban Flint and Cuban Dent, two distinct, unrelated races, were excellent yielders in Cuba and Central America. Del Valle's outstanding suc-

TABLE 2. Average yield (kg/ha) of each variety, its 10 crosses F_1, and of the F_1 in percentage of the average yield of the parents, the superior parent, the constant parent, and the checks (average of six locations)

	Yield					
	kg/ha		F_1 in percent of			
	Parent	*Average F_1*	*Average of parents*	*Superior parent*	*Constant parent*	*Check*
Group A Dents						
Sin. Bl. (Tuxpeño)	5559	5810	116.3	104.5	104.5	103.8
Mix. 1 (Tuxpeño)	6032	5770	110.5	95.6	95.6	103.1
Capitaine (Tuxpeño)	5537	5646	114.1	102.0	102.0	101.0
D. V.-101 (Tuxpeño × Común)	5145	5354	112.0	104.0	104.0	95.6
Cuba 28 (dent)	4615	5297	117.2	115.0	115.0	94.6
Paulista Dent[a]	4374	5213	118.5	118.3	119.2	93.1
Azteca (Tuxpeño)	4758	5155	112.5	108.3	108.3	92.1
Venezuela 3 (CTF)	4953	5123	109.4	103.4	103.4	91.5
I-452 (Costa Rica)[b]	4130	4953	115.8	112.4	119.9	88.5

Carmen (Early Tuxpeño)	4068	4662	110.7	107.1	114.6	84.1
(Average)	(4920)	(5298)	(113.7)	(106.5)	(107.7)	(94.7)
Group B Flints						
N. 330 × P. 330 (CF)	4405	5787	123.9	117.6	131.4	103.4
ETO Blanco	5573	5773	110.0	103.6	103.6	103.1
ETO Am.	5392	5516	106.8	102.3	102.3	98.5
S. C. Florida[c]	4339	5390	116.7	110.1	124.2	96.3
N. 330 (CF)[d]	3303	5371	130.3	109.1	99.6	95.9
Ven. 1 CTF	4690	5255	109.3	106.8	112.0	93.9
Am. Sal. (CTF)	4670	5139	107.5	105.2	110.0	92.7
PD (MS) 6 (CTF)	5023	5155	104.2	102.6	102.6	92.8
Cateto	3845	5003	114.2	101.7	130.1	89.4
Cristal Bl.	2775	4598	119.5	93.4	165.7	82.1
(Average)	(4407)	(5299)	(113.7)	(105.2)	(120.2)	(94.7)

[a] Dent from State of Sao Paulo, Brazil—probably introduced from Southern U. S. A.

[b] Variety synthesized from Cuban materials by the Interamerican Institute of Agricultural Sciences at Turrialba, Costa Rica.

[c] Variety synthesized from combination of CF and CTF.

[d] Propagated from a single ear.

cess can be attributed in part to the hybrid vigor resulting from crossing these two types. Good sources of Cuban Flint in the CIMMYT maize bank are Cuba Group I, Cuba Group II, Cuba 11J, Nariño 330, and Nariño 330 × Peru 330. Of these the purest forms are Cuba Group I, Cuba 11J, and Nariño 330. Nariño 330 was propagated from a single ear found in a market in Colombia and has been the source of many good inbred lines in the Colombian hybrid program.

Coastal Tropical Flint as described by Hatheway (1957) and Brown (1960) is widely distributed in the West Indies and along the east coast of South America. Its center of origin appears to be Venezuela and in some way is associated with development of the early maize culture of the Arawak Indians in northern South America. Its precursors are unrelated, and distinct from those of Tuxpeño.

The more typical and less contaminated forms of CTF today are found in the small islands of Antigua, Dominica, Saint Vincent, Barbados, and Guadaloupe. These tend to be earlier in maturity, two-eared, and shorter in plant height. One of the typical varieties now widely used in tropical breeding programs is Antigua 2D and Antigua Group 2, the latter representing a composite of several collections. Crosses between Tuxpeño and Antigua 2D or Group 2 were consistently among the highest-yielding crosses tested in Latin America. The Antigua variety, however, has certain defects. In the lowland, high-rainfall areas of Veracruz, it is very susceptible to a number of leaf diseases. It is also susceptible to root lodging. Early forms of CTF were introduced into Europe during the time of Columbus and from there were distributed to South and Southeast Asia in ancient times.

Although distinctly different in their origin, the CF and CTF complexes have intermixed and have become commonly known throughout the tropics as the Caribbean Flints.

A variety synthetized in the 1940s by Eduardo Chavarriaga at the Estación Experimental Tulio Ospina at Medellín, Colombia, 1500 m above sea level was ETO, which was basically a mixture of Venezuela I (mixture of CF and CTF) and Blanco Común, the predominant race in Colombia at elevation 1000–2000 m, plus selected improved lines and varieties from Mexico, Puerto Rico, Venezuela, Brazil, Argentina, and the United States. Since many of the improved lines added to the mixture were derived from the Cuban and Coastal Tropical Flints and since Común itself was influenced by Costeño derived from the intercrossing of Coastal Tropical Flint and Tuxpeño, it appears that ETO was developed primarily from a complex of Caribbean germplasm. This variety has not only proven to be one of the highest-yielding ones in the temperate climates of Colombia, but also an excellent source of inbred lines for the development of hybrids. Seed of the original variety of ETO is available in the Colombian Seed Bank maintained by the Instituto Colombiano Agropecuario.

The four complexes discussed above have become extremely attractive to tropical maize breeders and have completely revolutionized the breeding and production of maize throughout the lowland tropics in the last 20 years. Some very outstanding open-pollinated varieties and hybrids have been produced and have become widely distributed thoughout the tropics through CIMMYT and the International Maize Program of the Rockefeller Foundation before CIMMYT.

DEVELOPMENT AND DISTRIBUTION OF IMPROVED OPEN-POLLINATED VARIETIES

In Mexico three outstanding open-pollinated populations of Tuxpeño have been developed in a cooperative program between CIMMYT and the National Institute of Agricultural Research (INIA): Crema I, Tuxpeño La Posta, and Tuxpeño 1 (Tuxpeñito).

