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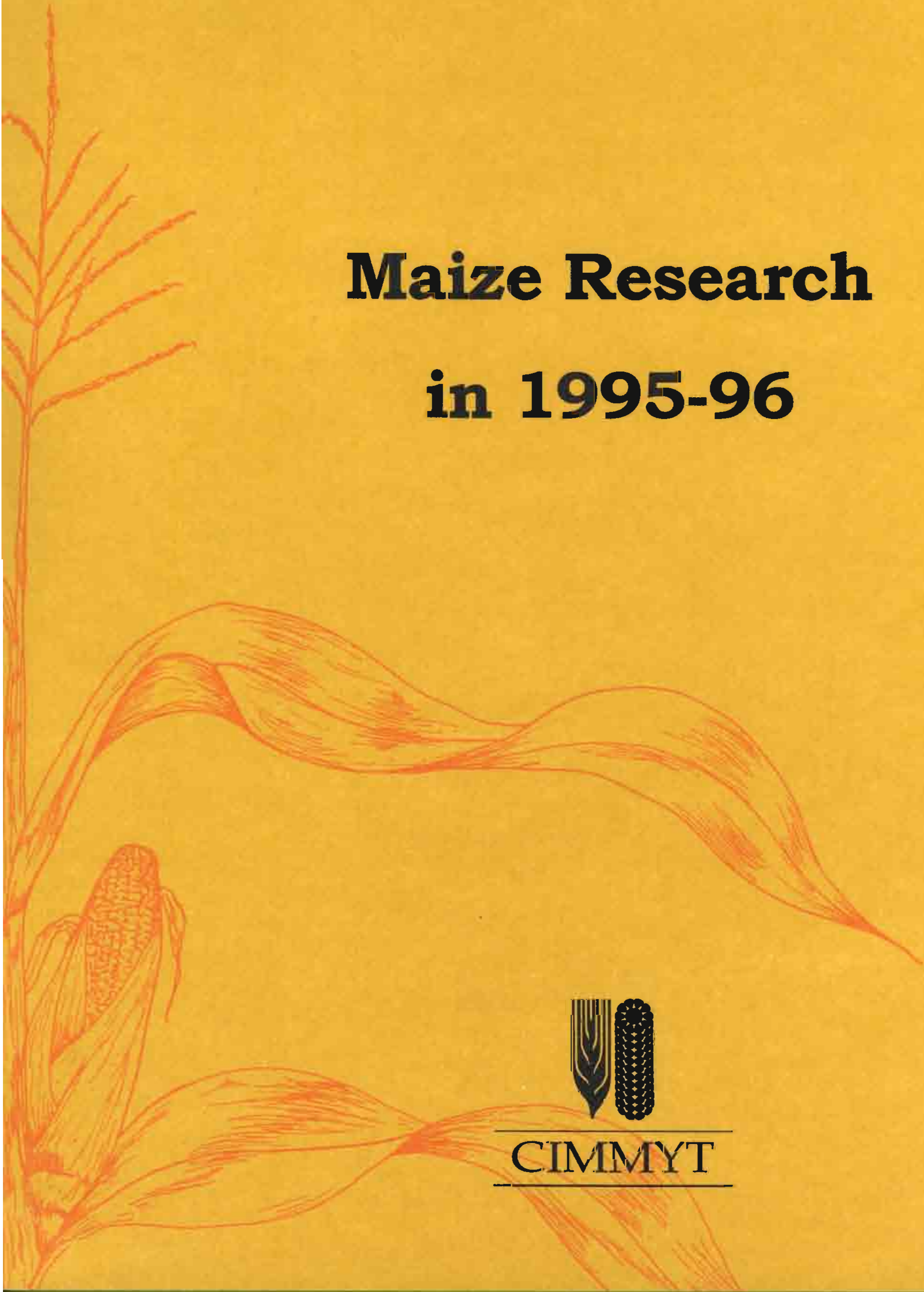

Maize Research in 1995-96

CIMMYT

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CIMMYT

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Other Maize Program Special Reports:

International Testing: Evaluating and Distributing Maize Germplasm Products. R.N. Wedderburn, technical editor.

The CIMMYT Maize Germplasm Bank: Genetic Resource Preservation, Regeneration, Maintenance, and Use. S. Taba, technical editor.

Stress Tolerance Breeding: Maize that Resists Insects, Drought, Low Nitrogen, and Acid Soils. G.O. Edmeades and J.A. Deutsch, technical editors.

The Subtropical, Midaltitude, and Highland Maize Subprogram. M. Bjarnason, technical editor.

The Lowland Tropical Maize Subprogram. S.K. Vasal and S. McLean, technical editors.

Maize Genetic Resources. S. Taba, technical editor.

Development of New Stress-Resistant Maize Genetic Resources (UNDP Project GLO/90/003); Final Report 1990-1996.

Latin American Maize Germplasm Regeneration and Conservation: Proceedings of a Workshop held at CIMMYT, June 4-6, 1996. S. Taba, technical editor.

CIMMYT is an internationally funded, nonprofit scientific research and training organization. Headquartered in Mexico, the Center works with agricultural research institutions worldwide to improve the productivity and sustainability of maize and wheat systems for poor farmers in developing countries. It is one of 16 similar centers supported by the Consultative Group on International Agricultural Research (CGIAR). The CGIAR comprises over 50 partner countries, international and regional organizations, and private foundations. It is co-sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP).

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Abstract: This publication contains a collection of summaries of longer reports on research by subsections of the CIMMYT Maize Program, in collaboration with national programs and other institutions worldwide, in 1995-96. Topics covered include breeding for the major maize ecologies of the developing world, physiology and stress tolerance breeding, the conservation and use of maize genetic resources, international testing, maize pathology and entomology, and collaborative regional efforts of the Program in Latin America, Africa, and Asia. There are descriptions of breeding materials, research methodologies and outputs, and Program policies.
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Contents

Foreword

This is the first in a new set of yearly reports on major objectives, activities, methodologies, and products of the CIMMYT Maize Program. The publication contains a collection of summaries of longer reports on research by subsections of the CIMMYT Maize Program, in collaboration with national programs and other institutions worldwide, in 1995-96.

For the Maize Program, 1995-96 was busy period in which staff pursued long-term research goals while adjusting to rapidly changing circumstances in the agricultural research and funding environments. A period of major downsizing had been completed and a stable level of staffing achieved. In response to the rising interest in hybrids, the Program continued moving toward more inbreeding and the development of inbred lines, while implementing hybrid testing and procedures that will allow the improvement of populations for the production of both open-pollinated varieties and inbred lines. In international testing, the Program began emphasizing data from "key-sites" known to be reliable for gauging germplasm performance for given traits. A major UNDP-supported research project focusing on stress tolerance in maize came to a close, and the Program began work to apply the resulting methodologies in sub-Saharan Africa, where small-scale farmers in marginal production zones stand to reap special benefit. Related to this work, the Program continued efforts to verify the utility of selection using DNA markers and of genetic transformation, in collaboration with CIMMYT's applied biotechnology laboratories. Finally, owing to the growing complexity of its work and to ensure that useful germplasm and information are more likely to reach farmers, the Maize Program sought innovative partnerships with a range of players involved in agricultural development, including national research programs, private companies, non-government agencies, and other international centers.

The above is just a taste of the breadth and complexity of CIMMYT's global research program aimed at benefiting maize farmers in developing countries. More detailed accounts follow. We hope you will find this report useful, and encourage you to contact the Maize Program Directors' office with comments, queries, and requests for seed or further information.

Delbert C. Hess
Director, 1992-96

Richard N. Wedderburn
Associate Director

The CIMMYT Maize Program

Lowland Tropical Maize

Surinder K. Vasal, Scott McLean, Felix SanVicente,** Sai Kumar Ramanujam** and Miguel Barandiarán***

1995

The Lowland Tropical Maize subprogram at headquarters continues to follow a two-tier germplasm management system. Hybrid research activities are being strengthened and fully integrated with germplasm development and population improvement activities. Two additional cycles of selection were completed in two extra-early white and yellow pools (Pool 15E and Pool 17E) using modified half-sib system with emphasis on earliness and improving resistance to maydis leaf blight through artificial inoculations.

Four early, two intermediate and four late tropical pools are undergoing improvement using a combination of S_2 and half-sib recurrent selection procedure. During the year under report S_2 progenies from several pools were evaluated in replicated trials at Poza Rica. Superior progenies will be recombined separately in each pool to complete cycle of selection. In addition synthetics will be formed using only 10-12 superior selfed progenies. Elite S_2 progenies from each pool will also be evaluated for drought stress next cycle.

Thirteen maize populations (21, 22, 23, 24, 25, 27, 28, 30, 31, 32, 36, 43 and 49) are under active population improvement. A rapid shift is under way to interpopulation improvement methods. Populations 21 and 32 are being improved using modified reciprocal recurrent selection (MRRS-HS). Recombination among superior selfed progenies could not be attempted for lack of data from some sites. During 1995, half-sib progenies in Population 30, full-sib among selfed S_2 progenies in Population 31 and interpopulation full-sibs among selfed S_2 progenies in Population 28 and 36 were sent out as IPTTs. Interpopulation full-sibs between 22 and 43, 23 and 49, and 24 with 27 will be attempted and sent out in 1996. In other populations selfed progenies were advanced and seed increased.

Twelve Experimental Varieties (EVs) were generated from IPTT data of Populations 22, 23, 25, 28, 36, 24, 27, 43, 30, 31 and 49 and advanced to F_2. In addition 14 synthetics were formed and advanced to F_2. These varieties will be included in EV trials. Also 15 new EVs were formed from different populations and will be advanced to F_2 in 1996 for inclusion in 1996 EVTs. During 1995, two experimental variety trials EVT-12 and EVT-13 were put together for distribution to different countries. EVT-12 consisted of tropical late white varieties and EVT-13 of yellow flint and dent varieties.

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* Left CIMMYT in 1996.

** Appointed in 1995.

Results on performance of experimental variety trials conducted during 1994 and 1995 were summarized. In 1994 trials, the EVs, Poza Rica 9243, Poza Rica 9043 and La Posta Sequia C_3 (F_2) gave good performance across locations. Entry Tuxpeño Seq. (TS6 C_2 F_2) was the poorest performer in the whole trial. EVs from Population 28 and low nitrogen selection Across 8328 BNC5F_2 also gave good performance. Pool 26 Sequia C_3 F_2 did not perform well. In early and intermediate maturity materials the entries with good performance were Across 9130, Pichilingue 9130, and DTP1C6F_2. In 1995 trials, Dan Phuong 9243, Across S9043 and three EVs from Population 28 were the top performing entries in across location data.

We attempted to merge several hybrid-oriented populations. IBP-1 was combined with THG-A and IBP-2 with THG-B. In Pop. 302 LDR, IBP-3 and IBP-4, selfed S_2 progenies were evaluated. The selfed progenies in stay-green populations were further advanced by selfing.

Inbred line development was continued using different germplasm sources. Recycling of elite lines and special trait inbreds has been increased. Several different procedures alone or in combination with one another are being used to advance inbreeding generations. Seed increases of CMLs and other promising lines were made by selfing to meet needs within CIMMYT maize program and fulfill seed requests from public and private institutions.

Three inbred line evaluation trials, LETW-9508, LETY-9509 and LET (E and I) -9510, were conducted at three locations in Mexico and in some countries of Central America. Several superior lines yielded four t/ha or more. The outstanding white lines were CMLs 49, 8, 46, 251, 271, 273, 274, 56 48, 13 and 3. Six top performing yellow lines include CMLs 40, 294, 31, 27 and two lines derived from Population 27. A few other yellow lines, CMLs 282, 284 and 299, also performed well. Lines derived from Population 49 were among the top performers in LET 9510.

Several white lines were evaluated in testcrosses with CML 247 as a tester. Several recycled lines, representing Populations 21, 22, 43 and Pool 24, and lines tracing back to full-sib families 218, 43 and 109, were among the top performers. It was encouraging to note that several testcrosses outyielded CIMMYT reference check CML 247 x CML 254 as well as private company hybrids from Pioneer, Dekalb and Asgrow.

Several yellow lines were also evaluated for their testcross performance with either CML 287 or CL00331 as tester. A number of testcross entries with superior yield performance were observed, but in most ear placement was rather high. Most top performing lines came either from Population 24 or 36.

Specific white hybrid combinations involving a line and different testers were developed and evaluated during 1995. Several new hybrids were identified that outyielded the CIMMYT reference hybrid and private company hybrids included in the trials.

Specific yellow hybrid combinations were also developed and evaluated. A number of superior hybrid combinations were identified and all of them had CML 287 as one of the parents. The cross of CML 287 x CML 288 gave good performance and had good ear placement. The cross CML 285 x CML 287 also looked good.

Specific hybrid combinations involving plants with ears of good length and diameter resulted several good hybrids, involving lines derived from FS219 of Population 21. The other lines were from Population 21 (Pob. 21 C5HC109-3-1-5-B-4-3-##-2-B*5), Population 32 (Pob. 32 (MRRS) C1-659-1-B-*7 and Population 25 (Pob. 25 $HC_2$46-3-1-BB-2-##-BB).

Early hybrids were developed and evaluated during 1995. Most top performers had a common line from Population 31 (P31DMR#1- 55-2-3-2-1-B). Other lines that generated good hybrids were from Pool 15, Pool 16, P17 and P18. A few of the good early hybrids also involved lines from Population 49.

During 1995 two international hybrid trials, CHTTW and CHTTY, were distributed internationally to several locations. Five top performing white hybrids were CMS 943207, CMS943053, CMS933137, CMS 933081 and CMS 933125. In yellow hybrids, CMS 933080 ranked first. The other two hybrids which performed well were CMT 933030 and CMT933156.

A small effort was devoted to research on testers. Besides CMLs 247, 254, and 287 and CL 00331, additional lines were identified that can be used as testers in conjunction with one of the above mentioned lines. In early germplasm two white lines (G15 $C_2$2 MH131#-1-3-4- 1-2-4-B and G16 C19 $HC_2$19-3-1-1-3-2-B-##) and three yellow lines (G18 C19 MH100#-4-1-1-BBB, P31 DMR#1-55-2-3-2-1-BBB and G17TSRMH5-2-4-7-1-1-3-BB) were also identified as testers.

Promising white and yellow lines were evaluated for drought. Lines derived from $FS_2$19 and MH 247 of Population 21 gave excellent performance and had yield levels of 3.0 t/ha and above. A few lines from Sint. Bco. TSR and Population 49 STE also performed well. A few yellow CMLs, 20, 52, 27, 29, 40 and 31, showed good tolerance to drought stress. A few early generation recycled lines from Pop. 49 and some lines derived from Pool 16 yielded quite well, with ASIs not exceeding 2 days.

A few white and yellow hybrids gave superior performance under drought stress. Some of the hybrids in CHTTW and CHTTY had consistent rankings both under drought and multilocation international testing. A few lines (CMLs 273 and 294) and hybrids (CML 247 x CML 254, CML 264 x CML 273) performed quite well under low nitrogen conditions.

Several previously untested lines were found resistant to the insect pests, fall armyworm, *Spodoptera frugiperda,* and the sugarcane borer, *Diatraea saccharalis*. Some of the lines were quite comparable to the highly resistant CML67 in leaf feeding damage, but had much better ear aspect. CML 25 was found resistant to the parasitic flowering plant, *Striga* spp.

With regard to diseases, 30 lines revealed resistance when screened against maize streak virus. Screening of CMLs and promising lines against downy mildew, banded leaf and sheath blight and ear rots led to the identification of a few lines resistant to each disease.

Notes for the registration of 24 white lines and 21 yellow lines from the Lowland Tropical Subprogram have been submitted and accepted by Crop Science. Several superior combining lines have been identified from hybrid trials. Information on these lines is being compiled and seed increased for making an announcement in 1996.

Staff and post-doctoral fellows working in the lowland tropical maize subprogram delivered lectures to the maize breeding trainees on basic genetics as well as on population improvement and hybrid research.

Numerous internal and external seed requests were met during 1995.

1996

The Lowland Tropical Maize subprogram at headquarters continues its activities related to germplasm development, population improvement and hybrid research, in a integrated germplasm management system. In the extra-early white and yellow gene pools, G15E and G17E, two cycles of selection (C10 and C11; C8 and C9, respectively) were completed using modified half-sib system with emphasis on earliness and improving resistance to 'maydis leaf blight' through artificial inoculations. Selected S_2 families from four early, two intermediate, and two late maturity tropical pools were recombined to complete the following cycles of selection: G15, C19; G16, C23; G17, C29; G18, C25; G19, C_3; G21, C4; G23, C28; and G26, C27. In 96B, additional cycles of selection were completed using a modified HS breeding system. In the other two late gene pools, G24 and G25, HS families were selfed and the S_1s advanced to S_2.All families were artificially inoculated with 'maydis' and 'stalk rot'.

In population improvement no major activities were carried out since data from some sites was not received for IPTTs 30, 31, and 28 x 36. In 96A intra-population full sibs between S_2 families were formed form from populations 22 and 43, 23 and 43, and 24 with 27. The corresponding IPTT's were offered to National Programs for evaluation.

Nineteen synthetics were formed and advanced to F_2 from different gene pools and populations with a varying number of S_2 families.

Four Experimental Variety trials were distributed to different countries. The experimental varieties Poza Rica 9443, Sinematiali-9443, Across-9225 and Across-9243 gave good performance across locations in EVT-12. Iquitos-9328, Monteria-9336 and Across-9227 gave good performance in EVT-13. Across-9331, Monteria-9331 and Dholi-9331 performed well in EVT-14A. Varanasi-9349, Across-9349 and Poza Rica-9349 showed good performance in EVT-14B.

In the hybrid-oriented populations THG-A and THG-B, S_1s were obtained and a balanced composite was used to advanced both populations to S_2. Bulked selfing was also continued in IBP-3 and IBP-4 and S4 ears were harvested in 96B. On the other hand, S_2 families from the these two populations were recombined in separated HS lots and selected HS families were selfed in the following season. Inbreeding activities were continued in lines derived from different source populations, using various procedures.

Seed increases of CMLs and other promising lines were made to meet needs within CIMMYT maize program and seed requests from public and private institutions.

Several Line Evaluation Trials (LET's) were conducted in Mexico and Central America for yield and other specific traits. Lines from population 21 and 43 yielded more than 4.0 t/ha. Among the yellows, lines from Sintetico Amarillo TSR and population 27 had yields per se above 4.0 t/ha.

Specific early-intermediate and late maturity single hybrid were evaluated in different trials. In the early germplasm, high yielding crosses involved white lines G15C$_2$2NH131#-1-3-4-1-1-2-4-B, and G16C19HC$_2$19-5-1-1-3-2-B-#. Among yellow lines, were G18C19MH10#-4-1-1, P31DMR-88-3-#-B*11 and G17TSRMH5-2-4-7-1-1-1-1-BB. These lines were identified as testers in 1995 trials. Most early hybrids were below 2.0 in plant height and good ear placement (EHT/PHT<0.5). Some hybrids yields above 6.5 t/ha.

In the late maturity white hybrids, many crosses out-yielded the reference check CML 247 x CML 254. The hybrid CML 273 x CML 254 was among the top yielding crosses in several trials. Among the yellows, the reference check CML 287 x CL 00331 was lower in yield than other crosses. CML 287 was involved in the most productive crosses. Particularly with lines from population 24.

Early and intermediate maturity lines were evaluated for their test-cross performance with testers from G15, G16, G18 and P31, mentioned above. Lines from population 49 were involved in the top yielding crosses with the G16's tester: Ikene 8149.SR-68-3-#-2-BBB-3-B*11 and (P49C$_2$MH12-5-4*PR8549-1-1)-1-5-3-BBBB. In the yellow germplasm, lines from G18 had good yields with the tester derived from the same gene pool.

Late maturity lines from populations Tuxpeno-1 and La Posta were evaluated in different trials for their performance with three testers from population 22, 25, and 32. Crosses involving lines derived directly from Tuxpeno-1 were better in yield than those involving lines obtained from recycling Tuxpeno-1 with Blanco Cristalino. Lines from recycling within population La Posta also had good performance. The tester from population 32 had positive GCA effects in both trials and was involved in the top yielding crosses.

During 1996, three international hybrid trials CHTTW, CHTTY and CHTTEW&Y were distributed to different countries. Top performing white hybrids across 18 locations were CMS 9530033 and CMS 9530101, both involving CML 48 as male parent and being superior to CML 247 x CML 254 in 7%. In yellow hybrids, CMS 9530054 and CMS 9530052 yielded 16% more than CML 287 x CL 00331 across 16 locations. These two hybrids had CL 00331 as one of the parents. Among early hybrids the top yielding crosses were CMS 9510218 and CMS 9510216. These hybrids were formed with the same female parent (G17TSRMH5-2-4-#-1-1-BB) and two lines from G18.

In research on testers, results validate the early lines from G15, G16, G18 and P31 identified as testers in 1995. Among white tester lines P32C4HC$_2$0-3-4-ff-#-B combined well with lines from populations 21 and 43.

At Ciudad Obregon, State of Sonora, Mexico, 825 advanced early, intermediate and late maturity white and yellow lines were tested to evaluate their response to drought and heat tolerance in April plantings. In the early germplasm, lines derived from G16C20MH11 yielded above 1.0 t/ha. Two yellow lines, G18C20MH144-2-4-1-BB and G17C12MH111#-1-4-3-3-2-B yielded 1.62 and 1.49 t/ha. In the late maturity germplasm, two white lines: CML 269, and CML 247 and the yellow line TSR 23-3-2-4-1-BBBB-##-B-#-B had good performance.

Promising white and yellow lines were evaluated for drought. Among intermediate material evaluated, only lines derived from G21 and population 200 were better in performance and had yield levels of 3.0 t/ha and above. Among early material evaluated, lines derived from G16, G18, and TEY-DMR yielded 2.0 t/ha and above. Among late material evaluated, lines derived from IBP-1, G23 and THG-A were better in yield. Lines derived from G16, G18 and population 24 performed well under severe stress and high density.

A few white and yellow hybrids gave superior performance under drought stress. Among whites CML 24 x CML 9, CML 247 x CML 250, CML 47 x CML 9 and CML 264 x CML 271 were the best yielding crosses. Among yellows were CML 297 x CML 304, CML 20 x CML 27, CML 297 x CML 288 and CML 20 x CML 52.

Several previously untested lines were found resistant to Spodoptera frugiperda and Diatraea saccharalis. Some of the lines were quite comparable to CML 67 in leaf feeding damage but had much better ear aspect and yield.

Staff and Post-doctoral fellows working in the lowland tropical maize subprogram delivered lectures to the maize breeding trainees on basic genetics as well as on population improvement and hybrid research.

Numerous internal and external seed requests were met during the year.

Table 1. Number of families and ears selected in the Lowland Tropical Maize Gene Pools during 1996.

Gene pool	1996A				1996B			
	Selection cycle	Type of progeny	Families	Ears selected	Selection cycle	Type of progeny	Families	Ears selected
Pool 15E (Pop. 101)	10	HS	504	648	11	HS	648	448
Pool 17E (Pop. 146)	8	HS	631	648	9	HS	648	459
Pool 15	29	S_2	200	461	30	HS	461	458
Pool 16	23	S_2	202	450	24	HS	450	466
Pool 17	29	S_2	141	393	30	HS	393	389
Pool 18	25	S_2	171	400	26	HS	400	450
Pool 19 (Pop. 200)	3	S_2	292	440	4	HS	440	457
Pool 21 (Pop. 145)	4	S4	203	432	5	HS	432	458
Pool 23	27	S_2	198	476	28	HS	476	487
Pool 24	30	HS	559	581	30	S_1	581	412
Pool 25	29	HS	517	583	29	S_1	583	398
Population 102	6	S_1 bulk	158	100	6	S_1 bulk	100	166

Subtropical Maize

Hugo Córdova and *Harold Mickelson**

1995

Lines Released

In 1995, 19 inbred parents from this subprogram were released, based on the information collected from single-cross diallels, testcrosses, and three-way cross hybrid trials, including advanced subtropical intermediate white lines tested at seven locations and the international hybrid trial (CHTSW) planted at 100 locations during 1994 and 1995. Twelve subtropical intermediate white inbred parents -- CMLs 311 through 322 -- were selected and announced to cooperators.

Based on performance data collected from single-cross hybrid trials -- including advanced subtropical intermediate yellow inbred lines -- planted at six locations in 1993 and 1994, and international trials (CHTSY) planted at 61 locations in 1994 and 1995, seven subtropical intermediate CMLs were announced to cooperators on 15 July 1995: CMLs 323 through 329.

Promising Early Hybrids

Fifty-five single-cross hybrids formed by crossing eight subtropical and four tropical advanced early white inbred lines were coded and tested in 1995 at six locations of elevations from 60 masl (Poza Rica, Veracruz) to 1,800 masl (Pabellón, Aguascalientes). Exciting results from Tlaltizapán, Morelos, showed that the single-cross $P_1 \times P_{10}$ (subtropical x tropical) yielded 9.4 t/ha (15% moisture) at 101 days to harvest, while the hybrid checks A-7520 and P-3002 yielded 8.3 and 9.1 t/ha respectively at 116 days and 30% moisture. The two-week difference in maturity means they produced 69 and 79 kg/ha/d, whereas the early hybrid produced 93 kg/ha/d (Fig. 1). Days to 50% silk in the late checks was 57 and in the early hybrid 50. Hybrid $P_5 \times P_8$ (Subtropical x Tropical) topped the trial planted at Celaya, Guanajuato, with 13.1 t/ha and 67 days to 50% silk, while the hybrid check A-7520 yielded 11.5 t/ha with 77 days to silk (ten days later than the early hybrid; $P_5 \times P_8$ also performed better than A-7520 at Tlaltizapán, Morelos). At Poza Rica, Veracruz, $P_5 \times P_{10}$ (subtropical x tropical) ranked first in yield with 6.8 t/ha and 50 days to silk, outyielding A-7520. The most stable early hybrid across three environments was $P_7 \times P_8$, with yields of 13.5, 9.3 and 6.4 t/ha; the hybrid was 10, 7 and 7 days earlier than A-7520 at Celaya, Guanajuato (1,700 masl), Tlaltizapán, Morelos (960 masl), and Poza Rica, Veracruz (060 masl), respectively.

These results with early hybrids open new alternatives for national programs and the seed industry, given the need for early elite germplasm in subtropical areas of the developing

* Left CIMMYT in 1996.

world. The information collected and analyzed permitted us to select stable hybrids for testing in the international early subtropical hybrid (CHTSWE) trial during 1996.

High Potential Subtropical x Tropical Single Crosses

Single-cross hybrid from intermediate elite lines were tested in 1995 and the best results came from a trial involving 66 subtropical x tropical single-cross hybrids tested at seven locations in Mexico ranging from 060 to 1,750 masl. Yields at Celaya, Guanajuato, were as high as 16.6 t/ha (shelled grain at 15% moisture) for the single-cross hybrid CML311 x CML247; 3 t/ha more than A-7520 and the checks kindly provided by the Mexican National Institute of Forestry, Agriculture, and Livestock Research (INIFAP). The high yield potential -- 10 t/ha across seven locations -- demonstrated by the new single-cross hybrid is due to its capacity to produce more than one ear. At 80,000 plants per hectare, the uniformity in ear size, plant and ear height was very impressive.

Sources of Resistance to Foliar Diseases

Trials conducted at the Ceres location in Nayarit and the Asgrow location at Gómez Farías, Jalisco, permitted us to identify new specific sources of resistance to *Cercospora* and confirm the differential response of resistant lines identified in 1995. Three lines from Population 502, one line from Population 500, four lines from Population 42C8 and three lines from Population 44 have been identified as potential sources of resistance to *Cercospora* at harvest time. Response for yield and *Cercospora* will be confirmed. For many diseases, it is necessary to evaluate germplasm in different environments. Such is the case for *Fusarium* stalk rot in Jalisco and Guanajuato. In 1995 we identified new S_5 lines from Populations 501 (four lines) and 502 (five lines) that showed resistance to *Fusarium graminarum*. These will be advanced to S_6 at Tlaltizapán for testing per se in Jalisco, Morelos, and Guanajuato during 1996.

From hybrid trials planted in Guanajuato and Jalisco we have selected more than ten hybrids resistant to *Fusarium* stalk rot and expect that resistance will hold and correlate with yield in Jalisco and at Tlaltizapán.

International Hybrid Trial Evaluations

White single, three-way, and top cross hybrids were selected from hybrids coded in 1995 and the five best performers in 1994. The seed was produced in during cycle 95A at Tlaltizapán and shipped for international testing at 47 locations. The related trial (CHTSW95) comprised sixteen entries including two checks in a 4x4 alpha lattice design, with plots of two 5 m rows and four replications.

Preliminary information showed that CMS936431 yielded 15.1 t/ha at Bangalore, India; 57% more than the best hybrid check (9.6 t/ha). The same hybrid yielded 59% more than the best hybrid check at Udaipur, India, 12% more than the best check at Godhra, India, and 10.1 t/ha at Tlaltizapán (A7520 yielded 8.9 t/ha and Pioneer 3002 9.7 t/ha at this location). The best hybrid was CM935005, which averaged 11.0 t/ha.

CMS935005 also topped the CHTSW at Ameca, Jalisco, Mexico, with 8.3 t/ha -- 20% more than the best check, Dekalb B-840. At the India sites, the same hybrid yielded 13.0 t/ha, whereas the best hybrid check yielded 9.6 t/ha at Bangalore. At Udaipur and Godhra, same hybrid outyielded the best checks by 30 and 12%.

Information on the performance of this hybrid under severe moisture stress was collected at Tlaltizapán in 1996A. CMS935005 (CML78 x CML321) yielded 4.9 t/ha, with an anthesis-silking interval (ASI) of 4.0 days, as well as values for firing of 2.7 leaf and leaf rolling of 2.5 (1.0 = excellent; 5.0 = poor), outperforming all checks. By comparison, Tuxpeño Sequía C_6 (a population bred specifically for superior performance under drought stress) yielded 2.0 t/ha and had values for ASI of 9.5 days, for firing of 3.25, and for leaf rolling of 2.5. Hybrid CMS935005 ranked among the top performers in 1994 trials. The information from new sites in 1995 demonstrates the adaptation of this CIMMYT subtropical hybrid (Fig. 2).

The trial CHTYW was shipped to more than 30 locations in 1995. Preliminary information collected from India and Mexico reflect the potential of the material for adaptation to those environments. The three-way cross yellow hybrid CMT 945026 yielded 8.7 t/ha, 25% more than the best check, at Jalna, India. CMT955012 ranked first at Kampur, India, yielding 5.3 t/ha -- 12% more than the check. The same hybrid yielded 30% over the best check at Jalna, India.

Additional Activities

During 1995 the leader of the Subtropical Maize Subprogram participated in presentations at Harare, Zimbabwe, and in South Africa, contributing to discussions with breeders from Eastern and Southern Africa in a workshop at the Harare station to define collaborative projects for the maize and wheat improvement research network for the Southern African Development Community (SADC).

1996

The subtropical maize subprogram has strengthened breeding activities through three years of applying new strategies, extensive field work, and line selection techniques. The emphasis on Reciprocal Recurrent Selection (RRS) in population improvement under stresses such as drought, insects, and ear and stalk foliar diseases, has allowed notable progress in the development of lines for use in hybrids formation and synthetic varieties. The emphasis on stress breeding is assisting us to enhance yield stability in the new products of the Subprogram, which have been adapted in different countries of the subtropical mega-environment.

A continuous collaboration among subprograms included the exchange of germplasm with the Tropical subprogram, Mid-altitude (Zimbabwe) subprogram, Stress unit and assistance from the Physiology subprogram, the Pathology and Entomology units in evaluating germplasm under drought, diseases and insects.

In 1996, efforts were divided among three main activities: germplasm development (5%), population improvement (25%), and hybrid development and testing (70%).

Based on the information collected from single-cross diallels, testcrosses and three-way cross hybrid trials, including: subtropical early white lines tested in seven locations and international hybrid trial (CHTSE96) planted in twenty five locations during 1996, six subtropical intermediate early white inbred parents were selected as candidates for announcement as CMLs.

Descriptive characteristics were presented to the Maize Direction for consideration for release on November 28, 1996. Announcements will be sent to collaborators in national programs and the seed industry in developing countries by August 1997. The new CMLs include CML367, CML368, CML369, CML370, CML371 and CML372 (Table 1).

CML369 and CML370 ranked first and second for GCA estimates in single and three-way hybrid specific combinations topped the hybrid trials. Single cross hybrid combinations of these lines produced 87 kg/ha/d while, seed industry check only 57. CML369 is resistant to rust and *Exserohilum turcicum*. Information for their release has been collected from replicated trials planted at 32 locations for a total of 114 replications during 1993, 1994, 1995 and 1996, plus 8 nurseries under inoculation with such pathogens as *Exserohilum turcicum* and natural inoculation for rust. Information of the performance per se is very important for seed production; the inbred parent candidates for releasing were evaluated in replicated trials inoculated with *H. turcicum* at Tlaltizapán and Poza Rica during 1997A.

A preliminary study of the gains from selection in various white and yellow populations was conducted in 1995A. A larger and more thorough evaluation of gains per cycle of selection was conducted in three locations during 1996. Results in 1995 for yield coincided with what might be expected: populations and experimental varieties from later cycles of selection tended to perform better than those from earlier cycles of selection. Regression analysis was used to estimate the increase in yield per cycle of selection. Yield increased 5.7% per cycle for Population 34, 3.0% in Population 44, 3.1% in Population 47 and 4.3% in Population 45. Changes in Population 42 were not significant (see report 1995). The evaluation conducted in three locations in 1996 revealed somewhat differences in gain per cycle of selection, yield increase per cycle of selection was significant in P47 = 6.09%, P34 = 2.73% and P42 = 2.07%; populations 44 = 2.8% and P45 = 2.3% increases in yield per cycle were no significant. Ear rot reduction per cycle of selection was significant in P44 = -5.6%.

Four sets of single-cross hybrids were formed:

SSCW961: Crosses among advanced subtropical late lines = 121 crosses.

SSCW962: Crosses among advanced subtropical late lines = 49 crosses.

SSCW963: Crosses among elite intermediate lines within heterotic groups x late lines = 42 crosses.

SSCW964: Crosses among twelve advanced elite lines HGA heterotic group "A" and heterotic group "B" were included in 12 x 11, design II = 131 crosses.

The 186 intermediate late hybrids were coded and evaluated in four different trials at seven and four locations during 1995. The most exciting results are coming from the SSCW964 hybrid trial tested at seven locations.

At our research station at Ciudad Obregón, Sonora, Mexico, in fall-winter plantings, several single cross hybrids out-yielded the best check, A-7545, by more than 1.0 t/ha. SC hybrid P501C_1#-303-1-1-2-2 x P502C_1#-771-2-2-1-1 produced 1.9 t/ha more than the best check, and 1.9 t/ha more than CML78 x CML322 (Table 4A). The highest trial mean yield was obtained in Celaya, Guanajuato, where hybrid P501C_1#-303-1-1-2-2 x P502C_1#-771-2-2-1-1 gave 17.7 t/ha and 8% plants with fusarium stalk rot and 0% ear rot. The best check H-358 yielded 15.8 t/ha with 19% of plants with fusarium stalk rot, ASGROW 7545 yielded 14.7 t/ha and 27% fusarium stalk rot. At the ASGROW location in Tlajomulco, Jal. (lower trial mean 6.8 t/ha), the incidence of fusarium ear and stalk rot was highly important. P501C_1#-886-3-1-1-B x 502C_1#-771-2-2-1-3, yielded 11 t/ha with 0% of plants damaged by fusarium stalk rot and 6.8% ear rot; the best check (A-7573) yielded 7.7 t/ha with 17% ear damaged and 38% stalk rot disease.

In trial SSCW961, the highest mean yield per trial (13.0 t/ha) was recorded at Celaya, the yield ranged from 15.9 t/ha in P43SR-4-1-1-2-1-B-B x CML78, to 9 t/ha in P44-216-S_8 x CML321. Four lines combining well with both testers were CML108, 89[MBR]11-F_2-4-3-1-3-3-4, [SPMAT/600]#-84-4-BBBB and CML264. The lowest mean yield per trial (5.9 t/ha) was obtained at Los Mochis, Sin., with yield ranging from 8.3 to 5.9 t/ha. The mean yield increase at Celaya was due mostly to the length of growing season, plant density (80,000 plant/ha) and high technology practices. At Nayarit CML312xCML314 topped the trial and showed resistance to gray leaf spot. CML216xCML78 ranked first at Tlaltizapán, Mor. 1996A, fourth at Tlaltizapán, Mor. 1996B and fourth at Bangalore, India. P43SR-4-1-1-2-1-B-B x CML78 ranked first at Celaya, Gto. third at Tlaltizapán, Mor. 1996A, seventh at Pabellón, Ags., sixth at Bangalore and seventh at Bajaura, India.

Nine hybrids yielded 10 t/ha across locations and were superior in yield to hybrid checks used in each location. But hybrids CML216xCML321 and P43CAM-4-S_7xCML321 topped the trial with yields of more than 10 t/ha and good resistance to fusarium stalk and ear rot. These hybrids also showed good levels of resistance to gray leaf spot in 1995 evaluations. The best five hybrids will be increased in TL97B for testing in CHTSW in 1998.

MBR-Et(W) trials conducted at CIMMYT Harare and Mazowe, Zimbabwe, and Tlaltizapán, Morelos permitted us to identify new specific sources of resistance to MBR and confirm the differential response of resistant lines identified in 1995. Four lines from MBR-ET(W) and three lines from Pop-43SR have been identified as potential sources of resistance to MBR and *E. turcicum* at harvest time. Response for yield was confirmed.

From hybrid trials planted at Harare and inoculated with *E. turcicum* at Mazowe, Zimbabwe we have selected four resistant MBR and *E. turcicum*, that resistance hold and correlate with yield locations. CML216xMBR-Et(w)14-S_8 and CML216xMBR-Et(w)S_6-S_8; outyielded the hybrid checks from seed industry and CML202xCML206, same results at Tlaltizapán. This new hybrid combination has potential to make impact in Tanzania, Malawi, Zimbabwe, Uganda; in China, Guiyang, Guizhou the best MBR-ET(W) single cross hybrid yielded 10.6 t/ha, 50% more yield than the best hybrid check Q2001xA232-22. At Bangalore, India P43SR-177-S_6xCML216 yielded 14.8 t/ha and the check hybrid 22701 yielded 8.8 t/ha.

Two hundred S_4 developed from recycling SC hybrids resistant to both diseases and tested in S_1, S_2 and S_3 in Tlaltizapán, Morelos; Jalisco (for *F. moniliforme*) and Celaya, Guanajuato (for *F. graminearum*) were tested in three environments during 1996. The best 10% lines resistant to both diseases was selected and planted in Tlaltizapán 1997A to form BSRF C_1. Superior lines at Celaya, Guanajuato; showed excellent performance for yield and *F. graminearum*. I consider we have now good sources of resistance to both diseases.

The subtropical maize subprogram conducted 93 trials during 1996 in different sites across six countries. Due to the excellent performance of superior hybrids across locations, seed demand of superior white and yellow hybrids and inbred parent had been highly during 1996. We have shipped: 53 kg to Dr. Ernesto Preciado (INIFAP Guanajuato), 16 kg to Dr. José Luis Ramírez (INIFAP Jalisco), 14 kg to MC Rodolfo Gaytán (INIFAP Aguascalientes) in Mexico, 10 kg to Dr. Chen Zong Long (Yunnan, China), 45 kg to Dr. N.N. Singh (New Delhi, India), 12 kg to Dr. Zubeda Mduruma (Tanzania) and small quantities to national private seed companies in Mexico, such as Genotec, Berentsen and Ceres and internationally with: Pioneer, Dekalb and Asgrow.

In country, trials with the superior hybrids will be conducted during 1997. The exciting results in China and India presage new releases for 1998. In Mexico, seed companies are releasing hybrids in which at least one parent is a CIMMYT subtropical CML.

Table 1. Best single crosses among elite lines from Subtropical Intermediate White Heterotic Groups "A & B"(Populations 501 & 502)

SSCW964 ; Across Locations 1, 2, 3, 4, 6, 7; México, 1996B.

Ent. no	PEDIGREE (CIMMYT)	Yield1 T/Ha	Yield2 T/Ha	Rank	Erott (%)	Ant date	Silk date	ASI	Plt ht (cm)	Ear ht (cm)	Ear ht / Plt ht	#Ear / #Plt	Moist (%)	Fus (%)	Plt asp	Ear asp	Ear clean	Riodg (%)	Slodg (%)	Bhcov (%)	Ear #	Plt #
109	P501c1#-401-3-1-2-B x P502c1#-771-2-2-1-1	11.78	12.22	(1)	3.6	82	81	1.4	216	123	0.55	1.44	24.7	3.1	3.3	2.5	2.1	5.8	0.8	2.4	33	23
110	P501c1#-401-3-1-2-B x P502c1#-771-2-2-1-3	11.44	11.95	(2)	4.3	81	82	2.6	219	126	0.56	1.46	24.8	2.9	3.0	2.4	2.2	3.9	0.0	2.0	33	23
132	P501c1#-886-3-1-1-B x P502c1#-771-2-2-1-3	11.27	11.79	(3)	4.4	78	78	1.1	214	125	0.56	1.34	24.2	6.4	3.2	2.3	1.9	1.0	1.9	2.5	31	23
131	P501c1#-886-3-1-1-B x P502c1#-771-2-2-1-1	11.13	11.64	(4)	4.4	79	79	1.0	213	127	0.57	1.32	23.5	16.3	3.6	2.5	2.1	2.2	4.9	1.8	30	23
50	P501c1#-140-3-1-1-B x P502c1#-488-2-2-1-B	10.93	11.39	(5)	4.0	76	76	1.5	225	127	0.54	1.40	24.3	9.9	3.5	2.9	2.1	2.3	3.6	1.9	29	21
99	P501c1#-303-1-1-2-2 x P502c1#-771-2-2-1-3	10.93	11.26	(6)	2.9	83	81	-0.3	229	128	0.54	1.30	26.5	2.8	3.2	2.4	1.8	1.3	0.9	0.9	30	23
108	P501c1#-401-3-1-2-B x P502c1#-771-1-1-1-B	10.87	11.34	(7)	4.1	81	80	0.6	222	125	0.55	1.25	24.2	4.3	3.2	2.4	2.1	1.9	1.0	2.4	29	24
66	P501c1#-284-1-1-3-B x P502c1#-771-2-2-1-3	10.87	11.57	(8)	6.1	83	81	-0.1	215	122	0.54	1.35	23.0	4.0	2.9	2.6	2.2	2.7	1.8	2.2	31	23
93	P501c1#-303-1-1-2-2 x P502c1#-480-3-4-1-1	10.84	11.39	(9)	4.8	83	81	-0.1	224	121	0.52	1.16	25.3	11.0	3.4	2.4	2.0	2.6	4.3	12.6	26	23
98	P501c1#-303-1-1-2-2 x P502c1#-771-2-2-1-1	10.84	11.18	(10)	3.0	86	83	-0.5	226	124	0.52	1.12	26.4	3.4	3.4	2.4	1.9	3.5	0.5	2.0	27	23
43	P501c1#-140-1-1-3-3 x P502c1#-771-2-2-1-1	10.70	11.15	(11)	4.0	81	80	1.3	200	116	0.56	1.52	23.1	20.0	3.2	2.7	2.0	2.8	3.3	0.4	36	24
88	P501c1#-303-1-1-1-2 x P502c1#-771-2-2-1-3	10.64	11.05	(12)	3.8	83	82	0.1	222	125	0.54	1.26	25.0	2.5	2.9	2.5	2.2	1.0	0.5	15.2	29	23
65	P501c1#-284-1-1-3-B x P502c1#-771-2-2-1-1	10.54	11.13	(13)	5.3	83	82	1.0	207	115	0.53	1.32	23.3	4.7	3.1	2.5	2.1	3.0	2.8	2.9	30	23
*[128]	CML-78 x CML-321	10.09	10.59		4.7	81	78	0.3	226	114	0.48	1.03	22.0	25.9	3.2	2.4	2.0	3.8	6.3	8.1	24	23
133	A-7545 (ASGROW)	9.89	11.18	(33)	11.6	76	77	1.9	222	118	0.51	1.04	21.1	27.7	3.5	2.8	2.9	5.0	1.9	14.0	24	23
135	Local Check (average)	9.70	10.61	(39)	8.6	79	78	2.0	234	125	0.53	1.09	23.2	23.9	3.7	2.8	2.4	5.3	4.0	10.1	24	22
134	CML-78 x CML-322	9.46	10.26	(48)	7.8	74	73	1.5	212	110	0.49	1.08	21.4	12.9	3.6	2.8	2.2	2.5	3.5	7.4	23	22
*[130]	CML-322 x CML-311	9.15	9.76		6.2	74	75	2.6	225	113	0.48	1.09	24.3	5.9	3.7	2.8	2.3	6.0	2.4	2.2	24	22
	CHECKS MEAN	9.70	10.61		8.6	78.6	77.8	2.0	234.4	125.1	0.5	1.1	23.2	23.9	3.7	2.8	2.4	5.3	4.0	10.1	24.3	22.3
	MEAN	9.06	9.66		6.3	79.5	79.2	1.3	208.3	117.3	0.5	1.1	23.4	12.1	3.3	2.9	2.3	3.4	3.4	7.4	26.0	22.7
	LSD 0.05		2.42		8.6	4.8	4.9	3.3	19.7	16.7	0.1	0.3	3.5	20.8	1.0	0.7	0.7	11.3	12.1	15.8	5.7	3.9
	CV (%)		12.78		8.3	3.1	3.2	5.7	4.8	7.3	6.1	11.5	7.6	13.0	15.5	13.0	16.7	10.2	11.4	11.5	11.2	8.8
	CORRELATION WITH YIELD2		1		-0.37	0.10	-0.04	-0.29	0.64	0.50	-0.18	0.54	0.33	-0.47	-0.40	-0.73	-0.28	-0.08	-0.42	0.03	0.51	0.13
	LOCATIONS NUMBER	6	6		6	4	5	4	5	6	5	6	6	3	5	4	4	6	5	6	6	6

Location 1 = Celaya, Gto. 96B, México. Location 3 = Aguascalientes, 96B, México. Location 6 = Tlaltizapán 96B, México.

Location 2 = ASGROW, Jalisco, 96B, México. Location 4 = Cd. Obregón, 97A, México. Location 7 = Genotec, Jalisco 96B, México.

Notes: Yield1= Yield in which has been taken out the percentage of ears rotten; and Yield2= Yield without any change about ears rotten. ()= Rank based on Yield2, n=135.

This table was done including the prediction of the two crosses (entries 128 and 130) that were estimated for the analysis of 6 locations. This prediction was decided to complete the information of Line P12 (Pop. 501).The original pedigrees of entries 128 & 130 which were checks, were substituted by the two predicted entries to keep the same experimental design for analysis. Prediction of yield (in each rep. of each trial) of entries 128 and 130 was estimated according with Eckhardt, R. C. method. For Erott(%) and Fus(%) for the new entries 128 and 130, the mean of each trial was used to run analysis.

* Original entries [128] & [130] were substituted by the two predicted entries 128 & 130 to run the lines by testers analysis. Data for the original [128] & [130] entries are showed at the botton of the table.

Table 2. Single crosses among elite lines H.G."A & B", Populations 501 & 502; GCA & SCA Estimates for yield (t/ha); SSCW964 ; Across Locations 1,2,3,4,6,7; Méx., 96B.

PEDIGREE LINES 501	Pop. 501 \ Pop. 502	L-13	L-14	L-15	L-16	L-17	L-18 SCA	L-19	L-20	L-21	L-22	L-23	GCA Est	MEAN t/ha
P501c1#-77-3-3-3-3	L-1	-0.081	0.591	1.351	-0.198	-0.554	-0.369	-0.158	0.762	-0.611	-0.041	-0.694	-0.840	8.80
P501c1#-77-3-4-4-1	L-2	0.086	1.160	0.359	-0.531	-0.527	-0.611	-0.188	0.810	-0.377	-0.467	0.287	-0.371	9.27
P501c1#-92-2-3-1-4	L-3	-0.559	-0.570	-0.033	0.113	-0.909	-0.601	0.819	-0.038	0.542	0.968	0.269	-1.512	8.13
P501c1#-140-1-1-3-3	L-4	-0.278	-0.753	0.155	-0.010	-0.049	0.748	-0.409	0.831	-0.132	0.424	-0.527	-0.109	9.53
P501c1#-140-3-1-1-B	L-5	-0.466	0.025	0.634	0.531	-0.535	1.025	0.172	-0.067	0.128	-0.892	-0.555	0.690	10.33
P501c1#-284-1-1-3-B	L-6	0.077	-0.922	0.282	-0.586	-0.425	0.121	0.131	-0.114	0.514	0.256	0.666	0.253	9.89
P501c1#-286-4-1-2-2	L-7	0.512	0.973	-2.659	-0.172	-0.037	0.924	-0.143	1.011	-0.212	0.145	-0.341	-0.375	9.27
P501c1#-303-1-1-1-2	L-8	0.090	-0.094	0.193	-0.096	0.759	0.823	0.034	-1.660	0.403	-0.247	-0.204	0.496	10.14
P501c1#-303-1-1-2-2	L-9	0.314	0.105	0.289	0.658	1.256	-0.689	-0.858	-0.715	-0.075	-0.226	-0.059	0.466	10.11
P501c1#-401-3-1-2-B	L-10	-0.168	0.083	-0.086	-0.657	0.227	-0.008	-0.349	-0.289	0.506	0.334	0.407	0.869	10.51
P501c1#-441-1-1-1-B	L-11	0.236	-0.463	-0.368	0.408	0.811	-0.860	0.118	-0.313	0.535	-0.335	0.230	-0.235	9.41
P501c1#-886-3-1-1-B	L-12	0.237	-0.134	-0.116	0.541	-0.018	-0.503	0.829	-0.217	-1.222	0.081	0.522	0.669	10.31
	GCA Est.	-0.025	-0.696	-0.328	-0.239	-0.040	0.042	-0.614	-0.681	0.282	1.230	1.069		
	MEAN t/ha	9.62	8.94	9.31	9.40	9.60	9.68	9.03	8.96	9.92	10.87	10.71		9.64

** Calculated using adjusted means
Locations mean = 9.64

Std error of SCA est.= 0.395
Std. error of GCA est., Lines 501 = 0.204
Std. error of GCA est., Lines 502 = 0.238

Table 3. Single crosses among elite lines H.G."A & B", Populations 501 & 502;
GCA & SCA Estimates for Fusarium (FSR %); SSCW964_; Across Locations 1,2,3,4,6,7; Méx., 96B.

Pop. 502 / Pop. 501	L-13	L-14	L-15	L-16	L-17	L-18 SCA	L-19	L-20	L-21	L-22	L-23	GCA Est	MEAN FSR %
L-1	4.685	-0.532	3.028	0.441	-0.505	-0.518	-5.301	2.286	4.986	-4.877	-3.694	10.621	22.53
L-2	10.892	-8.130	2.068	4.697	-0.396	0.863	-7.304	1.680	-2.395	-4.850	2.874	4.602	16.51
L-3	-4.508	3.259	-1.302	1.552	16.305	-5.839	-7.374	7.210	-0.585	-4.864	-3.854	12.225	24.13
L-4	-4.909	4.109	2.504	-6.345	-7.919	-0.429	7.745	-2.835	2.414	6.517	-0.853	3.707	15.61
L-5	9.172	-4.468	-5.834	-6.867	3.467	-3.109	1.602	-1.331	-1.232	4.162	4.438	-3.909	8.00
L-6	-1.469	0.709	14.840	8.425	0.303	-6.347	-1.357	-4.725	-5.048	-2.659	-2.674	-1.142	10.76
L-7	-2.086	-1.192	-2.039	11.340	6.329	-4.593	-1.596	-2.043	-1.605	-2.747	0.232	-2.227	9.68
L-8	-0.888	3.603	0.021	-0.599	-6.093	-2.359	0.908	2.076	-0.097	2.063	1.363	-4.474	7.43
L-9	-6.558	4.300	-3.065	-3.100	-0.004	1.233	7.035	0.341	-0.365	0.029	0.154	-5.878	6.03
L-10	-8.408	-0.066	-4.842	3.368	3.718	5.329	-0.207	-1.415	1.817	0.062	0.644	-6.106	5.80
L-11	4.165	1.735	-1.226	-3.957	-7.385	11.806	-0.154	-1.851	-2.704	-1.870	1.442	-5.609	6.30
L-12	-0.089	-3.328	-4.154	-8.955	-7.822	3.963	6.003	0.608	4.812	9.034	-0.071	-1.811	10.09
GCA Est.	5.538	-2.306	1.351	2.621	5.383	0.818	-2.117	-2.574	-2.260	-2.830	-3.625		
MEAN FSR %	17.44	9.60	13.26	14.53	17.29	12.72	9.79	9.33	9.65	9.08	8.28		11.91

** Calculated using unadjusted means
Locations mean = 11.91

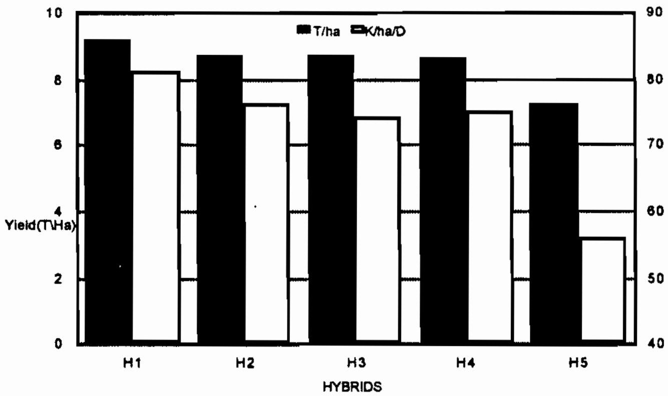
Std error of SCA est.= 4.77
Std. error of GCA est., Lines 501 = 3.00
Std. error of GCA est., Lines 502 = 3.11

Table 4. Best single crosses among Subtropical Intermediate White Lines crossed by CML-311 and CML-321 testers; SSCW961. Across Locations: 1, 3, 4, 10, 13, 14, 16, 17, 18, 19; 1996.