Tuxpeño Crema I was derived from the intercrossing of eight collections selected as the best performers out of 200 in yield trials of individual collections and their top crosses on two testers, conducted at several locations in Mexico and Central America. The collections composited were Veracruz 48, 143, 174, V-520-C from the Gulf coast, and Michoacán 137, 166, and Colima Group 1 from the West Coast of Mexico. The eighth collection Mixeño 1 was collected in a lowland area of Guatemala.

Tuxpeño La Posta was derived from the intercrossing of 15 elite Tuxpeño inbred lines. Tuxpeño 1, commonly referred to as *Tuxpeñito,* is a variety with shorter plants developed from Tuxpeño Crema I through recurrent full sib selection.

During the last few years tropical maize breeders have given considerable emphasis to shortening the height of Tuxpeño and other tall high-yielding tropical varieties. Johnson (1974) points out that CIMMYT has put high a priority on the development of tropical breeding materials with reduced plant height, using three different approaches: (a) use of genetic dwarfs (*brachytic*-2), (b) selection in advanced generation progenies of crosses between tall and very early, low yielding, short varieties, and (c) recurrent selection within tall, elite, high-yielding tropical materials. The CIMMYT found that all three approaches provided shorter plants; however, recurrent selection within elite tall materials appeared to be the best. The genetic dwarf gene (*br*2) produced certain undesirable side effects, such as excessive leaf width, erratic height and uneven development.

Johnson (1974) greatly reduced the height of both Tuxpeño Crema I and ETO through recurrent selection. Yield in both varieties was maintained, if not improved, and lodging and number of days to flowering were slightly reduced.

These results have stimulated CIMMYT to use the same procedure in reducing the height of many other elite populations with which its maize breeders and collaborators are working.

In El Salvador, Ing. Roberto Vega Lara of the Ministry of Agriculture compared the yields of Tuxpeñito with the original Tuxpeño Crema I and the *br*2 conversion at densities of 40,000, 65,000, 90,000, and 115,000 plants per hectare. The yield of Tuxpeñito was greatly superior to the *br*2 cultivars at all densities and slightly superior to the original variety at all densities except at 40,000. Furthermore, Johnson (1974) reported that in farm trials conducted in the state of Veracruz, Mexico, in 1973, Tuxpeñito was the highest yielding of all entries, including the commercial hybrid H-507, at 75,000 plants/ha and still in second place at a density of 50,000.

Tuxpeñito is being widely distributed throughout the tropics. Seven thousand tons of seed were produced in Mexico in 1975, about one-third of the total seed produced. Some of this will probably be used in other areas of the tropics and will rapidly substitute for the taller elite varieties of Tuxpeño in breeding programs.

The Caribbean area is particularly rich in outstanding breeding materials for the lowland tropics. It is where the outstanding germplasm complexes—the Dents and Coastal Tropical Flints (and more recently the Cuban Flints, or their precursors)—were brought together. Some very elite varieties have come out of the interhybridization of these complexes. Cuprico, a synthetic formed by CIMMYT from the intermixture of Cuba Group I and Puerto Rican flint-dents, is one of the highest yielding open-pollinated Caribbean varieties. In Southeast Asia, where hard yellow flints are highly desired, an excellent high yielding population has been developed from a combination of Cuprico × Cuba Group I.

About 15 years ago the late I. E. Melhus (Professor Emeritus, Iowa State University) developed a variety that he named *Tiquisate Golden Yellow* from a composite of Caribbean collections. It has become very popular in Southeast Asia, under the name of *Guatemala* in Thailand and *Metro* in Indonesia and the Philippines.

These more productive Tuxpeño dents, along with certain open-pollinated varieties, developed directly from the flint complexes or from combinations of dent and flint by various tropical breeders, have made a tremendous impact throughout the lowland tropics. Although only relatively small amounts of seed have been produced and distributed commercially, these elite germplasm complexes have spread rapidly from farmer to farmer with little effort on the part of research and extension workers. Today, open-pollinated varieties common 20 years ago in the lowland areas have been replaced, either directly by improved varieties developed from the elite materials or indirectly by varieties derived by farmers from the random hybridization between introduced materials and the previously predominating types.

In general, the initial impact of the farmer-developed varieties has been much greater than the direct utilization of the improved materials themselves. This presents a striking example of what can be accomplished with little effort, merely through the exploitation of two main evolutionary forces: (a) introduction and migration of elite germplasm complexes and (b) random hybridization and selection by the farmers themselves.

In the lowlands of Central America, the formerly prevailing local indigenous varieties of the Salvadoreño race have been replaced by varieties derived from the introgression of Tuxpeño, ETO, and the Caribbean Flints. In this area, Tuxpeño, although a little late in maturity, is rapidly replacing all other open-pollinated varieties.

In the lowlands of Venezuela and Colombia, indigenous varieties are being replaced directly by Tuxpeño or varieties derived from the random interhybridization of the local, and introduced Tuxpeño, ETO, and Caribbean complexes.

Varieties developed from mixtures of Caribbean flint–dents and Tuxpeño now predominate in the lowlands of Ecuador and Bolivia.

In Brazil the Azteca, developed by Pinto Viegas (1957) from collections of Yellow Tuxpeño introduced from Mexico, and subsequently improved versions are rapidly replacing all indigenous open-pollinated varieties in the vast region from the state of Santa Catalina to the Amazon Basin.

In tropical humid West Africa, the more productive Tuxpeños and varieties derived from interracial crosses of West Indian dents and Caribbean flints are rapidly taking over. Tuxpeñito, the shorter-growing Tuxpeño developed by CIMMYT, is at the top in most yield trials.

In the East African highlands the introduction of Ecuador 573 from the Colombian Maize Bank, has made a striking impact. With this introduction, varietal yield potentials were raised by 40%. Tuxpeño is also becoming widely distributed in the lowland more humid area.

In India, varietal yield levels were raised 100–200% through a combination of southern United States dents with the Caribbean Flints, both recently introduced.