Ent no	PEDIGREE (CIMMYT)	Yield1 T/Ha	Yield2 T/Ha	Erott (%)	Ant date	Silk date	ASI	Plt ht (cm)	Ear ht (cm)	Ear ht / Plt ht	#Ear / #Plt	Moist (%)	Fus (%)	Plt asp	Ear asp	Ear clean	Erott scale	Rlodg (%)	Slodg (%)	Bhcov (%)	Ear #	Plt #
26	CML 216/CML 321	10.66	10.88	2.1	81	78	1.7	263	137	0.51	1.07	22.1	7.9	4.4	2.4	2.1	1.5	8.3	3.9	5.1	48	48
42	P43CAMEROON-4-1-1-2-1-B-B/CML 321	10.28	10.41	1.3	81	76	1.0	240	120	0.49	1.05	23.8	2.2	3.5	2.4	1.9	1.3	4.3	0.3	2.9	48	48
47	[CML 108]-B/CML 321	10.20	10.34	1.3	79	75	1.6	236	114	0.47	1.05	21.8	2.8	3.0	2.2	1.6	1.5	3.0	2.3	3.9	48	46
55	P43CAMEROON-4-1-1-2-1-B-B/[CML 78]-B	10.14	10.71	5.2	76	74	3.3	232	109	0.45	1.02	21.0	3.7	3.4	2.5	2.4	1.8	3.0	1.0	5.6	46	47
25	89(L/LMBR)11-F2-4-3-1-3-B*4/CML 321	10.13	10.38	2.4	80	76	0.8	238	120	0.49	1.07	22.9	3.2	3.4	2.4	1.9	1.4	3.3	1.9	10.5	49	48
58	[CML 216]-B/[CML 78]-B	10.13	10.41	2.7	80	76	1.7	242	121	0.49	0.98	20.4	7.1	3.8	2.3	2.0	1.4	7.7	5.6	2.8	45	48
24	CML 311/CML 321	10.11	10.31	1.9	77	74	1.5	249	123	0.48	1.14	20.8	3.4	4.0	2.8	1.9	1.5	5.4	1.1	1.9	54	49
41	P43CAMEROON-177-1-1-1-1-B-B/CML 321	10.04	10.20	1.6	80	76	1.3	244	123	0.49	1.06	21.5	8.2	3.5	2.4	1.8	1.7	2.3	0.7	1.6	48	47
45	G.H."B"HC34-2-1-2-B-B-B/CML 321	10.02	10.06	0.5	80	77	1.2	231	116	0.49	1.05	23.2	4.3	3.2	2.2	1.5	1.4	1.9	1.5	2.8	49	48
56	CML 78/CML 322	9.95	10.14	1.9	75	72	1.4	228	108	0.46	1.02	20.4	6.6	3.6	2.5	2.0	1.7	3.4	2.0	6.8	46	48
67	CHECKS MEAN (A 7545 AND 1 7520) ASGROW	9.67	10.34	6.5	76	74	2.4	240	118	0.48	1.01	19.8	8.2	3.8	3.0	2.5	2.3	2.4	0.5	14.7	47	47
68	LOCAL CHECK AVERAGE	9.13	9.57	4.6	80	77	2.3	230	118	0.50	1.01	22.3	6.7	3.4	2.9	2.5	2.2	3.0	2.3	5.9	45	46
	CHECKS MEAN	9.40	9.96	5.6	78.3	75.4	2.4	235.0	117.6	0.5	1.0	21.0	7.4	3.6	2.9	2.5	2.3	2.7	1.4	10.3	45.9	46.2
	MEAN	9.33	9.57	2.5	78.0	75.1	1.8	235.5	119.2	0.5	1.1	21.5	7.1	3.7	2.7	2.1	1.6	5.1	2.5	5.8	48.8	47.2
	LSD 0.05		1.76	5.5	5.6	4.7	2.1	26.0	19.9	0.1	0.2	3.2	12.9	1.3	0.9	0.7	0.8	14.0	8.5	14.2	7.9	5.4
	CV (%)		9.39	6.7	3.6	3.2	3.8	5.6	8.5	7.3	8.1	7.6	10.6	18.6	16.6	17.3	26.1	10.3	8.8	10.5	8.2	5.8
	CORRELATION WITH YIELD2		1	0.12	0.18	0.09	-0.28	0.39	0.17	-0.15	0.02	0.22	-0.39	-0.13	-0.53	0.00	-0.13	0.08	-0.02	0.08	0.09	0.14
	LOCATONS NUMBER	10	10	7	6	10	6	9	10	9	6	10	4	7	7	2	3	8	7	7	8	7

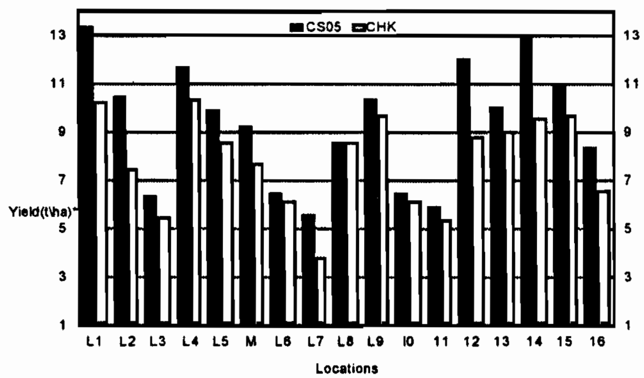
Location 1 = CIMMYT,Tlaltizapán, Mor., México, 1996A.
Location 3 = Bajaura, India, 1996.
Location 4 = DEKALB, Jalisco, Jco. México, 1996.
Location 10 = Bangalore, India, 1996.
Location 13 = INIFAP, Celaya, México, 1996B.
Location 14 = ASGROW, Los Mochis, Sin., México, 1996B.
Location 16 = INIFAP, Aguascalientes, Ags., México, 1996B.
Location 17 = INIFAP, Cd. Obregón, Son., México, 1996B.
Location 18 = CERES, Nayarit, Nay.,1996B.
Location 19 = CIMMYT, Tlaltizapán, Mor., Méx., 1996B.

Fig. 1. Subtropical Early White Hybrids Across 6 Locations, MEXICO,1995



H1.CMS954045, H2.CMS954071, H3.CMS954073
H4.CMS954047, H5=CHECK= A-7520

Fig. 2. CMS935005 vs BEST CHECKS Across 16 Locations



CHECKS

1.A7520, 2.SCG10, 3.TB2575.4.D860, 5.A7520, 6.H311,
7=C343, 8=SC501, 9=DHM103,10= P3044,6a.chk-1,11.yaya2,13.c222,
CMS935005 MEAN=9.3 t\ha, or 120% OF BEST CHECK =7.8(t\ha)

Highland Maize

Ganesan Srinivasan and Jose Luis Torres

Research on highland maize at CIMMYT, Mexico, was started in 1985 under the leadership of Dr. James E. Lothrop. The objectives of the highland maize program are to:

1. Develop improved maize germplasm in the form of open pollinated varieties (OPVs), synthetics, populations, inbred lines, heterotic groups, hybrids, etc. for the various highland ecologies in the developing world.
2. Provide training to maize researchers from National Agricultural Research Systems (NARS) in breeding methodologies as well as to familiarize with the improved highland maize germplasm developed by CIMMYT.
3. Disseminate the information, germplasm and technologies developed to the maize researchers around the world.

The collaboration between CIMMYT and other national institutions like INIFAP, ICAMEX, University of Chapingo, UAAAN, Saltillo, were strengthened during the course of the year. Scientists form UAAAN visited CIMMYT and CIMMYT experiments were conducted by UAAAN and vice-versa. Meetings of senior administrators of INIFAP and CIMMYT scientists resulted in a well conceived plan of action for collaboration. Highland initiative will be an important component of the collaboration. ICAMEX breeders visited our nurseries at Batán and made selections of materials that would be of interest to them. Similar collaboration with private companies in Mexico and elsewhere were also strengthened. Collaboration within CIMMYT with the disciplines of Physiology, Entomology and Pathology was intensifies this year.

1995

- Over 1500 rows of nurseries and trials were planted as part of a collaborative research project at ICAMEX station in Metepec, Toluca. Additional materials were planted in Aguascalientes in collaboration with INIFAP.
- Collaboration with national programs in Mexico and in Andean zone was increased.
- International Hybrid trials in highlands distributed for second year in a row to over 45 locations.
- CMT 939011 and CMS 929001 performed well in several on-farm locations and seed industry - both private and public in Mexico have shown interest in commercializing them.
- Ten promising inbred lines were identified for release as CMLs and seed was increased in Tlaltizapán in 96A cycle.
- Population 902 and 903 which are heterotic to each other were formed and top crosses made in the 96A cycle in Tlaltizapán for evaluation in 1996.

- Low-N work initiated in G-10 block at El Batán. Depletion of N in soil was done for two cycle in 1995 for screening in 1996.
- Drought work was initiated in Tlaltizapán in 1995A in Eary white semi-dent germplasm and drought tolerant synthetic formed in 1995 B cycle in Batán.
- Visited Andean highlands in Peru and Ecuador
- Training component was intensified with two Visiting Scientists and five Breeding Trainees participating in the highland program.
- Public awareness efforts intensifies. A Research Highlight Brief on Highland Maize in Mexico followed by a news article in "The News" in Nov 1995 on the potential of CIMMYT's highland maize in increasing yield potential in Mexico was pubished.
- Many prominent visitors including senior INIFAP officials and Minister of Agriculture from Mexico visited the highland program
- All the experimental trials and nurseries in highland program were generated using ADAM for the first time. Use of palm-top computers for data recording was intensified.
- Crosses between highland and tropical and subtropical germplasm identified high-yielding hybrids for the transition zone ecologies.

Nursery Results

1. Tlaltizapán - 1995 A: Tlaltizapán is used mainly as a winter nursery for the highlands for seed increases, advancing inbred lines and formation of progenies and crosses. A total of 2100 5M rows were planted in this cycle. Seed increases of hybrids for CHTH and other hybrid trials, advancing of generation in inbreds, formation of F_2 of the heterotic populations 902 and 903 and seed increases of lines were some of the major efforts undertaken. Crosses between highland and ICAMEX lines, CIMMYT's tropical and subtropical lines were made for evaluation in 1995.

2. Poza Rica - 1995A: The winter cycle in Poza Rica is used for improving transition zone materials for disease resistance (Tar spot and *E. turcicum*). A total of 1000 rows were planted. Transition zone late white and yellow materials comprising of Full-vigor, S1, S_2, S3, and advanced lines were evaluated. The nursery was inoculated with *E. turcicum* and selected for resistance to both turcicum and tar spot.

3. El Batán - 1995B: The plantings for El Batán are classified into different classes of germplasm based on their adaptation, maturity and grain color. A total of 21,000 5M rows were planted. The breakdown of number of rows for various classes of germplasm are given below:

Materials	Number of 5M rows
Transition Zone-White	1917
Transition Zone-Yellow	1525
Late White Semi-Dent	1797
Late Yellow Semi-Dent	1754
Early White Semi-Dent	11000
Early Yellow Semi-Dent	2450
Super Early White Semi-Dent	160
Super Early Yellow Semi-Dent	202
Miscellaneous (seed increases, demo, hybrid seed production)	500
Total	21,000 (approx.)

The transition zone materials were inoculated with *E. turcicum*. As always El Batán station has a good epiphytosis for rust due to the presence of the alternate host, oxalis. In all materials selection pressure was applied for good root and stalk quality, non-tillering and acceptable plant height, and other agronomic attributes. At the time of harvest ear aspect, ear rot and yield were given high priority. Based on these criteria superior families and among them superior ears were selected.

Several seed increases and five sets of diallel crosses were made. Simutaneously the seeds of the parents of the diallel were also increased. S3 lines were topcrossed to testers. In the case of early white semi-dent, the S3 lines were crossed with Pop.902 and 903 to identify their heterotic patterns.

B. Trials

A total of 32 trials and one international hybrid trial (CHTH) were conducted at Batán in 1995.

Stress Tolerance Breeding

David Beck and Martha Willcox

The major focus of the Maize Stress Breeding Subprogram is to develop tropical and subtropical maize tolerant to drought and low soil nitrogen, and maize resistant to various insect pests using both conventional and biotechnology tools.

1995

Germplasm

Significant progress has been made in the development of stress tolerant populations, synthetics, and inbred lines. Most noteworthy are the drought tolerant tropical lines from the populations La Posta and Tuxpeño Sequía, general stress tolerant lines from the tropical populations Semi-Prolific Early (SPE) and Semi-Prolific Late (SPL), and subtropically adapted insect resistant lines. These and other materials were extensively evaluated both per se and in combining ability trials. Numerous lines have shown outstanding performance under both stress and non-stress conditions. For example, several inbred lines from SPE and SPL in combination with CML254 exceeded the yield of the standard check hybrid, CML247 x CML254, by 20-25% under both drought and non-stressed conditions. Currently, we are on schedule to make approximately 15-20 stress tolerant tropical and subtropical inbreds available to cooperators in late 1996.

Information

Significant efforts are in progress to provide practical information on efficient means of developing stress tolerant maize germplasm. Javier Betran's postdoctoral project covers key issues and activities in this area:

- The genetic control and modes of gene action for drought tolerance and insect resistance.
- Dosage rate effects for these traits in hybrids, as well as the role of hybrid vigor in their expression.
- The relationship between line and hybrid performance under both stress and non-stressed conditions.
- Identifying single crosses to develop second cycle lines that combine several stress tolerance/resistance traits and good agronomic performance.
- Fingerprinting lines used in this study to compare alleles with stress tolerant alleles identified in other materials developed previously at CIMMYT.

We hope to apply the results of this work in the marker assisted transfer of tolerance to elite germplasm and in predicting hybrid performance. We will also share these results and other information from our research with colleagues at CIMMYT, staff of national agricultural research systems in developing countries, and members of the international scientific community.

Collaboration with Research Partners

Links with national agricultural research systems in developing countries have notably expanded, particularly in the development of drought and low nitrogen tolerant germplasm. Highlights for 1995 include participation in the drought and low N testing network, for which we have prepared and shipped 178 trials to date. In Mexico, we have expanded our collaboration largely through joint testing efforts with both the Mexican National Institute of Forestry, Agriculture, and Livestock Research (INIFAP) and the private sector. In fall 1995, the stress breeder traveled to Thailand and India to assist the CIMMYT Asian Regional Maize Program (ARMP) with a regional hybrid training course and to visit national system scientists involved in maize stress tolerance breeding. Valuable contacts were made with scientists from Bangladesh, China, India, Indonesia, Nepal, the Philippines, Thailand, and Vietnam.

Biotechnology Applications

Studies on mapping quantitative trait loci (QTL) and the use of marker assisted selection (MAS) to transfer insect resistance are nearing completion. Maize transformation with *Bacillus thuringiensis* (Bt) genes for insect resistance is showing excellent potential. A line containing the gene for the *Bt* toxin cryIA(b) was acquired in a research agreement with a private company. Four greenhouses were modified to biosafety standards for handling trangenics and for infestation experiments to evaluate the resistance of *cryIA(b)* transgenic plants to maize insect pests of the tropics. Backcrossing was initiated to move the *cryIA(b)* gene into elite CIMMYT maize lines (CMLs).

A three day workshop co-sponsored by CIMMYT, INIFAP, and the Mexican National Biosafety Committee (CNBA) was conducted during to discuss gene flow between teosinte, landraces, and improved maize, and the implications of testing or commercially producing transgenic maize in Mexico.

Successful QTL identification for flowering parameters, ASI, yield components, and various morphological traits was accomplished under drought and well watered conditions using an F_2 population. This map is being refined using recombinant inbred lines (RILs) and the information from both studies utilized in MAS programs for both line and population improvement.

Other Areas

An inbred line database developed using Excel is currently being linked with our seed inventory and hybrid trial database to increase our efficiency, particularly in generating useful inbred lines and hybrids.

Staffing and Acknowledgments

There were minimal staffing changes in 1995. We were ably assisted by numerous individuals from many sections of the Maize Program, but want to acknowledge the outstanding assistance of agronomist Ciro Sánchez, postdoctoral fellow Javier Betrán, and secretary Elba Maya. Additionally, we give credit to the field staff (especially the assistants) and the experiment station team, without whom we could accomplish little. Visiting scientist Mauro Sierra (INIFAP, Cotaxtla, Veracruz) participated in all aspects of our program during his five-month stay at CIMMYT; his contributions are greatly appreciated. We thank the entomology, physiology, and pathology staff of the Maize Program, as well as the CIMMYT Applied Biotechnology Laboratories (ABL) and data entry specialists, for their valuable collaboration. Finally, the financial support of UNDP is gratefully acknowledged.

1996

Germplasm

Significant progress has been made in the development of stress tolerant populations, synthetics, and inbred lines. Advances have occurred in identifying stress tolerant lines with good agronomic characters. We are excited to announce the release of 10 tropical and 9 subtropical lines in early 1997. The tropical lines possess good combining ability, acceptable agronomics, and either drought tolerance (DT), low N tolerance, and/or insect resistance (Tables 1 and 2).

Another group of tropical lines which showed outstanding performance in hybrids in 1996 came from two semi-prolific populations. Results from a trial of hybrids including lines derived from Population Semi-Prolific Late (SPL) evaluated in four non-stressed Mexican locations show the high yield potential of this material (Table 3). Among the various lines showing significant promise is SPLC7$F_2$54-1-2-3-2, which in combination with CMLs 258, 254, 264, and 273 ranked number 1, 2, 4, and 6 for yield. SPLC7$F_2$54-1-2-3-2 x CML258 yielded 10.2 t/ha across four environments with good standability. This hybrid had taller plant height, similar ear height, less lodging, less harvest moisture, and 29% more yield than the check hybrid CML247 x CML254.

In the subtropics, outstanding performers included white and yellow-grained insect resistant lines (Table 4) and lines derived from the Semi-Prolific Mid-Altitude population (SPMAT) (data not shown).

Information

Significant efforts are in progress to provide practical information on the most efficient means to develop stress tolerant maize germplasm. Javier Betran's post-doctoral projects are developing well with interesting results. His diallel study involving 10 superior lines from La Posta Sequia and Tuxpeno Sequia, along with 7 elite lines from the tropical subprogram has now been evaluated in 11 environments including drought stressed, low N stressed, and non-stressed conditions. Current findings from this ongoing project show the relative importance of GCA vs. SCA, expressed as the ratio between additive vs. non-additive genetic variance components, increased with water stress level (1.39 for well-watered treatment vs. 5.16 for severe stress) (Figure 1). These results suggest the presence of dosage effects and the need for drought tolerance in both parental lines to obtain acceptable hybrid performance under drought. Under low N, non-additive effects were more important than additive effects and a significant number of cross-over's were observed between GCA of lines under low N as compared to high N.

Several lines have been identified in Javier's study, particularly from La Posta Sequia, which have shown excellent *per se* and combining ability performance under both drought stresses, low N stressed, and non-stressed conditions (Table 5). La Posta SeqC_3-H297-2-1-1-1-3-# (now CML339) and CML258 had the highest GCA under drought conditions and across water stressed environments (data not shown). Hybrids including the lines LPSC_3-H1-2-2-2-1-1-# (CML341) and TS6C1-F118-1-2-3-1-2-# (CML344), and CML254 had good performance under low N conditions.

The classification of the 17 lines used in this study based on RFLP molecular markers genetic distance identified groups in agreement with their pedigree and source germplasm indicating the potential use of molecular markers to estimate relationships among tropical inbred lines. Preliminary findings from a second study of Javier's including crosses of subtropically adapted insect resistant (IR) lines and elite lines from the subtropical program has shown that genetic effects for IR are largely additive.

Greater efforts have been made to communicate information gathered in all aspects of our work to our colleagues at CIMMYT, the NARS, and to other scientists in the international community through publications, training courses, and direct contact with NARS. We made presentations at the American Seed Trade Association (ASTA) in Chicago; EUCARPIA Conference on Genetics, Biotechnology, and Breeding of Maize and Sorghum in Greece, and the CIMMYT sponsored Drought and Low N Tolerance Conference.

Support Staff Development

A 2 day training course was held in El Batán in July for our ayudantes. Objectives of the course included: 1) to increase ayudante knowledge about CIMMYT overall leading hopefully to more job satisfaction, 2) to increase ayudante knowledge of the CIMMYT maize program and its impact worldwide, 3) to increase knowledge about the maize stress subprogram and related programs including entomology, pathology, and biotechnology, 4) to increase exposure to our computer work including trial, fieldbook, entry list development, etc., 5) to allow the ayudantes from different stations to share common experiences, problems, etc. with each other, 6) to break up their routine and to say thanks to each for their dedication to CIMMYT.

Our highest priority objective was the work with computers particularly the hand-held palmtops. Each of the ayudantes engaged in the computer work with great enthusiasm. This already has contributed to significantly increased efficiency in our field work.

We especially want to acknowledge the outstanding work of our Ing. Agronomo Ciro Sanchez and our ayudantes Fernando Gonzalez Juarez, Oscar Fernandez, and Ezequel Bahena. Without these capable individuals and the team of people they supervise at our experiment stations little could have been accomplished in this program.

Collaboration with National Programs

Links with NARS have been expanded and improved particularly regarding the development of drought and low nitrogen tolerant germplasm. Highlights for 1996 include the excellent participation in the drought and low N tolerant conference and testing network where we have shipped approximate 200 trials to date. In Mexico, we have expanded our collaboration largely through joint testing efforts with both INIFAP and the private sector. M.S. Mauro Sierra, (INIFAP, Cotaxtla, Veracruz) and M.S. Cesar Reyes participated in all aspects of our program during their 2-5 month stays as visiting scientists.

The UNDP World Bank mission final review of the Stress Unit Project was conducted on December, 1996. We especially want to thank UNDP for their generous support of this project.

Table 1. Ten tropical CMLs made available to research partners in early 1997.

CML	Pedigree	Yield (1-5)	Days to male flwr.	Plant ht. (cm)	GCA	Heter. pattern	Special resistance/ tolerance
	White Grained						
339	LA POSTA SEQC_3-H297-2-1-1-1-3-#-#-B-B	3	66	169	Exc.	B	Drought
340	LA POSTA SEQC_3-H20-4-1-1-2-3-#-#-B-B	2.5	59	179	Good-Exc	A/B	Drought
341	LA POSTA SEQC_3-H1-2-2-2-1-1-#-#-B-B	1.5	63	160	Exc.	A/B	Mod. Drought, Low N
342	LA POSTA SEQC_3-H1-2-2-3-2-1-#-#-B-B	2	63	145	Exc.	A/B	Mod. Drought, Low N
343	LA POSTA SEQC_3-H17-1-2-3-2-1-#-#-B-B	2.5	65	163	Exc.	A/B	Mod. Drought
344	TS6C1-F118-1-2-3-1-2-#-#-B-B	3.5	63	140	Good	A/B	Mod. Drought, Low N
345	P390C1SCB-F72-1-1-1-1-#-6-B	3	58	156	Good	A/B	SCB,FAW
346	AC90390SR(SCB)-F430-1-1-2-3-2-2-#-#-B	3	58	152	Good	B	SCB,FAW
	Yellow Grained						
347	G26SEQC3-H71-1-1-2-1-B	3	60	150	Good	A/B	Mod. Drought
348	G26SEQC3-H83-1-1-2-1-B	3	61	175	Good	B	Mod. Drought

The subtropical lines have good agronomic characteristics, high combining ability, and resistance to the South western corn borer (SWCB) and/or the fall armyworm (FAW) (Table 2).

Table 2. Nine subtropical CMLs made available to research partners in early 1997.

CML	Pedigree	Yield (1-5)	Days to male flower	Plant ht. (cm)	GCA	Heter. pattern	Special resistance/ tolerance
	White-Grained						
330	89[SUWAN8422]/[P47s3/Mp78:518]#-7-1-1-1-1-1-B-#-B-B	1.5	57	155	Avg.	A	SWCB,FAW
331	89[SUWAN8422]/[P47s3/Mp78:518]#-183-1-2-1-2-2-B-#-B-B	1.5	62	181	Exc.	A	SWCB,FAW
332	89[SUWAN8422]/[P47s3/Mp78:518]#-183-1-7-3-1-2-B-#-B-B	2	57	122	Good	A	SWCB,FAW
333	P590C3F373-1-1-7-B-#-5-2-B-#-B	2	57	182	Good -Exc	A/B	SWCB,FAW
334	P590C3F374-2-1-2-B-#-3-3-B-#-B	1.5	65	217	Exc.	A/B	SWCB,FAW
	Yellow-Grained						
335	89[SEYF]/[P47s3/Mp78:518]B-23-1-5-1-1-2-B-#-B	2.5	58	137	G A F o / A o B W d		
336	89[TL8645]/[P47s3/Mp78:518]B-24-1-1-4-1-3-B-#-B	2	58	149	Good	A/B	SWCB,FAW
337	89[TL8645]/[P47s3/Mp78:518]B-24-1-3-2-1-2-B-#-B	2	57	144	Good	A/B	SWCB,FAW
338	P.590B F84-3-3-5-3-1-1-B-#-B	2	55	169	Exc.	B	SWCB,FAW

Table 3. Best semi-prolific late (SPL) hybrids with CMLS 254, 258, 264 and 273 across locations in 1996B.