In Southeast Asia, local varieties are being replaced by varieties formed primarily with the Caribbean fling–dent complexes. The flint population developed from an intermixture of Cuprico and Cuba Group I has been especially outstanding. It has become widely distributed in South and Southeast Asia and is widely used in breeding programs in this area of the world. Thailand's 2.5-million-ton corn export business is based entirely on the open-pollinated variety Guatemala (Tiquisate Golden Yellow) and its derivatives.

The influx of the superior Coastal Tropical and Cuban Flints, and to some extent Tuxpeño and related Caribbean dents, has greatly improved the yield potentials of the formerly predominating early white and yellow flint varieties of the Philippines and Indonesia. Throughout Southeast Asia the currently available synthetics developed from combinations of Tuxpeño, CF, and CTF outyield the native varieties by 100% in the absence of downy mildew and under good fertility and moisture conditions. However, they are a bit late in maturity for most cropping systems; earlier maturing varieties are badly needed.

Downy Mildew (*Sclerospora philippinensis, S. sacchari,* and *S. maydis*) is a serious disease in the high rainfall areas throughout Southeast Asia. The main source of resistance is from the local native Philippine varieties (College White and Yellow Flints). A composite of College White Flint and Tuxpeño seems to be a good source of resistant lines. The CIMMYT is concentrating on the development of a downy mildew resistant Tuxpeño, in collaboration with the maize program at Los Baños, using College White Flint as a source of resistance. Varieties resistant to downy mildew in the Philippines are also generally resistant in other areas of the humid tropics. The reverse is not true. Philippine maize breeders have been fairly successful in incorporating a high degree of tolerance to downy mildew into some of the new high-yielding synthetics.

IMPORTANCE OF HYBRID MAIZE TECHNOLOGY

Simultaneously with the improvement and distribution of superior exotic, open-pollinated materials, there has been considerable emphasis on the use of hybrid maize technology in the further improvement of yield potentials, especially in Latin America, East Africa, and India. In the early 1950s the Mexican Ministry of Agriculture, in a cooperative program with the Rockefeller Foundation, developed some very outstanding hybrids, utilizing principally the races Tuxpeño, Celaya, Chalqueño, and Bolita as basic breeding materials. Due to political difficulties in seed production and distribution, hybrid seed never gained much momentum. In the early 1960s emphasis was shifted to the formation of superior open-pollinated composites and their further improvement through recurrent selection. In this effort some of the resulting synthetics soon overshadowed the hybrids produced earlier. Nevertheless, about 70% of the 23,000 tons of seed produced in 1975 by the Mexican National Seed Producing Agency, PRONASA, continues to be hybrid. The remaining third is mostly Tuxpeñito. Together, this is sufficient seed to plant about 18% of the total maize area. With favorable pricing policies and heavy emphasis on increasing use of improved seed, fertilizer, and improved agronomic practices, plus the relaxation of seed-production policies that discouraged private producers, it is likely that there will be a new surge in the production of hybrid maize in Mexico by private seed companies. Genetic materials and hybrid patterns are well identified for the production of hybrids yielding significantly above that of present synthetics.

After the first big impact with superior open-pollinated varieties, breeders in Central America are beginning to concentrate on hybrids. Guatemala is successfully producing and distributing the intervarietal cross Tuxpeño × ETO (using shorter varieties developed by the CIMMYT). According to data compiled by Villena (1975), the 10 highest-yielding varieties in the 1974 cooperative yield tests in Central America (Table 3) were hybrids yielding an average of 8–9% more than the best Tuxpeño synthetic. As evident in Table 3, hybrids made from a combination of Tuxpeño × ETO or West Indian dents × West Indian flints tend to be higher yielding than hybrids made solely with lines from Tuxpeño. In addition, some of the hybrids are earlier maturing and shorter in plant height. El Salvador has been particularly successful in the use of the hybrid-maize technology. Over 60% of the maize area in El Salvador (consisting mainly of small farmers) is planted to hybrids, and much of the seed is produced by private producers. In addition, El Salvador supplies considerable seed to other countries. Demand is greater than supply.

Venezuela is successfully exploiting the Tuxpeño × ETO hybrid-vigor pattern. In 1975, through a combination of Government and private enter-

TABLE 3. Origin, yields, and agronomic characteristics of the 11 highest-yielding entries in the cooperative Central American yield trials (average of 12 locations) (Villena, 1975)

Entry	*Yield tons/ha*	*Days to flower*	*Plant height (cm)*	*Ear height (cm)*	*Germplasm*
Dekalb H-4[a]	5324	59	241	135	Tuxpeño × (ETO)[b]
Desarrural HB 105	4963	62	245	136	Tuxpeño × ETO
Pioneer 304A (×)[a]	4928	58	225	122	WI Dents × WI Flints[b]
Desarrural HB 104	4826	62	241	141	Tuxpeño × ETO
Poey T31	4819	62	241	142	Tuxpeño × Tuxpeño
E S-H B 1	4794	60	246	130	Tuxpeño × Tuxpeño
H 5[a]	4724	60	236	129	Tuxpeño × Tuxpeño
E S-H A 1	4633	59	234	134	Tuxpeño × Tuxpeño
Mexico H-507[a]	4584	64	253	148	Tuxpeño × Tuxpeño
Pioneer 304 B[a]	4583	58	215	114	WI Dents × WI Flints[b]
Centa 1 B (syn)[a]	4576	59	225	118	Tuxpeño Synthetic

[a] Seed is being produced.

[b] The source of germplasm for these hybrids is a guess based on their appearance and performance and may not be exact.

prise, Venezuela produced about 6200 tons of hybrid seed, enough to plant over 50% of total maize area. In addition, about 350 tons of certified seed of improved open-pollinated varieties were produced. Only about 5.3% of total seed production is open pollinated.

Colombia is principally exploiting the hybrid-vigor pattern among Tuxpeño, the Caribbean flints, and ETO, in areas below 1800 m elevation. Although the hybrids are excellent, the demand for seed in the past has not been great, due to the absence of effective programs for the acceleration of maize production throughout the country. In 1973, through the combined efforts of government and private enterprise, Colombia produced approximately 2885 tons of hybrid seed, enough to plant 165,000 ha in the tropical lowlands (ca. 20% of total maize area). This was more than produced in any previous year. Seed production in 1974 diminished about 10%.

In Peru, 90% of the maize in the lowland coastal area under irrigation is planted with hybrid seed (2200 tons) made primarily from a combination of lines from Perla (the formerly predominating local flint variety) and the exotic Caribbean flint–dent complex. The remaining 10% is planted mostly with advanced generation hybrid seed.

In Argentina approximately 80% of the 4–6 million hectares planted to maize is planted with hybrid seed. Since the dark orange Cateto flint type of grain continues to be the preferred type for export by the Argentinian Grain Board, most of the hybrids have been formed from the local Cateto flints. Hybrids made from a combination of U. S. dent lines with lines from Cateto, CF, and CTF, have proven to be greatly superior in yield, but grain types of these do not meet present export requirements.

Brazil is number one in maize production in Latin America, with about 12 million hectares planted annually and a total production around 16 million tons. About 40% of the total maize area in Brazil is planted to hybrid seed. However, in the central maize belt 50–80% of the maize planted is now hybrid. Seed is produced by both private companies and associated seed growers. Sementes Agroceres, S. A., one of the largest seed producers, produced about 25,000 tons in 1975 (personal communication from Gladstone Drummond, Director of Research).

The most striking example of the effect of exotic germplasm in increasing potential yields of hybrids is in Brazil. Dr. Ernesto Paterniani, Director of the Institute of Genetics in Piracicaba, Brazil, has kindly provided me with a summary of the progress made in the dynamic maize improvement program in Brazil since its beginning.

Thirty years ago the two most common maize races in Brazil were Cateto and Paulista Dents. Both of these races were described by Brieger, Gurgel, et al. (1958). Paulista Dent was derived from the interhybridization of Cateto and dents introduced from U. S. A. These varieties were inbred, beginning in 1932, and resulting lines were evaluated. In 1946 the first double-cross H-3531, developed by Carlos Krug and collaborators, with four Cateto inbreds (C1 × C2) × (C3 × C4) was released for commercial production by the Institute of Agronomy at Campinas (IAC). It yielded about 22% more than Cateto and somewhat less in comparison to Paulista Dent. The relative yield of this hybrid and of hybrids produced subsequently and of two open-pollinated varieties representative of Cateto and Paulista Dent, are illustrated in Figure 1. Although the graph only indicates comparative yield potentials, the hybrids are also superior to the open-pollinated varieties in agronomic characters and disease resistance. The curves on the far right in Figure 1 show the progress made in yield potential through half sib selection in four synthetic populations. These are discussed later.

In 1953 the semident hybrid H-4624 developed by IAC was released for commercial production to replace H-3531. In this double cross two Cateto lines C1 × C2 were combined with two dent lines (T1 × PD1); T1 is a line derived from Tuxpeño germplasm by the Texas Agricultural Experiment Station, and PD1 was derived by IAC from Paulista Dent. This flint–dent hybrid was strikingly superior to the pure Cateto hybrid H3531 and yielded about 43% more than the better varieties of Paulista Dent.

Also in 1953 the IAC received seed of 21 yellow Tuxpeño samples collected in lowlands of the state of San Luis Potosi, Mexico, by the Cooperative Mexican–Rockefeller Foundation Agricultural Program. A synthetic made by Pinto Viegas at IAC (1957) from these introductions was named *Azteca.* In yield trials Azteca was found to yield the same as H-4624. As mentioned earlier, Azteca has become widely distributed throughout Brazil and has provided a source of Tuxpeño germplasm for a new series of inbred lines and the development of still higher-yielding synthetics.

In 1956 the IAC released its third hybrid H-6999A. The only difference between the pedigree of this hybrid and the previous one is that the Paulista Dent line PD1 was substituted for a line derived from Azteca. Its yield was only slightly better.

In 1958 the IAC released its fourth hybrid H-6999B, a double cross between two Cateto lines and two Azteca lines (C1 × C2) (T1 × T2). In performance trials it yields about 9% better than H-6999A and 50% better than Paulista Dent. Since its appearance, this hybrid has become the standard to which all other flint–dent hybrids developed by private, federal, and state breeders are compared. Yields of most hybrids produced commercially in Brazil today are similar to H-6999B.

C. G. del Valle was among the first to develop commercial hybrids and improved open-pollinated varieties from the flint–dent heterosis patterns in the