Ent	Pedigree	MF	PH	EH	RL	SL	YD	EPP	MS
55	SPLC7F254-1-2-3-2/CML258	62.3	241	130	4	2	10.2	1.2	24.1
1	SPLC7F254-1-2-3-2/CML254	62.6	240	141	12	1	9.7	1.6	22.2
73	SPLC7F210-2-3/CML254	64.2	256	153	19	1	9.6	1.5	24.2
38	SPLC7F254-1-2-3-2/CML264	62.7	244	121	14	0	9.5	1.4	23.3
74	SPLC7F183-1-2/CML254	64.1	256	143	19	2	9.3	1.2	23.9
20	SPLC7F254-1-2-3-2/CML273	61.8	241	133	16	1	9.1	1.4	21.1
37	SPLC7F76-3-1-2-2/CML273	62.3	244	146	9	4	8.9	1.2	21.8
56	SPLC7F256-1-2-1-1/CML258	62.0	230	126	23	1	8.9	1.0	25.1
65	SPLC7F52-1-3-1-1/CML258	62.4	226	123	19	1	8.8	1.0	26.1
	Check CML247xCML254	64.7	229	133	11	2	7.9	1.0	26.7
	Mean hybrids	63.0	238	133	18	2	7.8	1.1	23.1

MF: male flowering date (d). PH: plant height (cm), EH: ear height (cm). RL: % of plants affected by root lodging. SL: % of plants affected by stalk lodging. YD: grain yield adjusted to 15.5% moisture content (t/ha). EPP: Ears per plant MS: % moisture content.

Table 4. Subtropical insect white-grained hybrids with CML311, CML320, and CML321 across four environments.

Pedigree	YD	MF	EH	RL %	SL %	MO %
P590C3F374-2-1-2-B-#-1-2-B-#-B /CML321	**11.2**	72.2	127.1	13.4	11.4	25.9
P590C3F374-2-1-2-B-#-3-3-B-#-B /CML321	**11.2**	73.0	132.9	1.3	7.7	26.0
P590C3F374-2-1-2-B-#-4-1-B-#-B /CML320	**10.7**	73.2	128.5	4.3	13.9	27.4
89[SUWAN8422]/[P47s3/Mp78:518]#-183-1-2-2-2-1-B-#/CML321	**10.5**	71.9	127.6	21.3	14.6	28.0
P590C3F374-2-1-2-B-#-1-2-B-#-B /CML311	**10.3**	68.6	129.8	14.4	8.2	24.7
CHECK1 CML320 x CML321	**8.3**	73.0	117.1	7.2	17.0	25.0
CHECK2 CML78 x CML321	**10.3**	69.7	113.0	4.9	20.0	23.1
CHECK3 CML264 x CML311	**9.3**	72.3	116.1	12.4	15.1	26.0
CHECK4 ASGROW 7545	**9.7**	69.7	119.4	5.7	9.4	20.9
Mean	**8.6**	69.6	121.1	13.0	17.8	24.6

Table 5. Performance of drought and low N tolerant hybrids across environments.

Best diallel hybrids across environments

Hybrid	Yield t/ha	PH cm	LODG %	MS %
TS6c1-F118-1-2-3-1-2-#/LA POSTA SEQC_3-H297-2-1-1-1-3-#	8.14	209.8	5.8	21.6
CML258/LA POSTA SEQC_3-H1-2-2-3-1-1-#	7.61	222.3	5.6	22.5
CML258/LA POSTA SEQC_3-H16-3-2-4-1-1-#	7.50	223.7	3.8	23.7
CML258/LA POSTA SEQC_3-H297-2-1-1-1-3-#	7.35	231.6	8.3	23.5
CML264/LA POSTA SEQC_3-H297-2-1-1-1-3-#	7.34	217.4	2	24.8
CHECK CML247 x CML254	6.35	196.9	6.8	28.5
Mean	6.03	209.6	8.3	22.9

Best diallel hybrids under drought (Average SS and IS)

Hybrid	Yield t/ha	LODG %	ASI days	AD days
CML258/LA POSTA SEQC_3-H1-2-2-3-1-1-#	4.78	0.2	4.5	98.6
CML258/LA POSTA SEQC_3-H16-3-2-4-1-1-#	4.77	2.0	5.3	97.2
CML254/LA POSTA SEQC_3-H297-2-1-1-1-3-#	4.72	6.1	5.7	103.8
TS6c1-$F_2$28-2-2-3-1-2-#/LA POSTA SEQC_3-H297-2-1-1-1-3-#	4.71	5.2	5.4	96.9
LA POSTA SEQC_3-H297-2-1-1-1-3-#/LA POSTA SEQC_3-H16-3-2-4-1-1-#	4.48	1.6	3.6	100.9
CHECK CML247 x CML254	2.50	12.3	9.6	101.5
Mean	2.79	7.8	6.2	

Table 5. (Cont'd).

Best diallel hybrids under low N (PR96b)

Hybrid	Yield t/ha	LODG %	ASI days
TS6c1-F118-1-2-3-1-2-#/LA POSTA SEQC_3-H297-2-1-1-1-3-#	4.29	2.0	0.2
CML254/LA POSTA SEQC_3-H1-2-2-2-1-1-#	4.16	7.3	-1.1
CML254/LA POSTA SEQC_3-H1-2-2-3-1-1-#	3.91	5.3	-1.0
CML254/TS6c1-F118-1-2-3-1-2-#	3.90	0	2.2
TS6c1-F118-1-2-3-1-2-#/LA POSTA SEQC_3-H16-3-2-4-1-1-#	3.86	1.5	0.0
CHECK CML247 x CML254	3.35	3.8	0.8
Mean	2.72	3.0	1.8

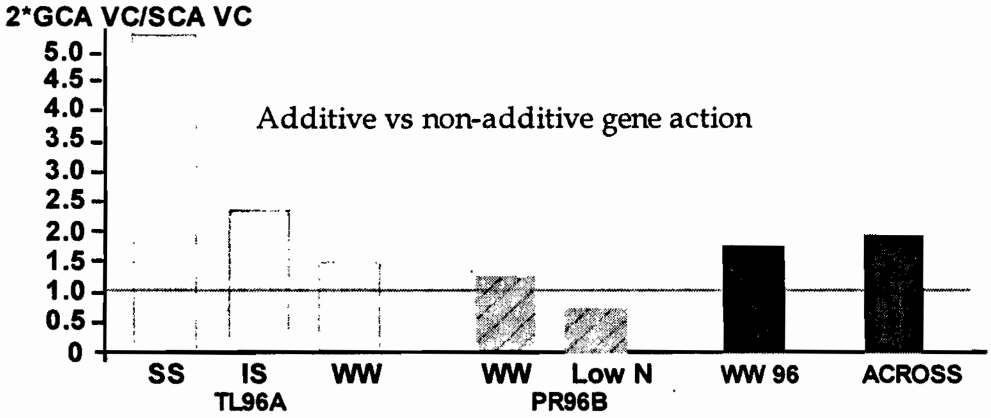


Figure 1. GCA vs. SCA variance components under drought stress, low N stress, and well-watered environments.

Maize Genetic Resources

Suketoshi Taba

Regenerating Seed Collections

Bank staff planted out seed of 550 accessions as part of routine regeneration activities in Mexico. Of these accessions, 391 were successfully regenerated -- that is, we were able to obtain the minimum 100 ears of seed per accession to ensure an adequate supply of fresh seed and significantly reduce the possibility of losing rare alleles.

Collaborative regeneration of Latin American landraces. CIMMYT is coordinating the regeneration of some 7,000 endangered holdings of maize landraces in genebanks of Argentina, Bolivia, Brazil, Chile, Colombia, Cuba, Ecuador, Guatemala, Mexico, Peru, and Venezuela. Supported by USAID and the USDA National Seed Storage Laboratory (NSSL), the project will end in September 1996. In 1995 we received 2,888 seed samples from cooperators, bringing the total received to 6,000, 4,066 of which have been registered as new accessions in the CIMMYT maize germplasm bank. Work includes providing long-term back-up storage for regenerated samples, as well as compiling and distributing characterization data in electronic form to all participants. Back-up samples are also being sent to NSSL for long-term storage only (i.e., none will be available for distribution in response to requests).

Forming Core Subsets of Major Race Complexes

To facilitate the use of maize genetic diversity, CIMMYT collections of the important tropical maize landrace *Tuxpeño* and of major Caribbean races (about 4,000 accessions in all) have been evaluated in international trials and the resulting data used to form breeder-targeted core subsets. Each comprises a mere 50-100 accessions but adequately represents most of the diversity present in the entire seed collection for a given race. We have collaborated extensively with CIMMYT biometricians to develop and refine our methodology for grouping accessions. Efforts in this area include using data from the Latin American Maize Project (LAMP) to form a core subset; the results will be compiled and a database made available to cooperators and other interested researchers in 1996.

Global Systematization of Work on Crop Genetic Resources

As part of the System-Wide Genetic Resources Program (SGRP) of the Consultative Group on International Agricultural Research (CGIAR), activities of the maize germplasm bank were reviewed by external experts (including a representative of FAO) in August 1995. Recommendations included continuing efforts to regenerate bank accessions.

The head of the germplasm bank participated in Latin American meetings of the International Conference and Program for Plant Genetic Resources (ICPPGR) to contribute to planning and discuss ideas for interfacing with this endeavor.

New Bank Facilities

Construction began on new maize and wheat germplasm storage facilities to replace the present bank, now more than two decades old. The new facilities, which are funded by the government of Japan and will provide space for some 60,000 maize accessions, are expected to be in operation by summer 1996.

In situ Conservation of Local Varieties

Together with researchers from CIMMYT's Economics Program, Natural Resources Group, and Applied Biotechnology Laboratories, we began developing a proposal for a project entitled "Conserving Maize Diversity in Mexico: A Farmer-Scientist Collaborative Approach." The aim is to test the hypothesis that selective breeding of landraces while preserving their distinctive local traits will increase the likelihood of farmers maintaining the diversity of the maize they grow. Among other things, research will assess both the genetic variation for selected traits among and within farmer-managed varieties and the importance of the traits to farmers, as well as preserving and characterizing representative samples of local varieties. A major objective will be to explore and capitalize on complementarities between in- and ex-situ conservation.

1996

An external review of gene bank operations by the System-Wide Genetic Resources Program (SGRP) of CGIAR was conducted in August 10-17, 1996. Details on the recommendations can be found in the report by the panel, but a key point was the need to continue efforts to regenerate accessions.

The USAID maize regeneration project will end in September 1996 (see detailed description below). We made certain progress in rescuing maize accessions preserved in the partner's germplasm banks in Latin America. Some countries regenerated more than the expected; others did less. Overall, including CIMMYT's effort, we will meet the initial goal of regenerating about 7,000 samples. To date 4,066 new accessions at CIMMYT have been registered from the project, out of the more than 6,000 samples of regenerated seed received from partners.

We have continued forming core subsets of races evaluated at CIMMYT stations. The methodology for grouping accessions was developed in collaboration with the CIMMYT biometrics unit. Part of the effort was devoted to using LAMP data to form a core subset. The outcomes of the all efforts to form core subsets will be compiled and made available in database form in 1996. We have now evaluated Mexican and Caribbean races, representing some 4,000 accessions.

Construction of new Bank seed storage facility was begun in October, 1995, and should be completed in May 1996, increasing our storage capacity to 30,912 samples for active collections --

sufficient for Latin American landrace accessions. Base collection capacity will be around 40,000 samples in the future.

Significant time was spent drafting three chapters for the book *Biodiversity in Trust*, a compilation of information on crop genetic resources preserved in CGIAR centers. The publication is being edited by IPGRI consultants and will be published by Cambridge University Press in 1997. To ensure its availability to our cooperators, much of the material on maize genetic resources was used in the Maize Program Special Report, *Maize Genetic Resources*.

In preparation for the 4th FAO technical conference, I participated in Latin American sub-regional meetings of International Conference and Program for Plant Genetic Resources (ICPPGR) in Costa Rica and Brasilia and reported on the LAMP project.

LA Regeneration Project

As reported in the mid-term evaluation by the project's technical advisory committee in April 1994, participants completed only one full cycle of planting, harvesting, and seed shipping by early 1994, the year originally set for completion of the entire project (Listman 1994). This was due to a range of unforeseen problems, including low germination, lack of adaptation, insufficient labor, poor institutional support, and difficult weather. Nonetheless, to ensure that project commitments were fully met, CIMMYT requested and was granted a two-year, non-funded extension of the project to September 1996 from USAID.

A total of 6,736 accessions were regenerated -- nearly all the 7,100 originally targeted -- and back-up samples of the seed were sent to CIMMYT and NSSL for long-term storage (Table 1). More than 15,000 regeneration plots were planted under the project. Bolivia, Chile, Cuba, Ecuador, Paraguay all regenerated the expected numbers of accessions, and Mexico regenerated one thousand more accessions than initially planned. CIMMYT itself has regenerated 1,655 accessions since 1993 (Table 2) and compiled a database on all regenerated samples. Copies of this inventory have been sent to project participants, so they can reference their ID numbers against CIMMYT accession numbers.

The maize germplasm holdings of national banks number about 26,000, as reported in the mid-term review of this project (Listman 1994). Project efforts regenerated a little over 25% of those accessions. In CIMMYT we registered 5,228 new accessions from the project. (Some accessions identified for regeneration by the national banks are duplicates of CIMMYT accessions.) Current CIMMYT holdings are on the order of 17,000, which indicates that about 9,000 unique samples are still preserved only in the national banks.

To discuss project outcomes and plan future collaboration, CIMMYT organized an end-of-project workshop in June, 1996, with generous support from the American Seed Trade Association (ASTA). Participants comprised principle investigators, representatives of CIMMYT and NSSL, and several recognized international experts on maize genetic resources. The following general conclusions emerged:

- Ex-situ seed conservation requires a good seed storage facility, seed drying and packaging, and documentation. Seed regeneration becomes necessary every 4-5 years unless seed is preserved in the recommended conditions. Without improved storage conditions, the regeneration crisis that necessitated this project will repeat itself.
- Duplicate storage ensures the safety and availability of seed. Each country with a national collection is encouraged to arrange duplicate storage with partners in the maize network. Finally, documentation and seed storage go together. Information exchange is improving among the partners in the network; this needs to continue.
- We observed during the regeneration project that a few countries have strengthened their genetic resources program. In the long run all countries will be concerned about genetic resources as part of the natural resource heritage of their country. The International Technical Conference on Plant Genetic Resources organized by FAO in 1996 has contributed significantly to knowledge on the status of plant genetic resources. There are also regional genetic resource networks centered around the Inter-American Insitute for Cooperation in Agriculture (IICA) in Latin America, in which CIMMYT cooperates on regeneration, seed storage and distribution, and developing a core subset of all important maize races in Latin America. Information networks will be built around the databases on accessions in individual banks.
- The on-farm conservation of economically important local maize races may complement ex-situ seed conservation. We intend to work with maize races grown in the highlands and those still cultivated at middle and low altitudes. We will form working populations in-situ based on farmer criteria. The populations will be maintained through cultivation and evolution (including the introgression of useful traits requested by farmers), as well as ex situ preservation.
- NSSL and CIMMYT exchanged a memorandum of understanding regarding the ex situ conservation of unique, Latin American maize germplasm. NSSL currently preserves some accessions that CIMMYT does not yet hold. CIMMYT will make an effort to regenerate and duplicate those accessions for use by research partners. These include accessions (3,986) from Mexico, Colombia, and Peru, regenerated under the coordination of North Carolina State University in 1980s (Goodman and Hernandez 1991).
- Germplasm banks with other endangered accessions will receive additional support through USDA-NSSL during 1997-98, as well as CIMMYT assistance with regeneration.
- Accessions regenerated under the project need to be evaluated. Germplasm evaluation projects such as the Latin American Maize Evaluation Project (LAMP) will be planned (Salhuana et al. 1991). Research by CIMMYT to develop core subsets of key collections has progressed with financial aid from USDA-NSSL; a major focus is germplasm classification and ordination using evaluation data from CIMMYT trials and projects such as LAMP. Accessions which belong to seed types that farmers grow for local consumption and sale may be evaluated in-situ to develop breeding populations. This type of work will aim at enhancing maize crop diversity in Latin America.
- The maize conservation network for the Americas requires further strengthening through the exchange of seed and information. The threat of genetic erosion makes further collecting in Central America and the Caribbean more urgent than ever. Core subsets of key races

will be developed to promote genetic resource utilization. Here again, in situ conservation will represent a viable alternative in the case of certain landraces.

Table 1. Seed shipments to CIMMYT from the Latin American cooperative maize regeneration project.

Country	No. of Samples	No. of Accessions	Duplicates with CIMMYT	CIMMYT new accessions
Argentina	401	329	0	329
Bolivia	458	380	0	380
Brazil	394	390	67	323
Chile	393	297	0	297
Colombia	1209	1195	303	892
Cuba	101	101	0	101
Ecuador	444	348	246	102
Guatemala	304	304	207	97
Honduras	42	42		42
Mexico	3531	2714	611	2103
Paraguay	84	84		84
Peru	454	422	52	370
Venezuela	141	130	22	108
TOTAL	7956	6736	1508	5228

Note: CIMMYT accessions = Seed samples received - Duplicate samples.

Table 2. Regeneration of accessions at CIMMYT, 1993-1996.

Year	Accessions planted	Accessions regenerated
1993	597	365
1994	634	452
1995	550	391
1996	818	447
TOTAL	2599	1655

Maize Pathology

Daniel Jeffers

Corn Stunt: Survey/Diagnostic Techniques; Screening

During 1995, many activities were conducted to identify sources of disease resistance in CIMMYT's maize pools, populations and advanced inbred lines, and collaborative activities continued for further improving disease resistance in maize germplasm being developed in CIMMYT's breeding programs. In addition, two special projects were initiated: 1) improving stunt resistance in maize for Central America, Mexico and the Caribbean, with funding from the Inter-American Development Bank (IDB); and 2) the development and application of the marker assisted transfer of resistance to *Fusarium moniliforme* ear rot into susceptible highland maize, with ODA support. Activities were also carried out in a third special project initiated in 1994: molecular diagnostic techniques for discrimination between components of the corn stunt disease complex in Central and South America with support from the UK Overseas Development Agency (ODA) funding. From this project pure cultures of the pathogens involved in the corn stunt complex were developed, and field surveys were initiated to determine which vectored pathogens are present in key corn stunt breeding nurseries of Central America.

Ear and Stalk Rot Resistant Germplasm

An important aspect in germplasm improvement for disease resistance is the development of selection conditions where resistant germplasm can be identified. Artificial inoculations were provided across the Maize Program for more than 59,000 rows of breeding nurseries and yield trials for turcicum and maydis leaf blights; *Fusarium moniliforme* stalk and ear rot; *Stenocarpella maydis* (Diplodia) ear rot; and *Aspergillus flavus* ear rot.

Working in collaborative projects with CIMMYT's maize breeding subprograms, germplasm was characterized for disease resistance, populations were advanced utilizing information on disease resistance identified in field evaluations, and diseases resistant synthetics were formed.

In collaborative activities with the Lowland Tropical Subprogram, CIMMYT maize lines (CMLs) lines were evaluated in replicated trials for resistance to foliar diseases, *F. moniliforme* stalk and ear rot, and *Stenocarpella maydis* ear rot. Trials for promising white and yellow lines and a lodging resistant line were evaluated for leaf diseases and *F. moniliforme* stalk rot resistance. A set of inbreds were shown to possess resistance to several important diseases found in lowland growing conditions; these will be evaluated further in 1996.

Through population improvement activities, lines were identified in 17 tropical lowland pools and populations with resistance to turcicum and maydis leaf blights and *F. moniliforme* stalk rot.

These lines will be used to form synthetics in 1996 and advanced through inbreeding. In the *S. maydis* ear rot resistant population, S_2 lines were evaluated for resistance to both ear rot and foliar diseases. These data, together with agronomic information, were used to identify lines for recombination and the formation of cycle four. A topcross and a three-way hybrid trial generated using lines possessing resistance to *S. maydis* ear rot were evaluated under artificial inoculations for disease resistance and agronomic characteristics. Several topcrosses and hybrids had high yields and ear rot resistance.

P. polysora Resistant Yellow and White Synthetics

Synthetics were formed using germplasm identified as having resistance to various diseases present in the lowland tropics. Assisting the Lowland Tropical Maize Subprogram, both a white and yellow *Puccinia polysora* resistant synthetic were formed. Lines included in these synthetics are excellent sources of resistance to other foliar diseases, including turcicum and maydis leaf blights and the tarspot complex. A set of five synthetics were formed from downy mildew resistant germplasm originally from Southeast Asia and which has been under improvement for resistance to maydis leaf blight and *P. polysora* rust. These synthetics performed well compared with their source populations for both agronomic and disease resistance characteristics in a yield trial. Narrow based synthetics were formed with lines under evaluation for *F. moniliforme* ear rot resistance in six tropical early pools.

In assistance to the Programa Regional de Maíz (PRM) for Central America and the Caribbean, two ear rot resistant populations from Costa Rica were evaluated for both *F. moniliforme* and *S. maydis* ear rot resistance under artificial inoculation in Mexico to identify the most resistant families.

In collaborative activities with the Subtropical Maize Subprogram, lines from various populations (including a multiple borer resistant/turcicum leaf blight resistant population) were evaluated for *F. moniliforme* ear rot resistance. This set of inbreds was also evaluated for resistance to ear colonization by *A. flavus*. Further characterization of these lines will be performed. A new set of 440 advanced inbred lines were evaluated for resistance for *F. moniliforme* ear and stalk rot.

I assisted the Subtropical Maize Subprogram in evaluating recycled lines for *F. moniliforme* stalk rot resistance at Tlaltizapán and turcicum leaf blight and *P. sorghi* rust disease resistance evaluations at El Batán. Performance data from both locations were combined with data from central Mexico to advance the lines in this new population.

In highland maize germplasm, work using *F. moniliforme* ear rot resistance sources from Population 85 continued. A *F. moniliforme* ear rot resistant synthetic was formed from resistant lines identified in replicated field trials during 1993 and 1994. Three mapping populations were also formed for use in the special project to develop and apply marker assisted selection to transfer *F. moniliforme* ear rot resistance to susceptible maize. The ear rot susceptible recipient lines in the three populations were chosen based on good agronomic performance and their potential usefulness for developing populations and hybrids. CIMMYT's Applied Molecular Genetics Laboratory analyzed DNA from parents and F_1s.

In preparation for field screening with the three pathogens involved in the corn stunt complex, pure greenhouse cultures of the pathogens were identified with assistance provided by the ODA special project. Procedures for producing infected plants were developed at El Batán; leafhoppers will later be placed on these to acquire the pathogens and for subsequent use in field screening of lowland tropical maize. Greenhouse facilities for mass rearing the *Dalbulus maidis* vector were also constructed at the Poza Rica experiment station, and work began to infest experimental germplasm in the field.

Maize Entomology

John A. Mihm, David Bergvinson, and Harish Kumar*

An Overview

Host plant resistance (HPR) is the least expensive method of crop protection available to farmers in the developing world. The Entomology Unit has continued to improve germplasm as a source of insect resistance while collaborating with the Stress Breeding, Lowland Tropical Maize, and Subtropical Maize Subprograms, and the Applied Biotechnology Laboratories to identify agronomically elite germplasm with elevated levels of insect resistance. To meet the demand for artificial infestation of experimental germplasm with target pests at CIMMYT experiment stations, 7 million sugarcane borers (*Diatraea saccharalis*), 9 million Southwestern corn borers (*Diatraea grandiosella*), 7 million fall armyworms (*Spodoptera frugiperda*), and 0.5 million corn earworms (*Helicoverpa zea*) were produced in 1995. Although this work has become routine, improvements are still being made in the production system to provide healthier insects in synchrony with field plantings. Modifications in the laboratory have also focused on worker safety by installing efficient filtering systems to reduce the levels of moth scales, which can cause respiratory problems.

Selected Highlights

1. Dr. John Mihm left CIMMYT after 19 years of service. Dr. David Bergvinson is the new entomologist and brings to the program a strong background in the phytochemical mechanisms of host plant resistance. Dr. Harish Kumar has been with the Entomology Unit since January 1993 and has provide a smooth transition between Drs. Mihm and Bergvinson.
2. During 1995 the pedigrees of the germplasm currently handled by the Unit were determined. This included over 8,000 families which are found in three environments currently targeted (Highland Tropical, Subtropical, and Lowland Tropical). The pedigrees have been entered into a database so germplasm can be exchanged with more information to collaborators. Fieldbook preparation has been expedited through use of the database.
3. Based on data collected from the 1994 Insect Resistant Progeny Trial (IRPT), the main borer resistant populations were recombined. Historically the Unit has worked with mixed color populations, but acceptance of this material has been low. During the 1995 recombination, the best families from the trial were chosen using a selection index and the top white and yellow families were recombined separately. Future recombinations will focus on developing white and yellow source populations to improve the movement of this source germplasm into other breeding programs within and outside CIMMYT.
4. Improvements to the insect rearing facility were made in 1995 to reduce the incidence of disease and reduce the development time for healthy pupae. After visiting a leading

* Left CIMMYT in 1995.

insectary in the United States, modifications to oviposition cages, diets and lab organization were tested. Air quality in the laboratory was a concern and changes have been made to improve it. Diets have been identified that reduce larval development time by 15% while still producing healthy pupae and adults.

5. The larger grain borer (LGB), *Prostephanus truncatus*, has become a serious pest to grain stores in West and Central Africa after its introduction from Central America. CIMMYT is the only international center which has actively pursued the development of resistant germplasm. Lines derived from germplasm bank accessions have been developed that possess good levels of resistance. Other international centers have focused on biological control agents, which should complement CIMMYT's efforts. Collaboration with a modeling group at IITA will enable researchers to assess the potential impact of resistant germplasm in controlling the LGB in the context of an integrated management strategy.

6. We have started to make crosses with elite germplasm to determine how resistance is expressed. Lines from these crosses will also be developed under insect pressure to improve the agronomics of germplasm from the entomology section. Some of these crosses will also be tested in on-farm trials during 1996.

Highlights from Collaborative Projects within CIMMYT

1. An exciting new area of integrated pest management is the deployment of transgenic plants. This has been of particular interest in maize due to the severity of tropical insect pests and the difficulty of developing conventional sources of resistance. The Entomology Unit has screened acquired transgenic materials (ATM) which contain the *Cry*IA(b) gene. This construct was developed to control European corn borer (*Ostrinia nubilalis*) but is also effective against Southwestern corn borer (*Diatraea grandiosella*) and, based on greenhouse screenings, sugarcane borer (*Diatraea saccharalis*). The big issues facing biotechnologists, entomologists, breeders and legislators is how to manage transgenics to provide an environmentally safe product that will minimize insect damage to food crops and delay the development of insect populations tolerant to transgenics. Most transgenics contain various genes from a soil bacterium, *Bacillus thuringiensis*, that produce insecticidal δ-endotoxins. Efforts at CIMMYT and around the world are focused on transgenic management strategies to prolong the utility of transgenics in developing countries.

2. Collaboration between the Entomology Unit and CIMMYT maize breeding programs has been productive in 1995, with lines and hybrids which show reasonable levels of tolerance being identified. Some of the hybrids tested have yields that are comparable to the standard CIMMYT checks. This demonstrates that insect resistance does not have to come at the expense of yield.

3. The Unit has been characterizing CIMMYT maize lines (CMLs) for insect resistance so this information can be incorporated into the database made available to research partners requesting CMLs. Initial efforts have focused on stem borers and fall armyworm, but future screenings will also include the storage pests *Prostephanus truncatus* and *Sitophilus zeamais*.