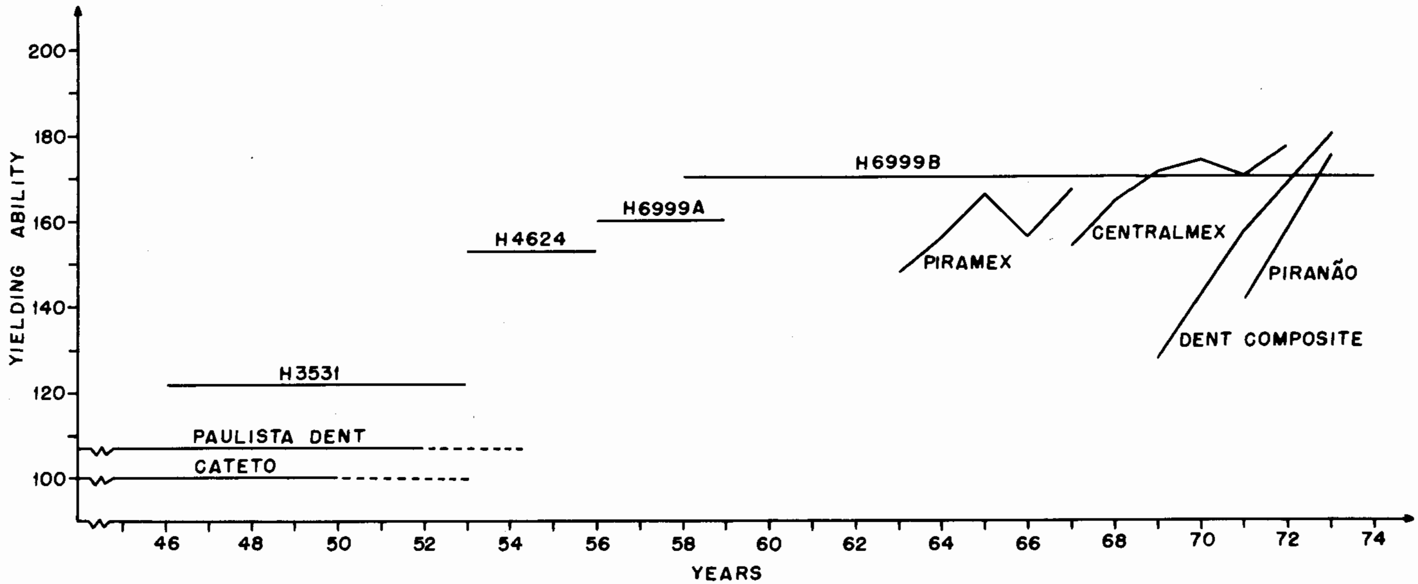

Figure 1. Progressive improvement of yield potential in Brazilian hybrids and effect of half-sib selection in four open-pollinated composites.

Caribbean. The Cornelli flint–dent hybrids developed by del Valle for Cornelli Seed Company were the first hybrids commercially available in the area. They were also used in Central America. Similar hybrids were later successfully produced in Cuba by Poey Seed Company. The open-pollinated synthetic produced by del Valle [PD(MS6)] is still used in breeding programs.

More recently, Pioneer International Hi-bred Seed Company has begun to exploit the flint–dent Caribbean heterosis pattern in the formation of hybrids for the Caribbean area and lowland tropics of Central America. In Central America, as indicated early in this chapter, some of the Pioneer hybrids are similar in yield to the best Tuxpeño or Tuxpeño × ETO hybrids but are shorter in plant-height growth and are earlier maturing.

Poey Seed Company has moved its base to Mexico, where it has become an affiliate of Northrup and King and is continuing to successfully exploit the flint–dent hybrid-vigor pattern in the production of hybrid seed for the lowland tropics.

Prior to 1969, 85–90% of the 432,000 ha of maize planted annually in Egypt was planted to two varieties: (a) American Early (a derivative of Boone County White U. S. A.) and Nabal Gamal (isolated from Hickory King U. S. A.). An earlier attempt to substitute these with double-cross hybrids made from U. S. A. inbred lines failed, primarily because the resulting hybrids yielded very little more than the prevailing open-pollinated varieties.

In 1969, at the beginning of the CIMMYT/Ford Foundation/Egyptian cooperative project, varieties of Coastal Tropical Flints, Tuxpeño and mixtures of Tuxpeño–U. S. A. dents developed by CIMMYT, were introduced into Egypt, and the program was reoriented toward the development of new elite heterozyous maize populations through interracial crosses. This approach has resulted in the formation of a new series of synthetics and intervarietal hybrids with a much higher yield potential.

Two interracial crosses—American Early × a Composite of Tuxpeño–U. S. A. Dents and American Early × Tuxpeño La Posta—and one interracial composite have been released for commercial production. The two interracial crosses in F_1 yield at the level of 12–14 tons/ha, 40–50% more than the better open-pollinated varieties and double crosses made with U. S. A. lines. Sufficient seed of this new material was produced in 1973 to plant about 7,000 ha in 1974.

In Kenya the major part of the hybrid seed industry is based on interracial hybrids made from improved populations of KII and EC. 573. According to the 1974 EAAFRO Maize Report, about 375,000 ha are planted to hybrids in the highlands of Kenya. This is about 30% of the total maize planted. Of the maize planted, about 89% is planted on small farms.

Breeders in India have concentrated on the formation and distribution of hybrids since the beginning of the maize-breeding program in 1954. A number

TABLE 4. Commercial seed production in Latin America, 1974

Country	Production (tons)		Percentage[a]	Kind of Enterprise
	Hybrid	Open-pollinates		
Mexico	16,000	7,000	18	Mostly government
Central America	4,500	1,000	25[b]	Government and private
Venezuela	6,200	400	60	Government and private
Colombia	2,900	?	20	Government and private
Peru	2,200	200	90[b]	Agr. univ. and private
Argentina	80,000	0	80	Private
Brazil	90,000	1,000	40[c]	Mostly private
Total	201,800	9,600		

[a] Percentage of total maize area planted with improved seed.

[b] Percentage of area in which improved varieties are adpated. In El Salvador 60% of total maize area is planted with hybrid seed.

[c] Eighty percent in State of São Paulo.

of outstanding hybrids has been made, with a yield potential of two to three times greater than the local varieties prevailing in the 1950s. These hybrids were formed in a short period of five years, from the combination of inbred lines from U. S. A. with lines developed from the Caribbean flint–dent complexes. However, due to a myriad of problems, mainly a lack of farmer incentives to produce more maize, these hybrids never made significant impact. Nevertheless, the hybrids served to introduce new germplasm into the hands of subsistence farmers from which they developed a new set of more productive varieties.

In spite of the many difficulties with the hybrid-maize technology in the tropics, much more hybrid seed is commercially produced than seed of open-pollinated varieties. In Latin America (Table 4), it is estimated that 202,000 tons of hybrid seed were produced in 1974–1975, sufficient to plant about 10 million ha, or about 37% of the total land area planted annually to maize. Only about 10,000 tons of open-pollinated seed were produced commercially (not including seed that might be sold by individual farmers). Countries that have encouraged private enterprise in hybrid-seed production have progressed more rapidly in increasing seed supplies. Private seed producers have not only helped to increase the volume of seed, but have been a big factor in its distribution and use with improved agronomic practices on all kinds of farms, large and small. As maize production becomes more sophisticated in the tropics, the trend definitely will be toward the formation and greater use of hybrids.

BREEDING METHODOLOGY FOR FURTHER IMPROVEMENT OF YIELD POTENTIAL OF HYBRIDS

In the attempt to raise yields of hybrid varieties still further, the Brazilian maize team is devoting a major effort to further improvement of a number of open-pollinated flint and dent composites (see Table 5).

All of these composites, with the exception of America Central, are being improved mainly through recurrent selection among and within half-sib families (modified ear-to-row selection). Very substantial increases in yield capacity are being obtained and yields of certain populations, as shown in Figure 1, are now equal or superior to hybrid H-6999B. Seed of the related dent composites, Azteca, Maya, Piramex, Centralmex, and IAC1, has been widely distributed in the vast region from northern Rio Grande do Sul to the Amazon basin. These new higher yielding varieties are rapidly spreading from farmer to farmer and gradually replacing open-pollinated varieties formerly distributed in this area.

The broad-based dent and flint composites (numbers 7 and 8, Table 5) are extremely promising for the development of higher-yielding hybrids and have

TABLE 5. Principal composites being improved through recurrent selection (Brazil)

Name	Year formed	Institution	Germplasm
Azteca	1953	IAC[a]	Yellow Tuxpeño dent
America Central	1961	ESALQ[b]	Mixture of West Indies and Tuxpeño Dents
Piramex	1963	ESALQ	Tuxpeño (Azteca) Dent (combination of 20 S_1 lines)
Maya	1965	IAC	Mixture of lines and collections of Tuxpeño (Azteca)
IAC 1	1965	IAC	Tuxpeño × Caribbean Flint
Centralmex	1967	ESALQ	Piramex × America Central
Dent Composite	1969	ESALQ	Wide-base Tuxpeño dent
Flint Composite	1969	ESALQ	Wide-base flint mixture (Cateto, ETO, CF, and CTF)
Piranão	1971	ESALQ	Piramex × Tuxpeño brachytic
Cateto-Colombia			Wide-base flint mixture of inbreds from Cateto, Venezuela 1, Nariño 330, ETO, and Cuba 23

[a] Instituto Agronómico Campinas.

[b] Escola Superior de Agricultura Luis de Queiroz, Instituto Genética, Piracicaba.

been widely distributed among public and private breeders. Recurrent selection is being continued within each, and a program for the further improvement of yield of both composites and their specific combining ability is underway at IAC.

Composite Cateto–Colombia is another very promising flint type. It is being further improved at the National Maize Center, Sete Lagoas, M. G., and seed is being extensively distributed in northern Minas Gerais, where the farmers still prefer the Cateto-type flints.

Piranão is one of the most interesting populations of all. It is a short plant population derived by Paterniani (1974) through recurrent selection within the advance generation progeny of the cross between Piramex and Tuxpeño brachytic received from CIMMYT. Reduced height is primarily due to the shortening of the internodes below the ear. Above the ear, internode length is normal, avoiding a compaction of leaves. It is equal in yield capacity to the dent composite Centralmex, but its plants are one meter shorter. It is being enthusiastically received by farmers and seed producers. One seed producer had about 800 tons available for planting in 1975. This new short plant variety presents a breakthrough for Brazil and other tropical maize programs, along with the short plant Tuxpeñito developed in Mexico.

All of these new, higher-yielding materials, in addition to their direct use as open-pollinated varieties, will be extremely valuable to the hybrid maize breeders in Brazil. Until a new series of inbred lines can be developed from these new materials, hybrid seed producers in certain cases are resorting to the production of intervarietal crosses or the substitution of one of the high-yielding composites for one of the single crosses in a double-cross hybrid. Some of the new flint × dent intervarietal crosses yield up to 12% better than H-6999B. Thus the Brazilian breeders now have the basic ingredients for the formation of a new series of double-cross hybrids that can be expected to greatly surpass the present ones in yield capacity and plant type. Breeding activities leading to higher yielding, open-pollinated varieties and hybrids in the fuller exploitation of certain heterosis patterns are also underway in other areas of the tropics.

In Venezuela the Ministry of Agriculture breeders have launched a population improvement program within two populations and a reciprocal, recurrent selection program between them. One of the two populations is a flint, synthesized from a mixture of ETO, Nariño 330, and Venezuela 1, and the other is a dent synthesized from a mixture of three local varieties of Tuxpeño. These two populations should offer the commercial breeders a new source of inbred lines. It might be highly beneficial to add CIMMYT's short ETO to the flint population and Tuxpeñito to the dent. During the last 3 years the prevalence of stunt virus and downy mildew diseases has increased. Venezuelan breeders are very much aware of this and are beginning to emphasize selection for resistance to these two potentially destructive diseases in their breeding programs.

The flint–dent hybrid-vigor pattern is also being further improved in the lowlands of Colombia, Peru, and Central America through the formation and improvement of separate wide-based flint and dent composites.

In Colombia, Torregroza, head of the ICA maize program, has established certain interracial heterosis patterns for the Andean highlands. Yield capacities of the component populations of these patterns are being further improved through recurrent selection for prolificacy.

Breeders at the Argentine Agricultural Research Center at Pergamino, looking forward to a time when the semiflints may be acceptable for export, have formed two populations: (a) a composite of local and Caribbean flints and (b) a mixture of U. S. A., Tuxpeño, and West Indian dents. These populations have now been grown for a number of years with the intention that once they become fairly well adapted to the Argentine environment, a reciprocal recurrent selection scheme between them would be initiated.

In the highlands of Kenya, the Kitale II × Ecuador 573 heterosis pattern has yielded some excellent hybrids and open-pollinated synthetics. Attempts are being made to further improve the yield of the two components and their combining ability.

Harrison, of the International Institute of Tropical Agriculture at Ibadan, is working on the improvement of a hybrid vigor pattern for West Africa (Harrison, 1970). Egypt is distributing seed of interracial crosses of American Early (Boone County White) and Tuxpeño and is concerned with the further improvement of these combinations.

In Thailand the dark orange-yellow flint population derived from a mixture of Cuba Group 1 and Cuprico is being further improved through recurrent selection for direct use in commercial maize production. It is the highest-yielding population available in Southeast Asia today. Although it is not specifically being improved for use in a hybrid pattern with Tuxpeño or related dents, it might be an excellent source of flint inbred lines for breeders interested in the production of superior flint × dent hybrids.