4. Shuttle breeding has developed into a major activity in the Entomology Unit. Since CIMMYT regional offices and many partners in national agricultural research systems do not have insect rearing facilities for stem borers, germplasm that has been adapted to East

Africa (with streak resistance), Asia (with downy mildew resistance), and Central America (with stunt complex resistance) has been exchanged to select for resistance to several other key biotic stresses in each region. This effort will be expanded in 1996 to include West Africa.

External Collaboration

The biggest challenge CIMMYT faces is to effectively promote the adoption of improved germplasm. This is particularly true for stress tolerant germplasm, which often requires careful management and inputs, and is especially for insect resistant germplasm. To facilitate germplasm adoption, entomologists who work closely with breeders in tropical environments have been identified and have conducted collaborative trials in the past. Strengthening these evaluation networks will be an important way to foster germplasm exchange in the future. Several collaborators are in Asia (China, India, Philippines, Thailand and Taiwan) and Central America (Nicaragua, Mexico and Brazil); there is a need for a good network in Africa. To encourage an integrated approach to stem borer management and germplasm exchange in Africa, an integrated pest management working group has been formed which includes CIMMYT (Zimbabwe, Mexico), IITA, ICRISAT and ICIPE. In consultation with national programs, the working group will summarize the research resources that are available, identify areas were research is needed, and develop effective management strategies. A draft proposal for this initiative was prepared in 1995.

1996

The Entomology Unit has continued to improve sources of insect resistance while collaborating with the Stress Breeding Unit, the Lowland Tropical, Subtropical and Highland Breeding Programs and the Applied Biotechnology Center to identify agronomically elite germplasm with elevated levels of insect resistance. To meet the needs for artificial infestations with insects on experimental stations, 9 million sugarcane borer (*Diatraea saccharalis*), 14 million Southwestern corn borer (*Diatraea grandiosella*), 6 million fall armyworm (*Spodoptera frugiperda*) and 0.5 million corn earworm (*Helicoverpa zea*) were produced by the Entomology Program in 1996. Although the production of these insects has become routine, improvements are still being made to the production system to provide healthier insects that are synchronized with field plantings. A few specific highlights include the following:

1. More than 30 agronomically elite lines from the various subprograms were identified as having good levels of resistance to armyworm and stem borer as well as tolerance to high plant density (132,000 pt/ha). Hybrid combinations using these lines will be made and tested in 1997, both on-station and on-farm. These hybrids should provide good yield potential under heavy insect attack (borers/armyworm) as well as under protected conditions.
2. Hybrid evaluation trials were conducted to determine the yield losses associated with stem borer attack at different phenologies. Leaf feeding damage can cause yield reductions of 50% in elite hybrids susceptible to stem borers while only 15% in elite hybrids with

moderate levels of stem borer resistance. Yield losses to tropical stem borers are largely due to tunneling caused by first-generation stem borer attack.

3. On-farm trials show the good yield stability of elite CIMMYT hybrids under natural infestation, with yield losses being less for hybrids derived from insect resistant lines.
4. Cycles of selection studies for insect resistant populations adapted to tropical (Population 390) and subtropical (Population 590) ecologies have shown an increase in the level of insect resistance and yield potential under artificial infestation with stem borers and fall armyworm.
5. Studies were initiated to investigate the interaction between soil fertility (nitrogen level) and insect damage. Experimental plots with a yield potential <2 t/ha did not facilitate borer or fall armyworm establishment, despite high infestations levels. Future studies will better define this interaction and have implications for soil management strategies to minimize insect attack and optimize yield potential. On-farm trials are also being planned to investigate the impact of nitrogen applications on natural infestations.
6. Germplasm bank accessions (Guadaloupe, Cuba, BRVI) have been identified with moderate to good levels of grain resistance to the larger grain borer (LGB), *Prostephanus truncatus*. Lines are currently being extracted from this material. A systematic screening of CIMMYT lines has begun to identify agronomically elite material with good levels of resistance to *Sitophilus zeamaiz* and *P. truncatus*. One promising line is CML268 (Pop23 STEC1HC45-1-1-1-2-3-BBF####) which showed only 40% grain damage (compared to 100% for most other CMLs) after 4 months of storage with *P. truncatus*.
7. Mapping of biochemical resistance factors for stem borers has confirmed the importance of leaf nitrogen content and leaf toughness. These biochemcial/biophysical traits map to the same QTLs as leaf feeding resistance. Future studies will be part of a CIDA project to map the secondary biochemistry of the mapping population CML67 x CML131.
8. An exciting new area of integrated pest management is the deployment of transgenic plants. This has been of particular interest in maize due to the severity of tropical insect pests and the difficulty of developing conventional sources of resistance. Most transgenics contain various genes from a soil bacterium, *Bacillus thuringiensis*, that produce insecticidal δ-endotoxins. Screening studies conducted under biosafety conditions have demonstrated a shift in tropical borer populations towards a build-up of tolerant individuals when insects are exposed to transgenic plants for short periods of time. These selection studies will continue through 1997 to determine the rate of tolerance development in two tropical borer species (*Diatraea grandiosella, D. saccharalis*). A strategic plan was developed by the Maize Program regarding priorities in transgenic development and deployment strategies which should delay the development of insect resistant populations.

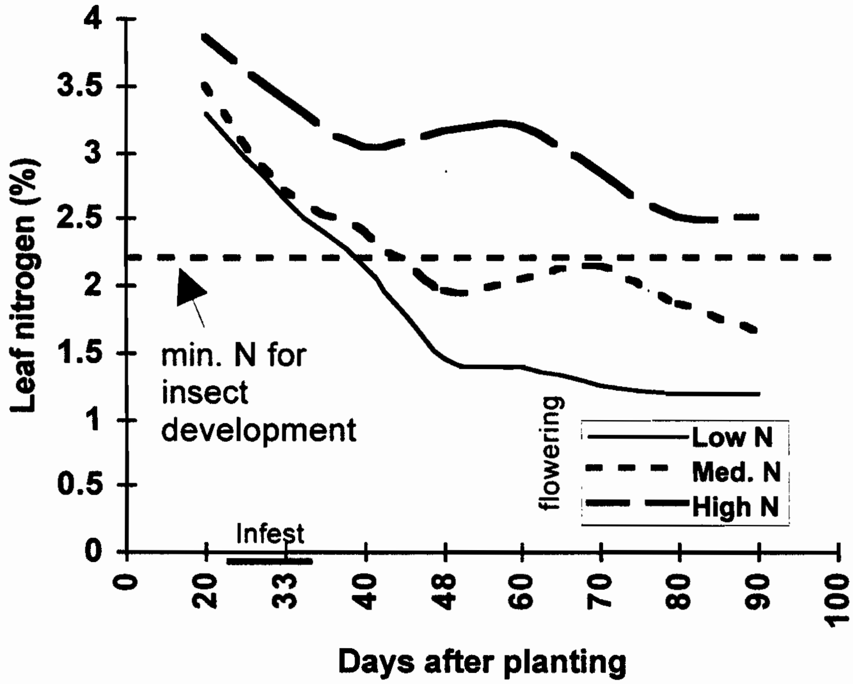


Figure 1. Leaf nitrogen profiles of maize under three fertility regimes (6, 4, and 2 t/ha yield potentials), Poza Rica 1996B.

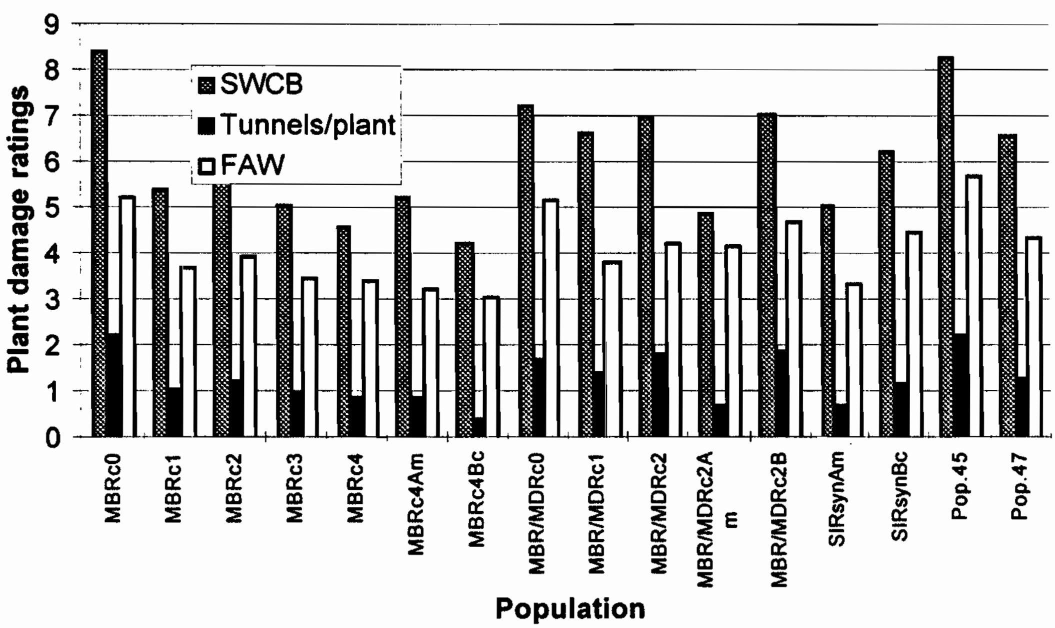


Figure 2. Plant damage parameters for subtropical maize under infestation with Southwestern corn borer and fall armyworm, Tlaltizapán, Morelos, 1996B.

Maize Physiology

Gregory.O. Edmeades, Marianne Bänziger, and Anne Elings***

Our products are more efficient selection methodologies for abiotic stress tolerance, improved sources of stress tolerance (especially to drought and low N), and a more functional understanding of how the maize plant responds to stress, to temperature, photoperiod. Specific goals include:

1. To identify the principal abiotic stresses which affect maize development and to quantify their effects in target countries.
2. Where possible to understand the physiological mechanisms of tolerance to the abiotic stresses identified in 1) above, with special reference to drought, low soil fertility and variable plant density.
3. To identify sources of genetic resistance to these abiotic stresses, and to stresses in general.
4. To develop efficient selection methodologies for improving stress tolerance in elite maize germplasm, both as populations (*per se*; and as experimental varieties) and as hybrid-oriented products (lines; line synthetics; topcrosses; hybrids). These methodologies usually include the development of selection environments where the stress of interest can be carefully managed; statistical methods to control variability; identification and use of secondary traits where appropriate; breeding methodologies; molecular selection techniques.
5. To apply these methodologies on a scale appropriate to a breeding program to produce stress-tolerant elite germplasm; to interact with CIMMYT's mainline breeders in headquarters and in outreach in the identification of superior stress-tolerant fractions among their high-performing adapted germplasm.
6. To understand and quantify the effects of photoperiod and temperature on the development rates of maize adapted to the lowland, mid-altitude and highland tropics. In so doing to provide a means of understanding and perhaps manipulating the genotype x environment interactions that occur because of the effect of these factors on phenology.
7. To provide data that would allow the field testing of models that predict maize productivity in a range of environments.
8. To foster and develop skills in these research areas in national maize programs in target countries, through training courses, consultation with NARS scientists and visits to national programs; to disseminate improved stress tolerant maize germplasm developed in this program to regions where it may be sufficiently well-adapted to be directly useful in national program breeding programs.

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* Moved to CIMMYT, Zimbabwe, in 1996.

** Appointed in 1995.

As the move from population improvement towards the development of hybrid products accelerates within the Maize Program as a whole, our goal remains to find the most efficient ways of identifying stress-tolerant hybrid products.

1995

During 1995 emphasis continued to shift from population products towards hybrid-oriented products. We could turn our attention to a greater degree of screening of hybrid products from other Maize subprograms because of continuing excellent financial support and because physiology remained fully staffed (two senior staff and one postdoctoral fellow). As a consequence around 70% of our plots were planted to inbred lines, topcrosses or hybrids. Of these, about 30% were from our own source materials, 15% were from the mainline breeding programs, 10% from outreach locations and 15% were from the stress breeding subprogram. The rest of our planted area was devoted to methodology development, calibration date set collection, model module development, evaluation of progress from previous selection experiments, and special topics in research.

Collaboration

Within CIMMYT. We increased collaborative research with other breeding groups, especially the stress, lowland tropical germplasm, and subtropical germplasm subprograms. Ongoing cooperation with CIMMYT's applied molecular genetics laboratory (AMGL) increased in studies on the genetic control of anthesis-silking interval[1] and photoperiod sensitivity.

With CIMMYT regional offices. We conducted joint research on drought and low-N tolerance conducted with CIMMYT outreach stations in Asia, southern Africa, and Central America in 1995. This work will increase in 1996.

Networks. In 1995 we sent participants in the drought and low-N development and testing networks a report on previous trials, and a trial set was announced in 1995 that included for the first time stress-tolerant hybrids or topcrosses as well as varieties. National programs of India, Thailand and Mexico conducted trials jointly with our group in 1995, mainly in the area of drought tolerance. We also worked with: John Innes Institute, UK; Linkage Genetics, USA; and the University of Nottingham, UK.

Students. Mr. Stephen Mugo commenced his PhD research in plant breeding. He is focusing on the relationship between ABA concentration and drought tolerance at different crop growth stages.

[1] We have found that reduced ASI is associated with increased yields under drought and, to a lesser extent, low nitrogen stress.

Research Highlights

- The ABA content of seedlings establishing under drought had no close relationship with survival and biomass production. It is easier to make progress in selecting for poor establishment than for improved establishment! Research is on-going.
- In collaborative trials of CIMMYT drought-tolerant selections with the Indian National program, about 45% of the gains in drought observed in Tlaltizapán were carried over to Indian conditions; resistance to barrenness in drought-tolerant selections resulted in gains in yield under waterlogged conditions as well.
- In 1995 a large study was conducted in which topcrosses (TCs) of a randomly-selected set of inbred lines from stress-tolerant populations and from their non-stress tolerant counterpart populations were compared. Under drought stress TCs derived from drought tolerant populations significantly outyielded those from conventional populations by an average of 22% (310 kg ha^{-1}) at 1.56 ton ha^{-1}, nonsignificantly by 1% (43 kg ha^{-1}) at 5.29 ton ha^{-1}, and yielded 2% less than the conventional TCs (-130 kg ha^{-1}) under well-watered conditions (6.08 ton ha^{-1}). The probability of obtaining a hybrid that yielded 40% greater than the trial mean under severe stress was four-fold greater when lines were extracted from the drought-tolerant source population than from its conventional counterpart. Topcrosses from Across 8328BN outyielded conventionally-derived lines under low N by a significant 11.1% (200 kg ha^{-1}) at 1.90 ton ha^{-1}, and by a similar amount under high N (3%, or 200 kg ha^{-1}) at 6.0 ton ha^{-1}. We conclude that drought- or N-tolerant elite source populations provide a greater proportion of drought- or N-tolerant inbred lines and hybrids than do conventional populations.
- The anti-gibberellin, Paclobutrazol, was found to ineffective (actually deleterious to grain yield) when used as a seed treatment on maize seedlings exposed to drought at sowing and establishment.
- Seven cycles of recurrent selection (HS; then S1) for increased prolificacy, standability and yield in the population SPMAT resulted in yield gains at optimum density of around 200 kg/ha/cycle at Tlaltizapan (A and B cycles), all of the gains coming from the increased yield of second ears. Harvest index, days to anthesis and total biomass also increased slightly but significantly, but lodging did not.
- Inoculation of seed by *Rhizobium* had no effect on any trait when evaluated in the field in Poza Rica. There were possible effects on greenness when the plants are young, but they were not reflected in yield.
- Highland hybrids outyielded the OPVs from which the inbred lines were derived by 27% across two plant densities (53K and 106K) in a low yielding season at El Batan. Hybrids also outyielded OPVs by 21% in total biomass. CIMMYT's hybrids and OPVs both outyielded the check hybrids across densities.
- The yields of tropical hybrids are unstable over photoperiods that range from 11.5 to 19 hr, while the yield of a well-known Corn Belt hybrid, B73 x Mo17, was stable across all daylengths. This suggests that broad adaptation in tropical germplasm would be helped by reducing daylength sensitivity. The critical and ceiling photoperiods of tropical hybrids in this study were around 13 hr and 17-18 hr, respectively.

- Within CIMMYT's elite germplasm, there is a two-fold variation in Fe and Zn concentration in the grain, and the variation becomes even larger in topcrosses based on elite lines. The correlations between line and hybrid Fe and Zn grain concentrations is 0.3-0.45.

Nurseries

In 1995 we made 5,062 line advances, along with 19 recombinations, and formed 2,478 hybrids or topcrosses. A total of 175 varieties or synthetics were either formed or increased during the year.

Trials

- A total of 105 replicated trials yielded usable results in 1995.
- Several important sources of tolerance to drought were identified. Lines derived from TS6 and La Posta Sequía continue to provide the best overall performance. One very promising line from the Lowland Tropical Program is P21C6S1H247-4-B-1-1-1-BB-#*5. Under low N, CML247 x CML254 generally performed very well, as did the drought-tolerant populations and Across 8328. Thai germplasm showed a high level of tolerance to drought, and some lines from INIFAP and PRM also showed excellent levels of drought tolerance.
- There are strong indications that highland germplasm can be effectively screened for drought tolerance at Tlaltizapán in the winter. Population 85 showed considerable genetic variability for stress-tolerance traits.
- A new selection strategy in Pool 16 $C_2$0 (now called Pool 16 BNSEQ) has begun. It involves simultaneous selection for tolerance to drought and low N.
- Detailed calibration data from five genotypes grown under several diverse environmental conditions have been collected; the radiation extinction coefficient for these is around 0.53. Information from these and other data is being translated into working maize crop process modules that address specific responses of tropical maize to the environment.
- High levels of resistance to lime-induced chlorosis (indicating iron deficiency) have been observed in Populations TBF and 490, meaning that these populations will do very well on calcareous soils -- a problem throughout much of Mexico, the Middle East, and many other areas where the climate is dry.
- By examining the heterotic responses of many inbred lines and their response under drought and low N, we formed late lowland tropical heterotic populations A and B, divided by color and characterized by the testers supplied by the lowland tropical maize subprogram.
- Progress continues in the management of N stress using intercropped wheat in winter and sorghum in summer. These have usefully increased the degree of N stress in the preflowering and flowering stages of growth, allowing us to screen effectively for tolerance.

Acknowledgment

Special thanks go to UNDP and to SDC for their generous financial support during 1995.

1996

The environmental and experimental conditions were in general well-suited to conduct our drought and low-nitrogen research. At Tlaltizapán there were no rains that affected drought trials in the winter cycle. Almost the entire O1 block lodged around flowering in the summer cycle, and the majority of experiments in that block had to be abandoned. Also in the summer season, heavy rainfall after sowing caused severe problems for emergence in some trials. At Poza Rica, night temperatures in January fell regularly below 5°C, causing delayed development. As usual, lodging posed a problem in some cases, especially in the wet summer cycle. Soil nitrogen levels in the low+medium nitrogen part of block G1 had fallen sufficiently so that we can now treat the entire half of the block as low nitrogen. In general, however, soil heterogeneity remains a serious problem. At El Batán leaves in September were heavily damaged by a hailstorm.

General Activities

Products of maize physiology were more efficient selection methodologies for abiotic stress tolerance, improved sources of stress tolerance (especially to drought and low N), and a more functional understanding of how the maize plant responds to stress, temperature and photoperiod. With two senior scientists and 1 post-doctoral fellow, staffing was similar to 1995 for the first half of 1996. Dr. M. Bänziger left to join CIMMYT-Harare in July 1996, leaving Dr. G.O. Edmeades and Dr. A. Elings to staff the Physiology Program. Adequate funding was provided by the UNDP Stress Project throughout the year.

A major activity this year was the organization of the International Symposium on 'Developing Drought- and Low N-Tolerant Maize', from March 25-29, 1996, at CIMMYT, headquarters in El Batán, Mexico, during this last year of the UNDP Stress Project. This 4.5 day long meeting had as goals to bring researchers together that had active roles in investigating and improving drought and low N tolerance of maize and to share their experiences on distribution and timing of these stresses; traits related to tolerance to drought and low N; selection methodologies and results from selection experiments; field techniques that improve efficiency of selection; sources of tolerant germplasm; crop management techniques that complement tolerant germplasm; and mechanisms for more effective NARS-CIMMYT collaboration. A total of 121 participants attended and 78 of these were national program invitees. The program included 36 oral presentations and 65 posters. Almost all attendees made presentations of one sort or another, and all have been included in the proceedings. During a field day at Tlaltizapán, CIMMYT's research programs at that station were presented to participants. Extensive consultation was conducted with NARS representatives at the meeting to identify major constraints to maize production in their countries and ways in which CIMMYT can assist them in maize development and production.

Outcomes from the symposium can be summarized as an acceptance that effective selection methodologies for tolerance to these stresses exist, but depend on managed levels of stress for efficient execution; that CIMMYT can best serve national programs by establishing regional breeding programs focused on improvement of regionally-adapted germplasm; and that networks are an acceptable mechanism for regional collaboration provided all participants are treated as equals in planning and execution phases. A proceedings will be published in October 1997.[2] Major sponsors were UNDP, Rockefeller Foundation, with assistance from Ciba Seeds and Mahyco India. Conference organizers were Marianne Bänziger, Anne Elings and Greg Edmeades, with extensive help from CIMMYT's Maize Program and Administration.

At the end of the year, the Final Review of the UNDP Stress Project was conducted by a team from the World Bank, and the review report was extremely positive. Copies of the final report of the UNDP Stress Project are available on request.

As in 1995, emphasis during 1996 continued to shift from population products towards hybrid-oriented products. Maize Physiology spent considerable resources on evaluation of lines, topcrosses and hybrid products from our own group and from the rest of CIMMYT (headquarters and outreach). More than 31,000 rows were sown in 1996, which is the equivalent of about 12 ha of plot space. Of these, 81% were allocated to evaluation of inbred lines, topcrosses and cycles of selection; demonstration trials; international network trials; development of calibration/validation data sets for simulation models; photoperiod experiments; ABA experiments; *Rhizobium* research; and sink manipulation research. Line development accounted for 7%, recombinations 1%, formation of hybrids, topcrosses and synthetics 3%, and seed increases (lines, populations) 8%. In another breakdown, 9% of the land space was used for services to CIMMYT outreach programs, 7% for services to CIMMYT headquarters subprograms, 10% for international network trials, and 19% for evaluating lines, topcrosses and synthetics. Twelve refereed journal articles, oral presentations and posters were published in 1996, and contributions to the March Symposium will be published in 1997.

Breeding and Research Highlights

Drought Tolerant Populations. As S_1 lines of DTP1 C_7 and DTP2 C_5 (separate white and yellow versions) performed very similarly, they were merged to form DTP C_8 (white and yellow versions), in which recurrent S_1 selection will continue.

La Posta Sequía Streak. On the basis of streak evaluation data of S_2 lines of La Posta Sequía C_5 by Dr. A. Diallo in Côte d'Ivoire and evaluation data of the 50 best LPS C_5 S_1 lines in Mexico, 19 S_1 lines that combined good agronomic performance and resistance to streak were identified. These lines will be recombined to form full sibs in 1997 and then supplied to the African Maize Stress Project based in West Africa at IITA for use in that project.

[2] G.O. Edmeades, M. Bänziger, H.R. Mickelson, and C.B. Peña-Valdivia, (eds.). 1997. *Developing Drought- and Low N-Tolerant Maize.* Proceedings of a Symposium, March 25-29, 1996, CIMMYT, El Batán, Mexico. Mexico, D.F.: CIMMYT.

Topcrosses. In collaboration with the Stress Breeding Unit we evaluated a total of 787 topcrosses of various backgrounds under high and low nitrogen conditions, normal irrigation, and intermediate and severe drought stress. On average, best topcrosses resulted from:

- DTP1-W lines crossed onto CML247.
- DTP-Y lines crossed onto CL00331 under favorable conditions; DTP-Y lines crossed onto CML287 under unfavorable conditions.
- EV7992*EV8449 lines (Dr. Pixley, Zimbabwe) with CML254 and CML247 under low nitrogen conditions.
- TS6*BS19 (from Central America) with CML254 and CML247 under high nitrogen conditions.
- LPS C_1 and Pop. 25 S_1 with CML 254 and CML247
- G26 Seq. and Across 8328 BN C_6 with CL00331; as a tester line, CL00331 resulted in the highest yielding topcrosses under low nitrogen, CML287 in the highest yielding topcrosses under high nitrogen.
- LPSC3H1-2-2-3-2-1-# x CML254 was the best overall performing topcross under a wide range of conditions in the tropical late white topcross network trials for drought and low nitrogen; CML271 x CML254 and CML247 x CML254 performed very well under low nitrogen conditions in PR96B; otherwise GxE was very high for tropical late white topcrosses, resulting in large shifts in rank among environments.
- Crosses with the tester line CML287 (except under low nitrogen conditions) were superior in the tropical late yellow topcross network trials for drought and low nitrogen; hybrid CML287 x CML298 did very well under low nitrogen conditions.
- In three-way crosses between (Pool17 x Pop. 31) and Pool 18 C_{23} and Pool 18 Seq. $C_{2,3}$, crosses with Pool 18 Seq. C_2 performed on average best under moisture deficit, whereas crosses with Pool 18 Seq. C_3 performed on average best under high nitrogen conditions. Pool 18 C_{23} produced less good topcrosses than Pool 18 Seq $C_{2,3}$.
- Subtropical topcrosses under severe drought stress: CML78 topcrosses performed better than CML321 topcrosses, which in turn performed better than CML311 topcrosses.

Line Performance

1. In collaboration with the Lowland Tropical Subprogram, we evaluated 120 late white and 120 late yellow lines. Among the white lines, POB21C6S1MH247-5-B-1-1-1-BBB-6-##-BBB-B, POB21C6S1MH247-4-B-1-1-1-BB-f-##-B and (21F218*21F76)-3-2-1-1-BB-####-18-B-B performed best under all conditions.
2. The best of 180 evaluated (DK888 x P26SeqC3) lines were crossed with CML287 and CL00331. These will be evaluated in 1997, and will serve as source material with drought tolerance for Asia.
3. We also evaluated 114 lines from CIMMYT-Colombia and CIMMYT-Ivory Coast, along with 623 highland lines.

Yield Trials

We spent considerable resources on various types of yield trials: 6 demonstration trials, 2 evaluation trials of recent physiology materials, and 16 international low nitrogen and drought network trials.

Sink Manipulation

As in similar studies in previous years, prevention of effective sink establishment by putting glassines over the first or second ears of a prolific resulted in biomass reduction. A possible explanation is that, under good growing conditions, grain filling is sink-limited and a reduction in sink size negatively affects total crop growth rate.