For years, certain breeders have dreamed about the formation of a high-yielding dwarf corn that could be planted at high densities and machine harvested. Mario Castro Gil (1973), working in Mexico with initial encouragement and support from CIMMYT, produced a dwarf hybrid adapted to 1000–1800 m elevation from inbreds developed from an interracial mixture segregating for *brachytic*-2, derived from a composite of Puebla Group I, Tuxpeño (V-520-C), and a variety from Argentina, with a square stalk (*Tallo cuadrado*), two ears from the same node, and erect leaves. The hybrid is currently commercially produced as a three-way cross. It grows about 1.5 m tall.

Yields of 15–18 tons/ha have been obtained with a density of 130,000 plants/ha in experimental plots under high fertility irrigated conditions, at elevations of 1100–1800 m. This is about double the yield of current hybrids in this area of Mexico. Commercial seed production of the three-way cross, as presently constituted, is difficult, because the inbred used as a pollinator is too short for good pollination of the female single cross. About 40 tons of seed were available for planting in 1976.

DEVELOPMENT OF MORE NUTRITIVE VARIETIES

Thus far very little impact has been made with high-quality-protein varieties in Latin America, but interest in the development of such varieties continues to be high. Work underway, accomplishments and prospects for the future, were recently reviewed in the worldwide CIMMYT–Purdue Symposium on protein quality in Maize (1975). This year Guatemala is starting a program in collaboration with CIMMYT and USAID, based on the modified endosperm, high lysine–trytophan varieties developed by the CIMMYT–UNDP project. These varieties are also being tested in other countries of Central and South America.

Colombia has had two high lysine hybrids (H-208 and H-205) in commercial production for a number of years; they yield about 10% less than their normal counterparts. Seed production of these hybrids has stabilized around 60–70 tons annually.

Peru has four hybrids converted to *opaque*-2 that are well adapted to the low and medium Sierra. However, like the Colombian hybrids, they yield 10–15% less than their normal counterparts but still considerably more than the common open-pollinated varieties. Very little seed is being produced.

Most of the high-lysine maize produced in Latin America is produced in Brazil. The best variety is Agroceres 504. About 800 tons of seed of this variety are produced and sold annually by Agroceres. This variety has also performed consistently well in CIMMYT's international yield trials. Another 800–1000 tons of seed are produced annually of the converted intervarietal cross Maya × IAC by various smaller producers. Practially all of the *opaque*-2 maize produced is fed directly to hogs by farmers not using commercially prepared, balanced rations. Some is being used in a nutrition project, in part sponsored by the USAID at Vicosa.

Seed producers everywhere, including Brazil, claim there is little demand for the better protein-quality maize in its present state of development. Breeders and extension workers talk about the need for special promotion campaigns. Even with these, it is doubtful that much progress can be made. I believe that introducing the more nutritive protein qualities in the form of special varieties is the hard way. In my opinion, the only way to attain the impact we all desire and know is feasible is to treat the high-quality protein character as one more attribute to add to all of the improved open-pollinated varieties and hybrids released for production. Wheat breeders have been operating this way for years, in the development of superior varieties, with the desired milling and baking qualities.

THE CIMMYT PROGRAM

This program is discussed by Johnson (1974) and in the CIMMYT 1973 annual report on maize improvement. As indicated in these descriptions, CIMMYT is devoting its major efforts to the formation, development, and initial improvement of broad-based gene pools, composited with emphasis on the combination of desirable attributes for different ecological situations, without regard to racial origins or heterosis patterns. Fourteen highland, 12 tropical and eight temperate pools have been formed. Breeding efforts are concentrated on the development of widely adapted, high-yielding, open-pollinated varieties, with desirable attributes as may be needed for different prevailing environmental situations, through recurrent, full-sib selection within a given pool. The full-sib progenies are widely tested within the environment for which a better variety is sought. The pool selected for improvement in a given area depends on the end product desired.

The CIMMYT procedure with 12 populations in the lowland tropics will certainly produce some outstanding varieties and probably some good hybrids; there is, however, another approach that I believe warrants special attention and would result in a fuller exploitation of the natural heterosis patterns existing between the flint and dent (and other) germplasm complexes. Instead of the formation of 12 populations, in which racial complexes and hybrid patterns are disregarded, it seems to me that tropical maize breeders might better focus their main cooperative efforts on the development of *two* broad-based, high-yielding, widely adapted, fertilizer-responsive, more nutritive, biologically efficient populations, as follows: (a) a dent composite, consisting of the combination of Tuxpeño and related dents, such as the Cuban, West Indian, and U. S. A. dents and their precursors and (b) a flint composite, consisting mainly of the Cuban, Coastal Tropical, and Cateto flints and their precursors. Each of these might be further divided into three subpopulations: (a) early, (b) medium, and (c) late maturity. For the short range, it might be better to start with more narrowly based populations constituted with only the best materials. For example, the late dent population might primarily be Tuxpeñito, and the medium and early maturing ones might be comprised of the earlier tropical dents. Each population would be constituted without regard to grain color. The color desired could readily be sorted out as needed, when varieties are formed for commercial production.

Desirable attributes, such as reduced plant height, high lysine, wide adaptation, elasticity and flexibility in performance under varying moisture conditions, and more comprehensive resistance to disease and insect pests, could be incorporated into each, along with a steady improvement of yield through indicated recurrent selection procedures. Once the desired performance level of each of the individual flint and dent populations has been attained, reciprocal recurrent selection procedures could be initiated to further enhance their combining ability.

Where open-pollinated synthetics are desired, the two populations could be combined and the resulting progeny further improved through recurrent selection. This, like the formation of hybrids, can best be done at the local level by local breeders. With our present knowledge of available materials, the combination of the flint and dent germplasm complexes into a single population should provide the best possible base for synthesizing open-pollinated varieties with a high yield capacity. However, where hybrids are feasible and practical and where maximum yield capacity is desirable, the best way to exploit the strong natural heterosis pattern existing between the flint and dent complexes is in the formation of hybrids. The yield capacity of the best hybrids, produced as modern technology provides, would be at least 15–30% higher than that of the best synthesized open-pollinated varieties in the same maturity class. Where wide adaptability is a desirable trait, one might resort to the use of multiline hybrids.

This kind of worldwide cooperative program would set the stage for the formation of both super open-pollinated varieties and hybrids at the national level. The Brazilian maize team is basically using this approach in the further improvement of the yield potential of hybrids and varieties in Brazil.

DISCUSSION AND CONCLUSIONS

Breeding and production of maize in the lowland tropics has been revolutionized during the last 20 years by the isolation, introduction, and widespread dissemination of four outstanding and distinct germplasm complexes: (a) Tuxpeño and related dents (Mexican, West Indian, Cuban, and Southern U. S. dents), (b) Cuban Flint (CF), (c) Coastal Tropical Flint (CTF), and (d) ETO Flint.

Today, open-pollinated varieties that prevailed in the lowland tropics 20 years ago have been replaced by: (a) improved open-pollinated varieties or composites, developed by breeders directly from the individual complexes or combinations of them, (b) intervarietal, interracial, or inbred-line hybrids (usually dent–flint crosses), or (c) varieties developed by the farmers themselves, either directly from the introduced materials or from the random hybridization of introduced materials with prevailing local, indigenous types.

The impact from the farmer-developed varieties has been much greater than from the direct utilization of the breeder-developed materials. In the early stages of most tropical maize improvement programs, the farmer-developed varieties often were very good, and in the absence of effective seed production and distribution systems, these varieties spread very rapidly from farmer to farmer, with little effort on the part of research and extension workers. This is a striking example of what can be accomplished with relatively little effort, merely through the exploitation of the two evolutionary factors of introduction and migration of elite germplasm complexes through random hybridization with prevailing less productive types.

Although a tremendous impact has been made with the development and distribution of open-pollinated varieties, as maize production becomes more sophisticated in the hands of both large and small farmers, and as reliable sources of good seed develop, the trend toward the formation and greater use of hybrids will definitely continue. Over 200 thousand tons of hybrid seed were commercially produced in 1974–1975 in Latin America alone, sufficient to plant about 10 million ha or about 37% of the area planted annually to maize. In the same year only about 10,000 tons of seed of improved open-pollinated varieties were produced. Use of hybrid seed is not limited to the large farmers. In Central America, where 80% or more of the maize is produced by small farmers with 1–5 ha, the demand for hybrid seed is growing rapidly. It has been demonstrated in this area that the small subsistence farmer, as his maize production moves from a low-input subsistence operation to a highly profitable operation with the use of fertilizer and improved agronomic practices, will abandon his former custom of saving his own seed and resort to the annual purchase of good seed with a higher yield potential for his conditions, provided he is assured of a constant and reliable supply. In most cases this will be hybrid, because the other is in limited supply commercially.

During my 32 years of promotion of maize production in the tropics, I have been able to interest neither the public nor the private sector in the production of large volumes of seed of open-pollinated varieties. Where it is produced, it is produced by individual farmers, or as a stopgap by commercial seed-producing agencies, until some kind of hybrid can be developed. In Central America, several good, improved open-pollinated varieties are available; yet the trend in both the public and private sectors is toward hybrid seed production, much of it initially in the form of intra- or interracial variety crosses. In Venezuela, a high-yielding open-pollinated variety derived from a combination of Tuxpeño by ETO is available; yet practically all of the seed commercially produced is hybrid, either as crosses between open-pollinated varieties of Tuxpeño and

ETO or as crosses between inbred lines developed from these races. Similarly in Brazil, in the maize area of Rio Grande do Sul, an open-pollinated variety is available that outyields the best of the hybrids, but no one seems to be interested in producing large volumes of commercial seed of this variety.

Hence it appears to me that the wise maize breeders in the lowland tropics are those who devote their major resources and efforts toward the further improvement of the components of the flint–dent heterosis pattern, and the combining ability between them, in the attempt to more fully exploit these outstanding germplasm complexes for the further improvement of hybrid yields. At any point along the line of progress, the two components may be combined to form an open-pollinated population from which outstanding open-pollinated varieties could be developed. Actual development of the open-pollinated varieties might best be left to the farmers themselves, especially those who save seed for their next planting. Experience has shown that some of these farmers will come up with open-pollinated varieties from this elite material, which for their purposes will be as good or better than any breeders may produce.

Many of the hybrid maize breeders in the tropics, especially in Latin America, are devoting major efforts to the next major increase in the yield potential of their hybrids by a more fuller exploitation of the flint–dent heterosis pattern. In Brazil, yield levels are being raised in both the recently formed wide-based flint and dent open-pollinated populations through recurrent half-sib selection. At the same time, reciprocal recurrent selection programs are underway to enhance the combining ability between them. Yield capacities of the dent composites are now higher than the best hybrids, and major progress is being made in increasing yield potential of the flint composites combining Cateto and Caribbean flints. In the early cycles of selection, yield increases of up to 8% per cycle have been obtained in the dent composites. Rate of increase in the flint composites has been equally striking. These new populations, in addition to being directly useful as open-pollinated varieties, have set the stage for the development of more productive hybrids.

The CIMMYT is devoting its major efforts to the formation and improvement of broad-based gene pools, consisting of a combination of different varieties with desirable attributes. However, varieties are pooled without regard to racial origin or heterosis patterns. Undoubtedly, some excellent open-pollinated varieties are being formed, but in view of the trends in commercial seed production, more attention to population improvement for the fuller exploitation of specific, natural heterosis patterns would be highly desirable. This new orientation would in no way hinder the development of immediately useful open-pollinated varieties, but it would be much more helpful to tropical maize breeders in general.

As a final comment, I would like to stress that the limiting factor in the acceleration of maize production in the lowland and highland tropics today is not varieties. Good varieties (open-pollinates or hybrids), highly stable in their performance and highly responsive to fertilizer and improved agronomic practices, are now available for almost all areas in which maize is grown. What is lacking are effective production campaigns in which good seed is combined with the use of fertilizer, improved agronomic practices, and input-product pricing policies that will allow the farmer to make a profit.

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