Transpiration Efficiency

Variation in transpiration efficiency was mainly due to variation in biomass, rather than variation in water uptake. Considerable variation exists in tropical maize for the amount of biomass produced with a certain amount of water. However, it is doubtful whether this would lead to a useful breeding approach. Results are more fully reported in the above-cited proceedings.

Seedling Drought Stress

Selection for improved survival under post-emergence drought is difficult under field conditions. Secondary traits, such as leaf rolling and ABA concentration, have higher heritability than number of surviving plants and biomass, but do not show an obvious relation with plant survival. Better agronomic practices may be more effective than breeding.

Photosynthesis

Open-pollinated varieties and hybrids were characterized by a significantly greater leaf nitrogen content and photosynthesis rate than lines. This may be caused by differences in nitrogen uptake or partitioning, or by one or more of the morphological or biochemical factors that determine photosynthesis rate.

Modeling Tropical Maize

Modelling growth and development of tropical maize requires improvement of prediction of leaf number, daylength sensitivity, leaf area development, number of kernels per plant and prolificacy. We are conducting research to obtain relevant quantitative information.

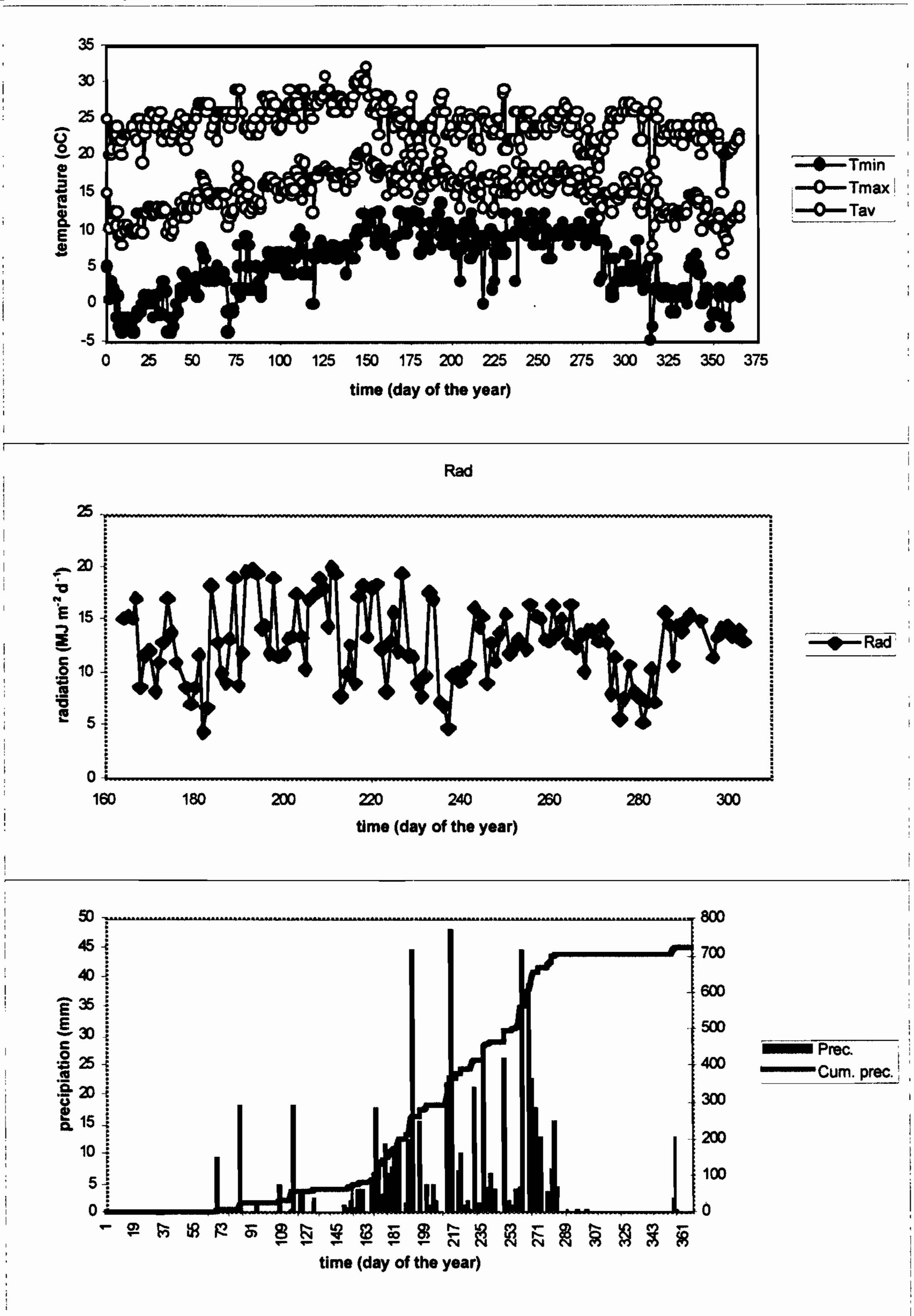
Leaf Insect Damage at Different Nitrogen Levels

Simulation studies indicate that yield loss due to reduction in green leaf area caused by foliar insects is probably a matter of concern at intermediate yield levels, if injury occurs a little before or after flowering.

Photoperiod

Clear genetic differences among CIMMYT's inbred lines in photoperiod sensitivity were observed under lights in 1996. This will affect the breadth of their geographic adaptation per se and in hybrid combinations. Research on QTL associated with daylength sensitivity continues. The original $F_{2:3}$ mapping population has been replaced by a population of recombinant inbred lines developed from the same cross, CML 9 x A632 Ht.

Figure 1a: Daily minimum and maximum temperature and precipitation for El Batan, 1996.



Maize Improvement Training

G. Granados

Two maize improvement training courses were conducted in 1995. The first (1995-A) was held from February 15 to June 15, and was given in English. Eight participants from six countries completed the course. The second course (95-B), from July 17 to Nov. 14, was offered in Spanish and had eight participants from six countries.

As in the past, the 1995 courses comprised both theoretical training (formal lectures given by CIMMYT staff and other invited experts) and field work, mainly on CIMMYT experiment stations in Mexico. There was approximately 120 hours of formal lectures covering basic genetics, population improvement, hybrid development, maize physiology, maize entomology, maize pathology, weed control, statistics, economics, biotechnology, and computer sciences. A week during both courses was devoted to the study of seed production and maintenance technologies. In addition, the 1995-B trainees traveled to Saltillo, Coahuila, to attend a Seed Technology course offered by the Autonomous Agricultural University "Antonio Narro" (UAAAN), Saltillo, Coahuila, Mexico.

For the practical training, each course participant was assigned to work with a CIMMYT researcher from the subprogram (Lowland, Subtropical, Highland) that corresponded to the ecology where he or she was working at home. This innovation -- a change from the former system where training coordinators had sole responsibility for staging practical field exercises and participants only "visited" the subprograms -- is being refined and has generally given excellent results, according to course evaluations completed by participants. The advantages of the new approach include enhanced interaction with senior staff and associate scientists (2-3 days a week) and a better opportunity to obtain in-depth knowledge of relevant germplasm and breeding methodologies. The results of the tests taken by participants on arrival and completion of the course (average grades of 4.5 versus 8.3, on a 10-point scale) would suggest a significant improvement in participants' knowledge about maize breeding in general and at CIMMYT.

The Asian Regional Maize Program

Carlos De Leon, Surinder K. Vasal,** and James E. Lothrop*

CIMMYT established the Asian Regional Maize Program (ARMP) in 1974. Initially located in Delhi, India, the program was moved in 1981 to Bangkok, Thailand, and began research to develop germplasm resistant to downy mildew. As a result of this and similar work on other diseases in collaboration with national programs of the region, germplasm popular in specific zones was made more useful through the addition of resistance to major endemic pathogens. An important function of the regional program is to assist national programs in utilizing germplasm developed at CIMMYT headquarters and other sites. We also develop germplasm in the region through cooperative arrangements with national programs, focusing on traits that cannot be handled as effectively in Mexico. For example, we have successfully improved CIMMYT maize populations for resistance to downy mildew and developed additional, locally-suited maize populations that possess high levels of resistance to this regionally important disease.

1995

We modified our breeding program significantly to better address the needs of our clients, who are increasingly hybrid oriented. We are developing heterotic populations in extra-early white downy mildew resistant (DMR), extra-early yellow DMR, late white DMR, and late yellow DMR respectively, using a reciprocal recurrent selection (RRS) breeding scheme. This core program is supplemented by activities in backcrossing and pedigree selection. Products are Asian adapted inbreds, populations, synthetics, hybrids, and OPVs. The new system is less effective than the previous S1-S_2 intrapopulation recurrent selection scheme for developing OPVs. Both schemes can lead to the development of lines. The RRS scheme is better for improving heterosis between lines from the CIMMYT populations. However, there have been several cases where lines from intrapopulation improvement show very good heterosis with local heterotic groups. When the RRS scheme is supplemented by materials from headquarters with special traits and/or good adaptation to Asian conditions, we can meet the germplasm needs of our clients.

In Asia, there is a great disparity among nations concerning the sophistication of their maize breeding programs, and the effectiveness of their seed industries. The four Southwest China provinces (Yunnan, Guangxi, Guizhou, and Sichuan), while varying from 85% single cross hybrids in Sichuan to 26% total hybrids (mainly three way and top cross hybrids) in Guangxi, are committed to developing hybrids for the more favored areas as soon as possible. Taiwan grows only single crosses. In Thailand, there has been a dramatic shift to single cross hybrids sold predominantly by private seed companies. In Mindanao, Philippines, hybrids are rapidly increasing in importance, although a lot of open pollinated varieties (OPV's) are still marketed.

* Moved to CIMMYT, Colombia, in 1996.
** Moved to CIMMYT, Thailand, in 1996.

In India, the role played by the private sector, producing mainly hybrids, has increased dramatically since the passage of the new seed legislation. However, some problems with the legislation have hindered the marketing of single cross hybrids. Nevertheless, at least one company will offer single crosses for this year's *rabi* (winter) planting. OPV's are still important for large areas. Vietnam expects to have 50% of the area planted to hybrids, and is pushing single crosses. There is some hybrid planting in Myanmar (Burma), Nepal (very little), Bangladesh, Sri Lanka and Pakistan, but OPV's predominate. The very small national programs in Bhutan, Laos, and Cambodia develop mainly OPV's at the present time.

In our region, the stronger programs using our inbreds are unlikely to use them directly in commercial hybrids, since the competition is so keen that our materials are not yet sufficiently elite. Rather, they will refine and improve them through pedigree selection. It is helpful for us to pre-screen non-ARMP lines here, so that we can only recommend the best to breeding programs in the region. Although occasionally national programs may use one of our lines in a commercial hybrid, the probability of two CIMMYT lines being used in a commercial hybrid is quite low at the present time. Therefore, the announcement of inbreds is more important than the announcement of hybrids.

Extensive testing, that is in 8-15 locations in Asia, should be restricted to test crosses coming from our RRS activities. Although we will be developing and testing some single cross hybrids as a spin-off from our RRS scheme, we feel that a moderate amount of testing is sufficient to serve those national programs that are in transition from OPVs to hybrids, and who might be able to use them if the inbreds prove to be well enough adapted for use in commercial seed production.

1996

The following points summarize our main activities and outputs in 1996:

- New full season downy mildew resistant heterotic populations 351 and 352 were formed in 1996. This class of germplasm is in great demand in the region. Several lines identified were advanced to S6-S8, and some will likely be announced in future as CMLlines. The F1 of an open pollinated variety spun off from crosses among P351 and 352 lines was developed.
- Extra-early white and yellow top cross trials were analyzed in 1996, and the best selected early generation lines will be used for recombination purposes in 1997.
- The population INDIMYT 345 cycle 4, selected for combined resistance to downy mildew and turcicum in an ARMP/Indian Directorate of Maize Research joint project, was recommended for general cultivation as an open pollinated variety in the Indian state of Karnataka.
- Collaborative research activities on *Rhizoctonia*, Asian maize borers, stalk rots, water logging, and low N involved key researchers in several countries in the region. Screening activities and the provision of newly identified tolerant germplasm continued.

- We shipped 45 trials to 10 Asian countries. In addition, we made shipments of 217 items of germplasm bulks, 2097 items of lines, and 98 items of miscellaneous materials. These shipments of germplasm went to 18 countries.
- The ARMP has identified a number of hybrids involving early generation lines that are tolerant to DMR. Also, a large number of DMR inbreds are available for use in our own program and in the Asian region.
- The regional crop management research training course held in the Asian Maize Training Center (AMTC) in Farm Suwan, Thailand was carried out during April 01-October 31, 1997. There were 16 participants completing the training out of the 26 officially nominated by NARS in the region. Nineteen technical papers the results of on-station and on-farm trials conducted by the trainees were completed and 10 country reports focusing on "Cropping Systems with Maize" were written into an published training report. These were distributed to the alumni, Head of NARS, donors, CIMMYT outreach staff, libraries, seed companies and other institutions including the other regional CMRT programs. Post training evaluation conducted underscore the relevance of the course offering to the alumni and the NARS. Post training activities of the course alumni on return to their home country were monitored in order to achieve the objectives and goals of the training center.

The South American Regional Maize Program

Shivaji Pandey, Carlos De Leon,** and Luis Narro*

Located at CIAT, Cali, Colombia, the activities of our program center around two types of environments: 1) the highlands of Colombia, Ecuador, Peru, and Bolivia, where different types of highland maize such as floury, morocho, chullpi (sweetcorn), cangill (popcorn), and blue (or black) maize are grown, and 2) the tropical lowlands of all these countries with the addition of Venezuela, Brazil and Paraguay. To a lesser extent we collaborate with a program in northern Argentina. Chile and Uruguay do not grow much tropical corn or conduct much maize research.

Four different types of regional trials are coordinated by our program. NARS provide seed to be included in ERSAT, ENSAT and ERVEZAS (described below). We prepare the trials and distribute them to cooperators. They send us data from each location. After carrying out individual location and across location analyses, we make the results available to NARS.

Progeny testing is an integral part of breeding projects to evaluate progenies of a given population in several different environments. The main objective of these evaluations is to select materials for stability and good performance (high yield) across environments. These trials involve progeny testing of acid soil tolerant populations (ASTP) and are different from the IPTTs distributed from headquarters.

Variety/hybrid evaluations are organized in the region to facilitate the exchange of materials and information among the participating NARS. The main objective of these trials is to allow each NARS to see the products of the other programs. Stability of performance is also studied. Two types of variety/hybrid trials are conducted: 1) highland maize variety trials (ERVEZAS) are separated by grain type into floury, morocho and special types (blue maize, popcorn, sweet corn), and 2) lowland trials for normal soils (ERSAT) and acid soils (ENSAT).

Technology validation trials have recently been conducted in Ecuador, Peru and Bolivia for ear rot inoculation techniques. The main objective is to test a given set of special research techniques under different environmental and genetic conditions.

Theses and other special projects are also frequently coordinated by our program.

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* Moved to CIMMYT, Mexico, in 1996.

** Moved to CIMMYT, Colombia, in 1996.

1995

Major Activities

1. Merger of population SA-5 with SA-3 and of population SA-8 with SA-7, their improvement, and development of one white and one yellow early populations with tolerance to soil acidity.
2. Development of inbred lines suitable for formation of 9 open-pollinated varieties (OPVs) and 727 hybrids for acidic and non-acidic soils and for physiological and molecular studies.
3. Evaluation of acidity tolerant OPVs in 13 acidic and two non-acidic environments in different parts of the world.
4. Five studies (effectiveness of recurrent selection, modified diallel, triallel, project with Prof. Walter Horst, and AFLP) to understand genetic and physiological bases for tolerance to soil acidity.
5. Evaluation of acidity tolerant OPVs in the farmers' fields in Colombia, Ecuador, and Peru.
6. Comparison of two sources of calcium (dolomitic lime and sulcamag) and four methods of their application to correct soil acidity in Colombia,
7. Collaborative project to develop two heterotic populations for NARS.
8. Establishment of collaborative research facilities at Alto Mayo and Pucallpa, Peru, for evaluation of acidity tolerant germplasm.
9. Collaboration with CIMMYT's Asian Regional Maize Program and CIMMYT-HQ scientists by growing their six trials and providing reliable information.
10. Identification of 19 trainees, students and visiting scientists for different courses in Brazil, Colombia, and Mexico.
11. Release of two OPVs in the region during 1995, using CIMMYT germplasm.
12. Provision of 29 trials and about 3,200 non-trial germplasms to 18 research programs.
13. Consultations of 215 man-days to NARS scientists and leaders, monitoring CIMMYT trials, and provision of useful information to NARS and HQ.
14. Organization of and participation in 9 national and international workshops, meetings, and symposia.
15. Logistical support to NARS during 1995.
16. Publication of seven refereed and seven non-refereed articles.

Regional Releases Using CIMMYT Germplasm

BR 473, a synthetic based on lines from populations 65 and 66, was released in Brazil, and Agua Blanca, a water-logging tolerant OPV based on La Posta, was released in Venezuela.

1996

Major Activities and Accomplishments

1. Improvement of populations SA3 and SA4 in yellow, and SA6and SA7 in white kernel colors with tolerance to acid soils, through reciprocal recurrent selection.
2. Improvement of one early yellow, and one early white populations with tolerance to acid soils, and one early yellow selected for nonacid soil conditions.
3. Formation of 11 open-pollinated varieties (OPVs).
4. Evaluate selected inbred lines and OPVs as testers in yellow and white populations.
5. Development of 340 single cross, and 272 topcross hybrids for acid and nonacid soil environments.
6. Evaluation of 493 advanced (S6 through S8), and 381 S_2 inbred lines, at 11 different locations.
7. Assamble and distribute to 17 locations in the world 120 yellow, and 157 white S3 inbred lines in an "Evaluacion de Lineas de Suelos Acidos" (ELSA).
8. Advance 16 experimental varieties generated in 1995 to F_2, and assamble these in an Acid Soil IV Trial for evaluation.
9. Summarise and analyze data collected in four studies: modified diallel, triallel, AFLPs, and studies with the Univ. of Hannover, initiated in 1995 to understand the genetic and physiological basis of acid soil tolerance.
10. Evaluation of acid soil tolerant OPVs in farmer's fields in Colombia, Ecuador, and Peru.
11. Development of 2 heterotic yellow populations for NARS in the region, through a collaborative project.
12. Collaboration with CIMMYT-HQ and WAfrican Regional Maize Program in growing 15 and 2 trials, respectively.
13. Selection of 10 trainees from NARS in the region to participate in the Crop Management Training Course at CNPMS, Brazil, and additional 32 scientists to participate in various meetings, and courses organized at CIMMYT-HQ and by SARMP in the region.
14. Release of one TWC hybrid selected from CIMMYT hybrid trials.
15. Distribution of 61 trials and approx. 1145 separate germplasm entries in 92 seed shipments to maize researchers in America, Asia, and Africa.
16. Consultation with NARS for 249 man-days, visiting national programs and monitoring performance of CIMMYT germplasm, supplying valuable information to HQ.
17. Organizing and/or participating in 12 regional and international scientific meetings, and.
18. Publication of one refereed, and 5 nonreferred scientific papers.
19. Dr. Shivaji Pandey, who had been leading the SARMP since Nov. 1984, was transfered to Maize Program at CIMMYT-HQ in June 1996. He was replaced by Dr. Carlos De Leon, starting May 1996.

Regional Releases Using CIMMYT Germplasm

In Peru, the three-way cross hybrid PIMTE, with pedigree (Pob. 36 C5-HC 144-2-2-b###) x (Pob. 24 C5-HC 219-4b### x Pob. 36 C5-HC-49-1-1-b-#), selected from a 1991 CIMMYT Hybrid Trial, was released in June 1996.

The CIMMYT-Zimbabwe Regional Maize Research Program

David C. Jewell, Kevin Pixley, Stephen Waddington, Marianne Bänziger, and Batson Zambezi*

The CIMMYT Maize Program operates a research station on the University of Zimbabwe Farm, just outside of Harare. The research activities and germplasm development activities at CIMMYT-Zimbabwe continue to be primarily directed towards tropical maize growing areas at elevations ranging from about 900 to 1,800 meters above sea level. This definition encompasses approximately 6.5 million hectares in southern and eastern Africa with a regional maize grain yield average of 1.3 t ha^{-1}.

Within eastern and southern Africa the major constraints to maize production (in order or importance) are low and declining soil fertility, drought, weeds, insect damage (particularly by *Chilo partellus*, *Busseola fusca* and termites), maize streak virus (MSV), *Puccinia sorghi* leaf rust, and *Exserohilum turcicum* leaf blight, coupled with generally compromised crop management. Lately, the foliar disease caused by the fungus *Cercospora zeae maydis* (grey leaf spot; GLS) is becoming an important concern.

Maize breeding research at CIMMYT-Zimbabwe addresses the issues of increasing yield and yield stability. Important objectives are host plant resistance to maize streak virus, resistance to foliar leaf diseases that are common in the region and resistance to attack by maize stem borers. Great emphasis is also placed on early maturity, a trait which allows farmers options for incorporating maize in complex cropping systems. Tolerance to drought and improved production under low soil fertility conditions are increasingly important objectives. Breeding research continues to move towards a hybrid orientated system from which open pollinated products are also generated. Agronomy research is focused on soil fertility management in maize dominated cropping systems, with emphasis on longer-term soil fertility trends for current cropping systems and the evaluation of technologies that may improve soil fertility.

We continue developing project proposals and donor contacts to promote improved awareness and collaboration between technology developers and technology disseminators. This is vital for accelerating the transfer of relevant, improved maize technologies to resource poor farmers. Finally, we are seeking ways to increase our involvement in research on natural resource management.

* Moved to CIMMYT, Zimbabwe, in 1996.

1996

The Breeding Program

This research program was initiated in 1985 with the primary objective of developing germplasm with resistance to maize streak virus (MSV) disease for midaltitude areas of eastern and southern Africa. In 1988 work was extended to include germplasm for lowland tropical areas in the region, but as of 1992 breeding of lowland tropical maize was taken up by the CIMMYT regional program in Côte d'Ivoire.

A total of 12,072 nursery rows were grown at Harare during summer 1995/96. Of these, 1,544 rows were evaluated with artificial streak virus epidemic, and 1,050 rows were evaluated with artificial *turcicum* leaf blight epidemic. A total of 8,400 nursery rows were grown at Mzarabani in winter 1996 for a variety of projects including new line development, inbred line increase, testcross formations, hybrid formations, recombinations of F1 to F_2 for various materials, and several seed multiplication activities. Yield trials were grown at 6 sites in Zimbabwe, representing 10 environments.

An elite hybrid trial containing 100 entries -- including 21 single-cross, 29 three-way, 9 double-cross and 4 topcross hybrids from the CIMMYT-Zimbabwe program, plus 5 hybrids from CIMMYT-Mexico, 31 commercial or pre-commercial hybrids from 4 private companies, and one variety cross -- was grown at 4 sites, one of which was the streak virus nursery at Harare. The highest yielding hybrids were mostly from private companies. The best general combiners for grain yield at three sites not including the streak virus nursery were N3 and CML216, confirming previous knowledge about these lines. Seven trials were made available in 1995/96 to regional collaborators. Seed was sent upon request only.

A maize weevil research project funded by the Rockefeller Foundation is under way to develop/improve maize populations with useful levels of resistance to *Sitophilus zeamais* and to test improved cultivars for weevil resistance before recommending their use by research partners. A student was hired to lead the project in May, and he began research activities at Mzarabani, during winter. Also during winter, the laboratory was set up at Harare. A study of the gene action behind resistance inheritance was initiated. The susceptibility to weevil of CIMMYT and regional lines is not yet known.

A French PhD student conducted research aimed at elucidating the genetic control of resistance against MSV and MMV (Maize Mosaic Virus) in maize, through use of molecular markers. Preliminary data suggest that MSV resistance is under control by one major QTL on maize chromosome 1 which has a predominantly additive effect and explained 53% of the phenotypic variance for resistance. In other work on MSV resistance, the coordinator of the Tanzanian National Maize Programme has a collaborative project with us to evaluate and improve the level of MSV resistance in one of its OPVs, KilimaST.

Research on Soil Fertility and Agronomy

CIMMYT-Zimbabwe conducts a modest agronomy research program, primarily on longer-term soil fertility issues within SoilFertNet and on maize germplasm x management interactions. Funding for this work comes from the Maize Program and the Rockefeller Foundation.

Yield and Soil Fertility in SmallHolder Maize-Groundnut Cropping. The rotation of maize with groundnuts is the most common legume + cereal association on smallholder farms in sub-humid parts of Zimbabwe, but area under groundnuts and yields appear to be declining. We studying the productivity and sustainability of this rotation compared to continuous maize with and without inorganic fertilizer. Returns over cash (i.e. seed and fertilizer) costs were higher for the rotation system than for the continuous maize plots, with or without inorganic fertilizer, indicating that farmers acutely short of cash may find the rotation attractive. However, when groundnut labour costs were added, the continuous maize with fertilizer system showed higher returns; returns for the rotation and continuous maize *without* fertilizer were identical. We calculate that maize grain yields need to be improved by at least 48% (2.54 t ha^{-1}) with fertilizer after groundnuts and 33% (0.82 t ha^{-1}) without fertilizer after groundnuts, to pay for the groundnut crop and foregone maize yield the first year.

Yield Sustainability of Maize + Grain Legume Intercrops. We continued our trial to measure the longer term effects of five maize + grain legume intercrop combinations. We found some important yield benefits with continued intercropping in this third year of the trial on the same plots. With fertilizer applied to maize, maize grain yields from several of the intercrop combinations were higher than those obtained from sole-crop maize. Without fertilizer to maize, the grain yield of maize intercropped with cowpea was over 0.5 t ha^{-1} larger than from sole-crop maize. In addition the cowpea was able to produce over 100 kg ha^{-1} of grain, ample leaf for relish and almost 2 t ha^{-1} of above-ground biomass when grown with unfertilized maize. These are very interesting results from using a low harvest index spreading-type of cowpea because nearly 2 t ha^{-1} of above-ground biomass will almost certainly help improve soil fertility. We will continue to monitor whether the yield improvements can be maintained or increased in coming years.

Fertilizer Options for Smallholders in Sub-humid Zimbabwe. Our long-term trial to test cheaper basal fertilizer options for maize continued into its fourth year (1995/96). At planting this season we applied the repeat dose (previously applied 3 years ago) of 115.5 kg P_2O_5 ha^{-1} as single superphosphate (SSP) to the plots designated for those treatments. This year the current recommendation (compound D at planting each year) and ammonium nitrate (AN) each year + SSP every 3 years in furrow significantly ($P<0.01$, CV = 13.17%) out-performed AN each year + SSP every 3 years on soil surface, AN + SSP each year and AN only each year. The two best fertilizer options were the ones with P applied into the soil (rather than not applied or applied on the soil surface) at planting. These may be the first signs of a yield response to P in this trial (after four years) and we plan to watch this closely next year.

Cattle Manure x Inorganic N Trial. Soil Fert Net developed this trial and it was first planted in 1995/96. CIMMYT-Zimbabwe planted one site of the trial – at Domboshava Training Centre. The objective is to quantify the productivity and N-use gains from combining organic material from cattle manure with inorganic N fertilizer for maize at rates practicable for smallholder farmers in Zimbabwe. There was no significant interaction between cattle manure and inorganic N and no effect of cattle manure on grain yield or total above-ground biomass. Adding 80 kg inorganic N ha^{-1} raised maize grain yield from 3.16 to 4.44 t ha^{-1} which was significant at P = 0.01. Based on discussions at the Soil Fert Net workshop held in Harare during October 1996, the trial will be modified for 1996/97 to include a fourth higher rate of cattle manure and each source of manure will be applied at all sites as satellite plots. Network members will plant it at six new sites. We plan to conduct two of those sites, at Domboshava and in Hwedza.

Maize N Use and Response Under Smallholder Conditions. Most maize in Zimbabwe is produced by smallholder farmers on infertile sandy soils. Mineral nutrient deficiencies, particularly of N, are acute and almost universal on these soils and, given fertilizer costs and lack of affordable credit, fewer smallholder farmers are using N fertilizer and those applying inorganic N are using it at lower rates. To address the resulting stagnation in smallholder maize yields, farmers require information on the benefits of combining resource-efficient maize genotypes with the management of inorganic N. With this aim, we started a project in September, 1996, with Rockefeller Foundation support, to 1) compare on smallholder farms the yield response to inorganic N of a range of maize genotypes including those that may be more efficient in N use; 2) establish realistic inorganic N fertilizer response curves for maize under smallholder farmer management practices; 3) test the relationship between leaf chlorophyll concentration and maize grain yield; and 4) select and characterize on-farm sites for the future evaluation of nutrient efficient maize. Trials will run for two seasons and involve significant farmer participation.

Final Report: Grain Yield Declines From Growing F_2 Seed. Results from our three-year study show that large yield reductions can be expected from planting F_2 maize seed, especially in lower yield potential conditions. Farmers who plant F_2 maize seed under those conditions may obtain lower grain yields than they can expect from planting adapted open pollinated maize varieties.

Drought and LowN Project

The Southern African Drought and Low Soil Fertility Project (SADLF) began on January 1, 1996. The project is a collaborative effort between CIMMYT and the National Agricultural Research Programs of the Southern African Development Community (SADC). The goals of the project are 1) to enhance the capacity of CIMMYT and the National Programs to improve and disseminate adapted drought- and low nitrogen-tolerant maize germplasm through regional collaboration, and 2) to develop, within ten years, maize germplasm which has increased yield and yield stability under conditions typical of resource-poor farmers, and to achieve this without further depleting natural resources (water, nutrients, land). Activities at CIMMYT-Zimbabwe on breeding for tolerance to drought and low nitrogen (N) and the project coordination are led by a CIMMYT scientist. National Program activities are guided by the Steering Committee of the Maize and Wheat Improvement Research Network for SADC (MWIRNET). In agreement with SACCAR, CIMMYT assigned an internationally hired scientist who had worked four years in the drought and low N tolerance breeding program at CIMMYT-Mexico and who transferred to Zimbabwe in 1996.

During 1996, Steering Committee members and maize crop leaders of SADC member states were surveyed on project components, and CIMMYT, the MWIRNET and SDC agreed on a definite project set-up. Project activities started with CIMMYT-Zimbabwe and National Programs developing screening sites in Botswana, Malawi, South Africa, Tanzania, Zambia, and Zimbabwe where maize germplasm can be evaluated under managed drought and low N stress for tolerance to these stresses.

Soil Fertility Network

The Soil Fertility Research Network for Smallholder Maize-Based Cropping Systems in Malawi and Zimbabwe, now known as "Soil Fert Net", is funded by the Rockefeller Foundation and aims to help smallholder farmers in Malawi and Zimbabwe to produce higher, more sustainable and profitable yields from their dominant maize-based cropping systems through improved soil fertility technology and better management of those inputs. Activities include:

- Research priority setting, planning, proposal development and review, and the sourcing of funds.
- Conduct of priority research and extension.
- Information synthesis and exchange, and training for Network members.
- Distribution and use of output information through links between farmers, research, extension, NGOs and fertilizer input suppliers.

Soil Fert Net made notable progress during the year in the following areas:

- Conduct of the first Network Trials, generating information on benefits from combined organic + inorganic fertilizers. Members ran these trials at five sites in Zimbabwe and one in Malawi. This work was strengthened by a workshop on the topic at the Crop Science Department, University of Zimbabwe in October.
- Development of integrated extension + NGO efforts to disseminate soil fertility technology, particularly in Zimbabwe. This included a major Network Workshop on the topic held during July in Malawi.
- Publication of research results from Network researchers. We developed a large report of research results and network outputs as a Network Workshop proceedings and circulated it widely. Reviews of soil fertility research and research and extension needs were produced.
- Better linkages between researchers, and improved regional awareness of the soil fertility constraint and opportunities to reduce it. These took place frequently during the year at meetings attended by Network members. Awareness and planning was especially productive during our large field tour of Zimbabwe in February 1996.
- The Network peer review process helped to secure funding from the Rockefeller Foundation for several new projects by national programs.
- Upgrading of our capacity to do our work. Soil Fert Net produced and distributed a wide range of review and methods working papers, workshop proceedings, newsletters and

bibliographies. Members participated in soil fertility research meetings in Kenya and Tanzania and in a crop modeling training workshop in Kenya.

- A higher publicity profile for the Network and its members. As examples, the Network has featured in several publications from CIMMYT HQ in Mexico, including a *Research Brief*, and in brochures about the CIMMYT Maize Program and Natural Resources Group.

Maize and Wheat Improvement Research Network for SADC

Initiated in 1994 and financed by the European Union, MWIRNET is developing improved varieties of maize and wheat, promoting the free exchange of this improved seed throughout the region, and helping provide training opportunities and access to relevant information for maize and wheat professionals. It operates under the auspices of SADC and the Southern African Centre for Cooperation in Agricultural Research and Training (SACCAR).

Training. To date, MWIRNET has supported the participation of 11 scientists from the SADC region in the crop management research training (CMRT) course at Egerton University, Kenya, four of these in 1996. The network also supported the attendance of several researchers from Angola and Mozambique to a CMRT course offered jointly by EMBRAPA and CIMMYT in Brazil. MWIRNET supported in-service training for five SADC scientists at CIMMYT-Mexico. Twenty-seven maize and wheat technical staff representing eight countries were sponsored to attend short courses offered by the College of Agriculture, University of Zambia.

Five candidates were accepted for enrollment in the Department of Crop Science, Masters of Science two-year program that began at the University of Zambia in February 1996. Network staff will assist in development of thesis problems that address the Network target foci established by the Steering Committee. Five PhD positions are available through the Network, and one candidate is currently enrolled at the University of Reading, UK. Four senior scientists were supported as Visiting Scientists to CIMMYT-Mexico to attend the symposium "Developing Drought and Low-Nitrogen Tolerant Maize" (March, 1996).

The MWIRNET also began a "Mentor Program", whereby researchers from stronger national programs assist sister programs in the region.

Regional Maize Workshop. The 5th Regional Maize Conference for Eastern and Southern Africa, entitled "Productivity Gains through Maize Research and Technology Dissemination", was held in Arusha, Tanzania, in June 1996. Southern Africa was represented by nearly 30 maize scientists, 16 with support from MWIRNET.

The Steering Committee decided to accept proposals for MWIRNET funding in the following research categories for maize: earliness, soil fertility, drought, nitrogen use efficiency, and pests/diseases.

Regional Distribution of Germplasm. The SADC Regional Maize Evaluation Nursery (RMEN) is used to assess the performance of early and intermediate maize varieties and hybrids in marginal rainfall ecologies of the SADC region. The 1995-1996 SADC RMEN consists of 14 entries, distributed as a three-replicate RCBD to six national maize improvement programs

(Lesotho, Mozambique, Swaziland, Tanzania, Zambia, and Zimbabwe). National program partners have been reluctant to submit germplasm for regional testing.

1996 SADC RMEN entry list.

Entry	Cultivar	Source
1.	Katumani	
2.	MM441	Zambia
3.	MM601	Zambia
4.	MM604	Zambia
5.	Kalahari Early Pearl	
6.	ZM607C_3F_2-#	CIMMYT-Zimbabwe
7.	INTAc1F1/INTBc1F1	CIMMYT-Zimbabwe
8.	(COMPE1/PL16-SR//COMPE1)C1F_2	CIMMYT-Zimbabwe
9.	Z$S_2$25/*POOL16-SR))F_2-S1-F3	CIMMYT-Zimbabwe
10.	TEWF-DRTOLSYN1/(K64R/P30-SR(S_2#)))-#	CIMMYT-Zimbabwe
11.	MH18	Malawi
12.	R201	Zimbabwe
13.	Local check	
14.	Local check	

In addition, to promote useful germplasm and facilitate its access throughout the region, MWIRNET recently compiled a list of maize varieties and hybrids released in selected countries of SADC -- a companion piece to the detailed listing of maize materials available through CIMMYT-Zimbabwe that was produced last year.

Other Activities

CIMMYT-Zimbabwe assisted ICRISAT, USAID and World Vision International on seed relief activities for Angola. The "Seeds of Freedom Project" is funded through a grant to ICRISAT and to World Vision International. Several NGOs and International Agricultural Research Centers are contributing.

The Fifth Regional Maize Conference for Eastern and Southern Africa was organized by CIMMYT's Africa based staff in collaboration with the National Maize Programme of Tanzania. The meeting was held in Arusha, Tanzania, from June 3 to June 7 1996 on the theme "Productivity Gains Through Maize Research and Technology Dissemination. The conference received primary support from the Rockefeller Foundation, the European Union through MWIRNET and from the Canadian International Development Agency through the Eastern Africa Cereals Program. A proceedings will be produced and distributed in 1997.

Table 1. CIMMYT-Zimbabwe Maize Breeding Trials, 1995-96.

Name of Trial	Description	Sites Planted*
Elite Hybrids	Elite CIMMYT & commercial hybrids 100 ent, 10x10 lattice, 2 reps/site	HA, GL, RA, MSV
TC Advanced 1	Testcrosses of advanced lines; 2 testers 196 ent, 14x14 lattice, 2 reps/site	HA1, HA2, GL, RA
TC Advanced 2	Testcrosses of advanced lines to 2 or 3 testers 182 ent, 13x14 lattice, 2 or 3 reps/site	HA1, HA2, GL, RA
TC ZM607	Testcrosses of promising lines to ZM607 91 ent, 7x13 lattice, 2 or 3 reps/site	HA, GL, RA
TC Early	Testcrosses of early maturing lines to 2 testers 130 ent, 10x13 lattice, 2 or 3 reps/site	HA, RA, LU
TC Exotic	Testcrosses of exotic lines to 2 to 4 testers 140 ent, 10x14 lattice, 2 or 3 reps/site	HA, GL, RA
Hybrids ZM601	Hybrids of ZM601 lines with K64R 36 ent, 6x6 lattice, 2 reps/site	HA, GL, RA, LU
ILHYB	Intermediate & late maturing hybrids 25 ent, 5x5 lattice, 3 reps/site	Regional and part of Elite Hybrids trial
ILCYCL	Intermediate & late maturing selection cycles 42 ent, 6x7 lattice, 3 reps/site	HA1, HA2, GL, RA, MT, ET MSV, NUE, and regional
ILPOP	Intermediate & late maturing populations 20 ent, 4x5 lattice, 3 reps/site	MSV, NUE and regional
ITOP	Intermediate & late maturing pop'n topcrosses 49 ent, 7x7 lattice, 2 reps/site	HA, GL, RA, MK, MT, and regional
EPOP	Early maturing populations 36 ent, 6x6 lattice, 3 reps/site	RA, LU, MSV, NUE and regional
ETOP	Early maturing population topcrosses 100 ent, 10x10 lattice, 2 reps/site	HA1, HA2, GL, MK, MT, and regional
FS POOL9A	Full-sibs of Pool 9A MSV conversion 156 ent, 12x13 lattice, 2 reps/site	Regional only
TC 202 ASI	Cosmos thesis; testcrosses to CML202 143 ent, 11x13 lattice, 2 reps/site	HA, GL, MK, MT
TC K64R ASI	Cosmos thesis; testcrosses to K64R 143 ent, 11x13 lattice, 2 reps/site	HA, GL, MK, MT

* HA, Harare; GL, Glendale; RA, Rattray-Arnold; MK, Makoholi; MT, Matopos; LU, Lucydale; MSV, maize streak virus nursery at Harare; NUE, low-nitrogen nursery at Harare; ET, *turcicum* nursery at Harare; Regional, includes all sites outside of Zimbabwe and managed by non-CIMMYT cooperators.

Table 1 (cont'd).

Name of Trial	Description	Sites Planted*
TC ASI	Cosmos thesis; additional testcrosses 56 ent, 7x8 lattice, 2 reps/site	HA, GL, MK, MT
Axel MSV	Axel Schechert Ph.D. thesis 215 ent, 5x43 lattice, 2 reps/site	MSV
Willcox 1	Martha Willcox post-doc (Mexico) 42 ent, 6x7 lattice, 2 reps/site	HA, GL
Willcox 2	Martha Willcox post-doc (Mexico) 20 ent, 4x5 lattice, 2 reps/site	HA
CHTSW	CIMMYT hybrid trial subtropical white (Mex.) 20 ent, 4x5 lattice, 3 reps/site	HA, GL
SMBR-ETW	Subtropical borer/turcicum hybrids (Mex.) 36 ent, 6x6 lattice, 2 reps/site	HA
IPTT 42	IPTT pop'n 42 (Mexico) 196 ent, 14x14 lattice, 2 reps/site	HA
IPTT 44	IPTT pop'n 44 (Mexico) 196 ent, 14x14 lattice, 2 reps/site	HA
DMRESR	Alpha Diallo varieties (Ivory Coast) 30 ent, 5x6 lattice, 3 reps/site	HA
Ghana QPM	QPM varieties (Ghana) 10 ent, RCBD, 4 reps/site	HA, RA
KM9503	IITA midaltitude hybrids 20 ent, RCBD, 4 reps/site	HA
KM9505	IITA early maturing populations 8 ent, RCBD, 4 reps/site	HA, RA
Pannar MSV	Pannar Seed Company MSV trial 25 ent, RCBD, 3 reps	MSV

* HA, Harare; GL, Glendale; RA, Rattray-Arnold; MK, Makoholi; MT, Matopos; LU, Lucydale; MSV, maize streak virus nursery at Harare; NUE, low-nitrogen nursery at Harare; ET, *turcicum* nursery at Harare; Regional, includes all sites outside of Zimbabwe and managed by non-CIMMYT cooperators.

Lowland Tropical Maize: West and Central Africa

Alpha O. Diallo

As of 1990, with support from the OPEC Fund for International Development, CIMMYT has posted a breeder at Bouaké, Côte d'Ivoire, to draw on of improved, streak resistant germplasm of lowland adaptation developed through cooperation between CIMMYT and the International Institute for Tropical Agriculture (IITA), as well as other materials, and to generate a range of streak resistant maize adapted to production environments in West Africa.

1995

Developing and Improving Streak Resistant Germplasm

- 13 early white, downy-mildew-resistant populations from Asia were crossed with a streak resistant source and evaluated; the three best materials will be converted to streak resistance.
- Two inbreeding-tolerant and streak resistant populations (one white dent and on e late white flint) were formed.
- Breeding activities relating to the conversion of 11 populations with special traits were completed.
- Cycle 1 of two intermediate maturity white flint and dent populations (POP32SR and POP49SR) under S_1 reciprocal recurrent selection were reconstituted and eight synthetics formed.

Developing Inbred Lines and Hybrids

Pedigree Selection Using Streak Resistant Sources. 276 streak resistant white and flint S_4 lines were evaluated for combining ability. The best were advanced to S_5 and will be tested in hybrid and synthetic combinations. 338 streak resistant S_3 lines were selfed and crossed to testers CML247 and CML254 for a combining-ability study in 1996.

Pedigree Selection During Streak Conversion and Reciprocal Recurrent Selection. 240 S_2 lines from SPLC5-SR were advanced to S_4 and 156 bulks were selected. S_1 lines from the following sources (number in parentheses) were advanced to S_2 and S_3 in nurseries under maize streak virus:

- THGA-SR (210)
- THGB-SR (195)
- POB302-SR (201)
- CIMCAL8843TSA8-SR (26)

The following streak resistant lines from the CIMMYT regional office at Harare, Zimbabwe, were advanced to subsequent generations under streak infestation:

- 16 S_4 from Pool 20
- 37 S_7 from Population 30SR
- 88 S_6 from Suwan-1SR

Breeding for Yield Potential

Open Pollinated Variety Trials. Late white germplasm from La Posta (S9343SR, Ferke 9143) outyielded all entries across five locations in Côte d'Ivoire, producing 7.3 t/ha. Another variety, TZLCOMP4, derived from La Posta by the International Institute of Tropical Agriculture (IITA), also performed well. Among varieties of intermediate maturity, S9243C_2 (a streak resistance source from La Posta) and TZUTSRW were the best, although the leaf disease resistance of the latter needs improvement. One intermediate streak resistant variety, Ferke (1)8323SR, ranked 1st at Bamburi, Kenya, and might be retained for further testing and eventual release in the coastal region of that country.

Hybrid Trials

Topcross Hybrids. The two best yielded 8.3 and 8.0 t/ha across five locations, vs 7.3 t/ha for the best OPV.

Single-cross Hybrids. 22 entries yielded more than 8.0 t/ha across five locations, vs 6.0 t/ha for the local OPV check. A record 12.3 t/ha was recorded at Odienné, where more than 16 single crosses gave yields of more than 10.0 t/ha.

Breeding for Stress Tolerance

Breeding for *Striga* Resistance. Inbred lines from different maize populations were compared in four trials at Ferke and at Kibos, Kenya. In those of a split-plot design, *Striga* count, days to silk, and anthesis-silking interval (ASI) were measured. In trials where a lattice or random complete block design were used and all plots were infested, the differences between *Striga* counts were significant, except at Kibos. The trials confirmed 1) the existence of variation among maize genotypes for the ability to reduce *Striga* emergence, 2) the resistance of CML25 to *S. hermonthica*, and 3) that certain CIMMYT C_1 lines result in reduced Striga emergence (trials in Kenya and Cameroon).

***Striga* Control via Management.** In trials testing the effects of nitrogen levels on *Striga*, there were significant genotype x *Striga* and nitrogen x *Striga* interactions, whereas the nitrogen x *Striga* x genotype interaction was significant only at 10%.

Breeding For Drought- and Low-N Tolerance and Stalk Quality. Evaluation of inbred lines under drought, high density, and low N and in natural environments helped us identify stable and tolerant lines.

Products

- 12 Striga resistant/tolerant lines
- 40 streak resistant lines
- 11 drought tolerant lines
- 6 strong stalk lines
- 13 streak resistant OPVs
- 30 CIMMYT maize lines (CMLs) and 13 drought tolerant lines from the physiology subprogram were identified as streak resistant and are available from CIMMYT headquarters

1996

In 1996, 3 projects were completed, in addition to the routine work involving the improvement of streak reistant populations and line and hybrid development.

Identification of Streak Resistant Testers and Single-Cross Hybrids

An important objective of the CIMMYT maize hybrid program in West and Central Africa was to identify streak resistant testers for discriminating different types of germplasm, or for use as parents in hybrid combinations, or as streak resistant sources for improving populations and lines for maize streak virus (MSV) resistance. One hundred seventy-five crosses between late white dent and flint streak resistant S_4 lines were evaluated at five locations in Côte d'Ivoire in 1995. In 1996, the best lines in crosses were selected and crossed with 3 testers: 2 heterotic lines, CML247, CML254, and one broad base population, TZEE-WSR. In addition, the lines were classified into flint and dent groups and crosses made between the two groups using design II mating system. All crosses were evaluated across three locations in Côte d'Ivoire. Results showed that 15 lines as possessing high and positive general combining ability (GCA) across locations, with the mean yield of their crosses with the 3 testers outyielding the commercial IITA hybrid Oba Super I by 32% (Table 1). Lines LI96017-SR, and LI96019-SR from the Tuxpe–o group gave high yields with most of the lines from Eto group, and were selected as streak resistant testers for this group. Also, lines LI963001-SR and LI963029-SR from the Eto group combined very well with most of the lines from Tuxpeno group and were selected as streak resistant testers for this group.

Dosage Effect of Streak Resistant Lines in Two- and Multiparent Hybrids

Currently, good streak resistant lines are available at CIMMYT Côte d'Ivoire and Harare maize sub-programs. A better understanding of the dosage effect on yield of streak resistant genes in different types of hybrids involving resistant and susceptible parents will help to exploit both streak resistant and susceptible germplasm in combination to produce resistant cultivars. This will increase the range of inbred lines available for use by research partners. In 1996A season, 8 homogeneous inbred lines with different levels of resistance to maize streak varius (Table 2) were crossed to produce the following types of hybrids: resistant x resistant; resistant x susceptible; susceptible x susceptible; (resistant x resistant) x susceptible; (susceptible x susceptible) x resistant; and (resistant x resistant) x (susceptible x susceptible).

Those hybrids and their parents were evaluated in separate trials across 6 locations under artificial inoculation with MSV. The locations were Sinématiali and Ferkessédougou (Côte d'Ivoire), Ibadan

(Nigeria), St. Denis (La Reunion Island), and Harare (Zimbabawe). The streak resistant lines showed large and positive GCA effects while the susceptible lines showed large negative GCA effects for yield. The GCA for the streak score was negative for resistant lines and positive for susceptible lines. The trial was affected by bad soil and weather conditions at three locations. Resistant x resistant and susceptible x susceptible hybrids showed 27 and 436% yield reductions, respectively. Regarding streak scores, significant differences were detected between hybrids. The streak scores varied from 1.3 to 4.4 for the resistant x resistant and susceptible x susceptible, respectively. All other crosses involving 1 or 2 doses of resistant showed tolerant reaction (scores 2.6-2.9). The IITA resistant check had the same score (2.6) as the resistant x susceptible hybrid (Fig 1).

Combining Ability for Resistance/Tolerance to *Striga hermonthica* in Maize[1]

Striga hermonthica (Sel). Bent. is one of the major constraints to maize production and productivity in West and Central Africa and affects particularly fields of smallholders who often cannot afford production inputs recommended to them. Better understanding of the genetics resistance/tolerance to *Striga* in various maize germplasm sources will provide a rational basis for effective selection and help in designing appropriate breeding strategies for the development of tolerant/resistant cultivars. This study was conducted to estimate General Combining Ability (GCA) and Specific Combining Ability (SCA) of new maize inbred lines for grain yield and *Striga* emergence counts under artificial *Striga* infestation. Screening for *Striga hermonthica* resistance/tolerance under artificial field infestation was initiated in 1992 with 98 S_3 lines extracted from 6 different maize populations.

Grain yield under infested and noninfested field conditions and *Striga* emergence counts were used as the selection criteria. After 3 cycles of inbreeding followed by evaluation under *Striga* artificial infestation, 4 lines (3 resistant and 1 susceptible) were identified. In 1996, the 4 lines plus 3 IITA checks making 5 resistant and 2 susceptible (Fig 2) were crossed in a diallel fashion excluding the reciprocals to obtain 21 F_1 hybrids. The hybrids were evaluated in 5 sites in 4 countries (Côte d'Ivoire, Ghana, Cameroon and Kenya). In Côte d'Ivoire, a split plot design (maize genotypes as main plots and *Striga* level as sub-plots) with 6 replications was used. A plot consisted of 2 rows (one row artificially infested, while the other row was non-infested). In the other sites the trial was planted under natural infestation with *Striga hermonthica*, using randomized complete block design with the same plot size and replications as the trials planted in Côte d'Ivoire.

Data were analyzed based on the tests of the null hypothesis that there were no genotypic differences among the F_1s. When significant differences were established, Griffing (1956b) method (fixed model) was used for the diallel analysis with the asumption of the basence of epistasis. In addition the data from the dates of planting at Ferkessédougou (Ferkessédougou 1 and 2) were analyzed as split plots. Also across location analysis was performed and the genotypic X location interactions tested for significance. Both GCA and SCA effects for yield were statistically significant sources of variation with the GCA mean squares significantly larger than the SCA mean squares. In general tolerant lines had larger positive GCA for grain yield, while the susceptible lines had larger negative GCA effects under both infested and noninfested *Striga* conditions (Fig 3). The mean grain yield of the top 10 resistant x resistant crosses under artificial infestation across locations was 20%, and 83 % higher than the mean yield of the best 10 resistant X susceptible and susceptible X susceptible crosses respectively. The cross of the most resistant lines had the lowest *Striga* emergence counts (20 plants/m^2) and the highest grain yield under

Striga infection, while the highest *Striga* emergence counts (65 plants/m^2) and the lowest grain yield were detected in the susceptible X susceptible cross (Fig 4).

The positive significant GCA effects for yield under *Striga* infection indicated a uniform transmission of *Striga* resistance/tolerance by parents to their offsprings and confirms the existence of genetic variability for resistance to *Striga* in the inbred lines studied. However the grain yield of a single cross hybrid under *Striga* infection cannot be predicted on the basis of GCA alone. Good progress could be expected from a pedigree breeding program by exploiting resistant parents in crosses to generate F_2 populations. With this breeding scheme, inbred lines with good GCA under infested and noninfested *Striga* conditions could be recombined to develop hybrids and synthetics.

Table 1. General combining ability (GCA) effects of selected lines for yield and other traits.

Line Names	Pedigree	Yield (kg/ha)	GCA effects for...				
			Yield	Days to silking	% bad huskcover	PLAS	EASP
LI963001-SR	EV87TZBSR-131-1-2-#-B1	5888	546	0.597	0.490	0.069	-0.096
LI963003-SR	[P43SR(S3##)]-106-2-1sb-#-B1	5744	402	-1.042	-3.442	0.174	0.023
LI963005-SR	P43SRC9FS95-1-2-6sb-#-B1	5651	308	0.542	2.697	0.188	-0.102
LI963007-SR	TZLCOMP3-230-1-2-#-B1	5646	304	-0.292	-0.736	0.132	-0.324
LI963009-SR	P43SRC9FS95-1-3-2sb-#-B1	5637	295	0.042	-0.783	0.077	-0.037
LI963011-SR	EV87TZBSR-301-1-3-#-B1	5620	278	0.125	0.659	0.020	0.093
LI963013-SR	TZLCOMP3-12-3-6-#-B1	5602	260	-0.903	2.779	-0.145	-0.144
LI963015-SR	EV87TZBSR-331-2-6-#-B1	5587	244	1.014	-3.706	0.077	-0.088
LI963017-SR	P43SRC9FS100-1-1-8-#-B1	5558	216	0.542	1.263	-0.132	0.037
LI963019-SR	[P43SR(S3##)]-254-1-2sb-#-B1	5551	209	-0.458	-4.665	0.021	-0.046
LI963021-SR	87TZBSR-211-3-1-#-B1	5545	203	1.125	-2.456	0.049	-0.282
LI963023-SR	P43SRC9FS9-2-1-2sb-#-B1	5524	182	1.403	5.369	-0.007	-0.032
LI963025-SR	P43SRC9FS40-1-2-1sb-#-B1	5524	182	-0.319	16.341	-0.215	0.232
LI963027-SR	EV87TZBSR-257-2-1-#-B1	5522	180	0.208	-3.720	-0.020	-0.213
LI963029-SR	EV87TZBSR-321-1-5-#-B1	5472	129	0.625	6.147	0.077	0.107
Mean		5605	263	0.214	1.082	0.024	-0.058
Standard Deviation		104	108	0.746	5.545	0.119	0.153

Table 2. Grain yield and reaction of inbred lines to artificial inoculation with maize streak virus (MSV), across three locations, Côte d'Ivoire, 1996B.

Line names	Pedigree	Streak rate (1-5)			Yield
		Seedling	Flowering	Average	(kg/ha)
LI9603031-SR	P43SRC9FS2-5-3-3sb#1#1 (R)	1.0	1.5	1.2	2086
LI9603033-SR	EV8721SR-25G-2-2sb#1#1 (R)	1.3	1.5	1.3	2015
LI9603035-SR	EV8725SR-88-1-2sb#1#1 (R)	1.0	1.8	1.3	2313
CML-274 (R)	-	2.3	2.0	2.1	1882
CML-273 (R)	-	2.8	2.1	2.4	1953
CML-37#1 (S)	-	3.3	3.5	3.6	67
CML-254 (S)	-	4.4	4.9	4.5	296
CML-247 (S)	-	4.6	4.1	4.6	22
CML-263 (S)	-	4.6	5.0	4.9	7
Grand mean		2.8	2.9	2.9	1182
C.V. (%)		10	8	8	49
$LSD_{0.05}$		0.3	0.2	0.2	582

(R) = resistant (S) = susceptible Streak rate: 1= resistant; 5 = susceptible.

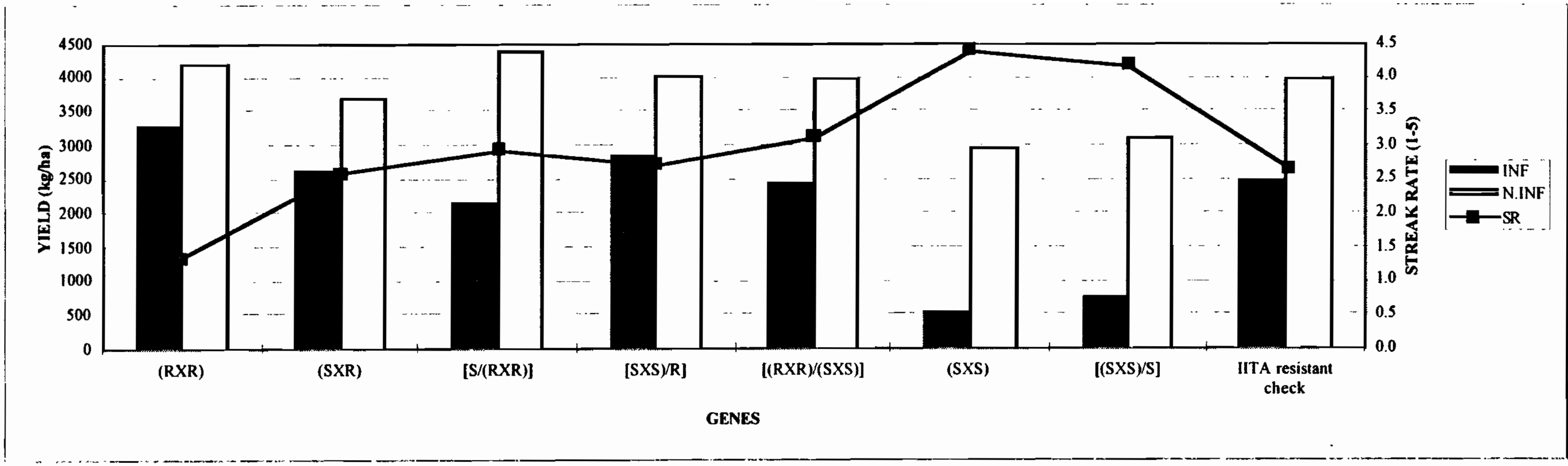

Figure1. Dosage effect on grain yield of resistant genes in two- and multi-parent hybrids. Data from 4 locations, 1996B.

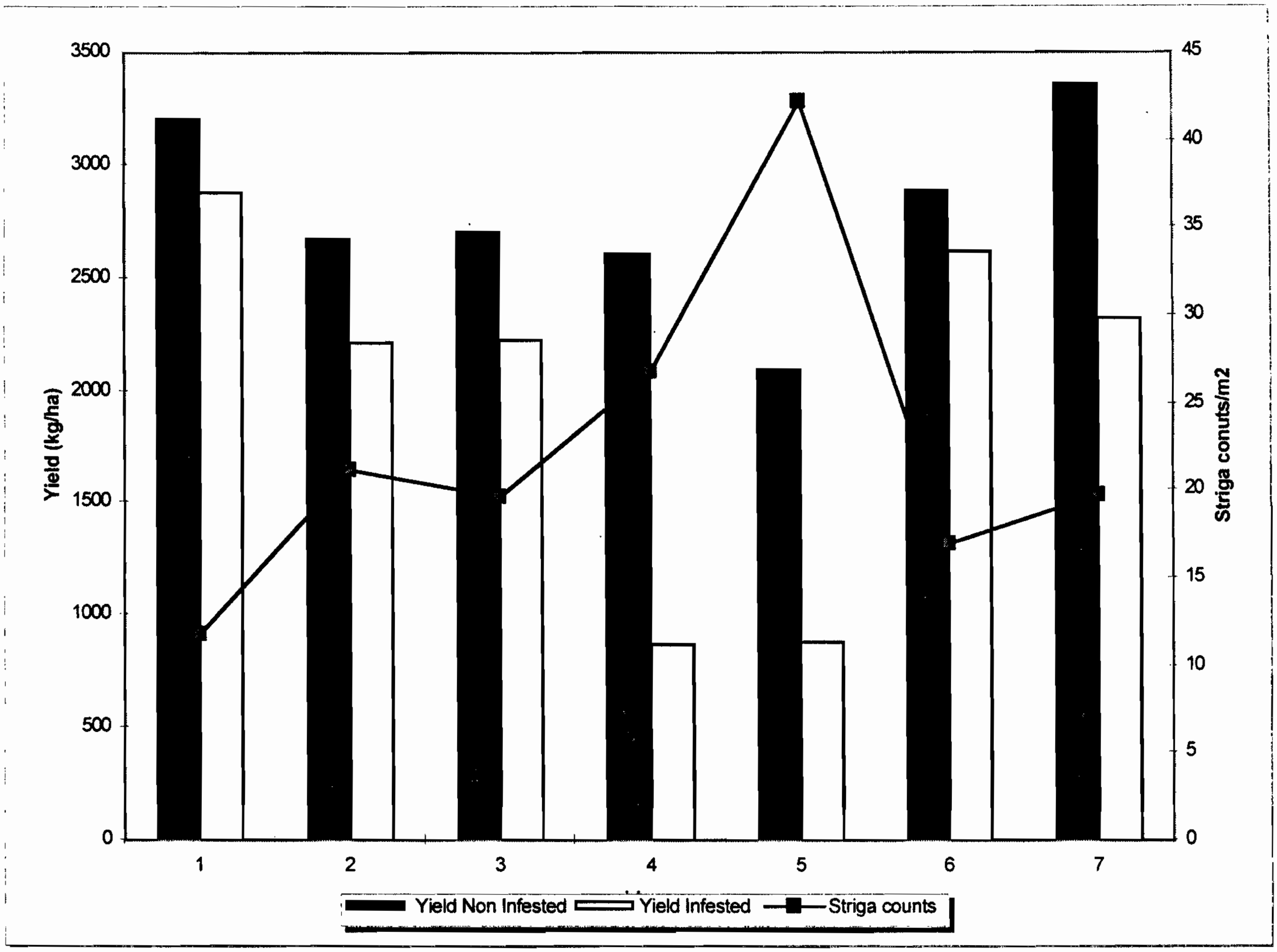

Figure 2. Means for grain yield and *Striga* emergence counts for inbred lines tested under infested and non-infested conditions with *Striga hermonthica*. Five years of data.

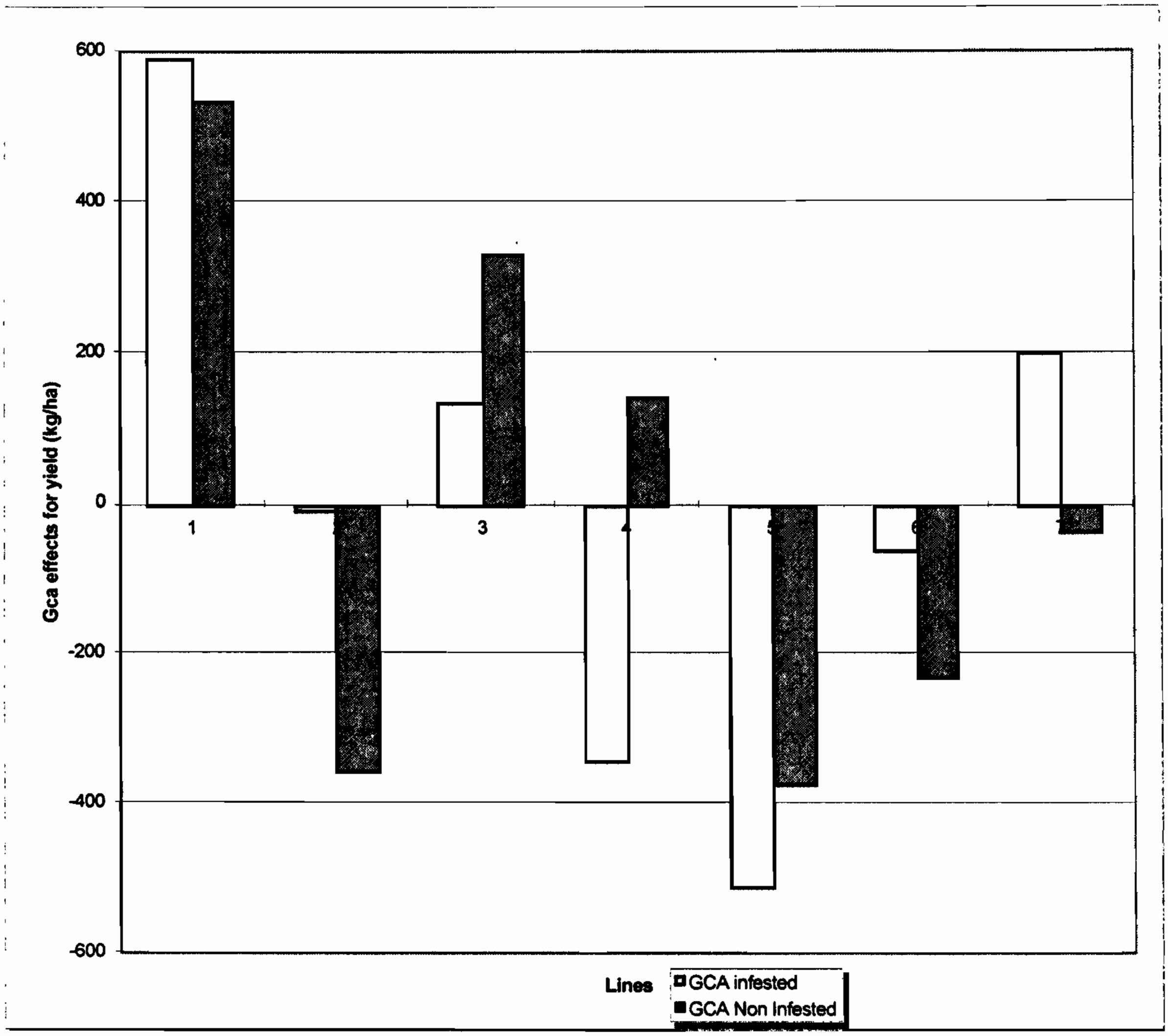

Figure 3. General combining ability (GCA) effects for yield in inbred lines tested under infested and non-infested conditions with *Striga hermonthica* across five locations.

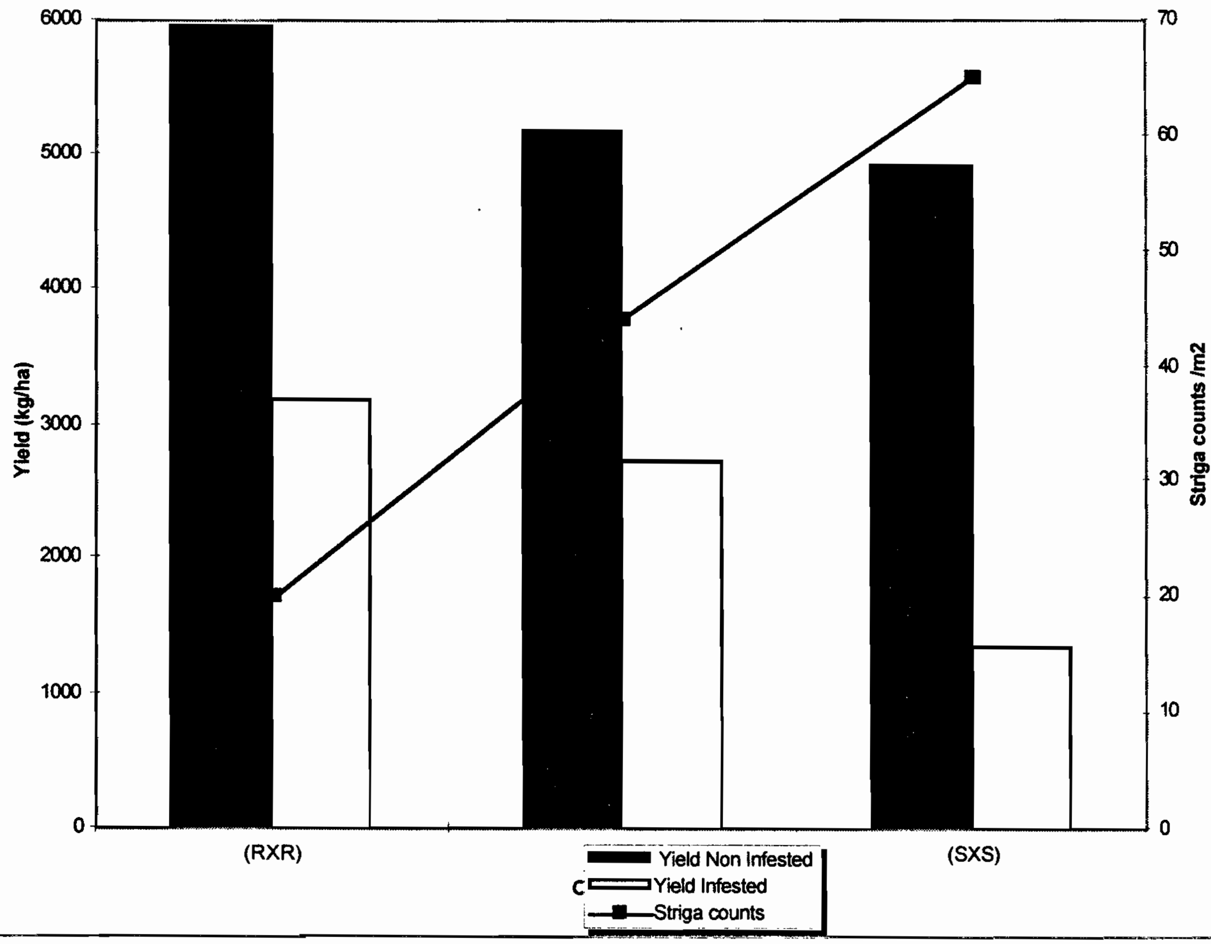

Figure 4. Means for grain yield and Striga emergence for the best R x R, R x S, and S x S maize hybrids under infested and non-infested conditions with *Striga hermonthica* across five locations.

Ghana Grains Development Project

Roberto Soza

1995

Introduction

The Ghana Grains Development Project (GGDP) is approaching 17 years of existence. It was initiated in 1979 as a joint venture between the government of Ghana and the Canadian International Development Agency (CIDA) who provided the financial assistance. Two executive agencies were nominated to conduct this Project, the Crops Research Institute (CRI) on behalf of Ghana and the International Maize and Wheat Improvement Center (CIMMYT) for CIDA. The Ministry of Food and Agriculture (MOFA) and the Grains and Legume Development Board (GLDB) participate as cooperating institutions. The International Institute for Tropical Agriculture (IITA) provides technical assistance in grain legumes through an agreement with CIMMYT. The main objective of GGDP is to assist Ghana in achieving food self sufficiency. The Project has made an important contribution to the country's food production by developing solid research and technology transfer strategies, by releasing nine improved maize and twelve grain legumes varieties, by providing agronomic/production, grain storage and seed production recommendations. Important efforts have been made to sustain the research and technology transfer activities by reinforcing CRI through staff training and provision of equipment. The Project is in Phase III; originally a five year period ending in June 1995. CIDA approved a two-year extension at no extra cost which brings the end of the Project to June 1997.

CRI administers the Project through a separate organization within the Institution, headed by a CRI Joint Coordinator and the Head of Sections. Research, technology transfer and training activities are conducted by the GGDP technical staff at the research stations and in farmers' fields.

CIMMYT has provided five resident technical staff during the length of the Project, who have acted as Joint Coordinators providing administrative leadership on the conduction of the Project and assistance in technical training, research methodologies for on station and on farm research, as well as technology transfer activities focused on maize production. CIMMYT administers project finances, graduate training and procurement, and provides technical leadership. IITA provided a resident scientist from 1985 to 1995 to assist the research work on grain legumes. IITA also placed a resident research liaison scientist in 1993 to assist other crops under CRI's mandate.

The GGDP Management Committee (MC) is formed by the CRI Director acting as chairman, CRI Joint Coordinator, A. Director of the CIMMYT Maize Program, CIMMYT Joint Coordinator, Director of the Department of Agricultural Extension Services (DAES), Director of the Department of Crops Services (DCS), Director of the Grains and Legumes Development Board

(GLDB), and representatives of IITA, and of the Ministry of Finance (MOF). The MC defines policies, approves procedures and reviews the overall progress of the Project. The MC meets twice a year, generally in May and November.

The local GGDP budget provided by the Government of Ghana was reduced by 47% during 1995, coinciding with the channeling of funds through the the Ghanaian Council of Scientific and Industrial Research (CSIR).

Training

Graduate Training. During 1995 the Project was training 9 staff members at graduate level (six for MSc and three for PhD) at US, Canadian and British universities. In addition, five other staff obtained fellowships outside GGDP for PhD training. Some student are finishing their training program and will return to Ghana soon. Since the inception of the Project a total of 12 PhD and 35 MSc staff have beeing trained so far. CRI has been very successful in mantaining the staff trained.

Technical Training. A total of 37 GGDP staff (23 research staff and 14 administration and support staff) received attended training courses in Research Management, Micro Computer and Women in Management, primarily at the Ghana Institute of Management and Public Administration (GIMPA). Out of these, 3 research staff travelled to Nigeria to participate in a course on Research Management organized by the Agricultural and Rural Management Training Institute (ARMTI) and IITA.

Visiting Scientists. During 1995 the visiting scientist program was suspended due to budget restrictions. In previous years this program was very active since the Project was sending dozens of staff annually for technical visits to CIMMYT, IITA, NARS, universities, conferences, seminars and special projects abroad.

Publications

The Project has produced nearly 100 technical and extension publications, particularly since 1991. These include technical reports (progress and annual), surveys and economics reports, maize and legumes production guides, farmers handbooks, flipcharts, extension and technical posters. All extension materials used by DAES have been published by the Project. The Project has been very active since 1993 in producing technical posters (16), most of them have been presented at the National Food and Industrial Crops Workshop (former National Maize and Legume Workshop) and the Agronomy Meeting, ASA. Four posters were presented in 1995 (Improving Rural Living Conditions Through Agricultural Research in Ghana, Grain Legumes Research and Production in Ghana, No-Till Planting with Glyphosate Dry Formulation in Ghana and The On-Farm Research Experience of the Ghana Grains Development Project).

Research

On-station research is done at seven CRI research stations (Fumesua, Kwadaso, Ejura, Damongo, Nyankpala, Kpeve and Pokoase). On-farm research is conducted in seven study areas where the Project has resident personnel for conducting the work. The research stations and the study areas represent the major agro-ecological zones of the country (Coastal Savannah, Forest, Transition and Guinea Savannah). From about 1,000 research trials and demonstrations originally conducted every year on-station and on-farm, budget constraints in 1995 forced a reduction to about 400 by transferring all demonstrations to MOFA and decreasing the number of on-farm trials. Reduced rainfall during the major season affected crops growth in different areas.

Maize Breeding. There was continued progress in population improvement, quality protein maize (QPM) development, hybrid development, and variety trials. Most of the germplasm used comes from CIMMYT. Streak resistant sources have been obtained from IITA. Sasakawa Global 2000 (SG 2000), a non-government organization that sponsors QPM research in the Project, has begun collaborative QPM trials with Nigeria, Togo, Benin, Mali, Ethiopia, Tanzania, Egypt, South Africa, Brasil and Guatemala.

Legume Breeding. Main activities covered germplasm evaluation, genetic improvement, varietal testing, screening for multiple cropping compatibility, drought tolerance and breeder seed production/seed increase.

On-Station Agronomy. Work concentrated on various intercropping systems (2-crop, 3-crop and 4-crop combinations) as well as the effects of mulch on weed management and soil fertility. Studies on responses of soybean to fertilizer application, density and time of planting were also carried out.

Entomology. The Entomology Section has been involved in research on the identification and spatial distribution of major insect pests of cowpea and soybean, screening cowpea germplasm for insect resistant sources, development of a scouting methodology for the management of insect pests, and determining the minimum insecticide application for cowpea. There have also been studies on maize streak resistance, resistance of varieties to stem borers, persistence of plant products on treated maize seeds, as well as screening of maize and cowpea varieties for resistance to storage pests.

Weed Science. Trials were conducted on the chemical control of *Chromolaena odorata*, chemical weed control in soybean, the effect of spatial arrangement on weed control in soybean, the evaluation of Roundup dry formulation, and the evaluation of legumes for use as in-situ mulch.

Virology. This has involved integrated pest management surveys, cowpea international trials, and collaborative research with Clemson University, USA, to evaluate cowpea germplasm and multiple cropping systems.

On-Farm Research. Trials were conducted in seven study areas during the major and minor season: 71 in the Coastal Savannah zone, 194 in the Forest zone, 123 in the Transition zone and

104 in the Guinea Savannah. Issues studied included maize and grain legume varieties, intercropping, land preparation (no-tillage), weed control, insecticide spraying regimes, effect of planting date, production and storage, and control of diseases and insect pests. As of 1995 all demonstrations were transferred to the Department of Agricultural Extension Services (DAES). Due to budget restrictions the number of trials in the minor season was reduced.

Training, Communication and Publications. The main activities of the Training, Communication and Publications Unit (TCPU) during 1995 were:

- No-Tillage Course (May 30-31) conducted for extension workers in collaboration with DAES, Dizengoff, Monsanto and SG 2000.
- Two Workshops on Poster Preparation (April and June, two days each).
- Maize and Legumes Seed Production course for Beninois (July 10-22) sponsored by SG 2000.
- International Crop Management Research Training (CMRT) Course in Seed Production Tecniques (August 14-25).
- Development of Agricultural Extension Materials Course (July).

The latter two courses were conducted in collaboration with WECAMAN and IITA. International CMRT Course in Roots and Tubers (September 28 - October 12). A total of eight international courses have been conducted by CRI since 1993. The TCPU was heavily involved in the preparation and conduction of the planning workshops and training sessions in seven study areas. The TCPU also participated in the organization of the First National Food and Industrial Crops Workshop, October 1995. Finally, the TCPU organized a field day for DAES (July 8, 1994) to show the Demonstration Farm (roadside) at the Fumesua Research Station to 115 participants.

Socio-Economics. Work included recovery of secondary information for re-defining recommendation domains, characterization of cropping systems in each recommendation domain, marketing studies on maize and cowpea, and determining the socio-economic feasibility of technology. Links were also established with other socio-economic research groups, specifically in work on gender analysis. Village level studies on gender issues were conducted in the Wenchi district. Exploratory survey on soybeans, pineapple and rice production in various part of the country were conducted. Finally, work included participation in the Roots and Tubers Project, the Inland Valley Rice Project, integrated pest management, and the evaluation of SG 2000 extension test plots.

Biometrics. The Section was maily involved in the analysis of 1994 minor season and 1995 major seaon trails.

Visitors to the Project

Representatives from a range of national and international scientific and agricultural development institutions observed GGDP activities. Among the important visitors were Dr. N. Borlaug, President of SG 2000; his Excellency Mr. John Schram, the Canadian High Commissioiner to Ghana; the Hon. Minister for Environment, Science and Technology, Dr. Christiana Amoako-Nuama (Ms) and Prof. W.S. Alhassan, Director General of CSIR; Drs. E. Heinrichs and D. Johnson, from WARDA; the Cowpea IPM Team from Clemson University; the NARP/NAEP World bank Team (implementation mission), headed by Dr. S.R. Singh; and Dr. R. Tripp, Former Asst. Director of CIMMYT Economics Program and presently working with ODI, UK.

Major Events

Important events during 1995 were included:

- The Second National Food and Industrial Crops Workshop (Kumasi, October 25 to 27, 1995) with attendance of about 600 policy makers, researchers, extensionists and farmers (former National Maize and Legume Workshop).
- The Crop Management Research Training Course on Seed Production.
- The Extension Material Development, both courses sponsored by WECAMAN and assisted by IITA.
- The final Report of the Mid-Term Evaluation of the GGDP, Phase III conducted by a Review Team contracted by CIDA.
- The Planning Worshops and Training Sessions conducted in seven study areas by the Project in collaboration with MOFA. This was the first time that other important crops (roots and tubers, plantain, vegetables and rice) and livestock were covered in the workshop in addition of maize and grain legumes which had been the normal procedure in previous years.

Project Termination

This project ended in 1996. The CIMMYT technical advisor completed his term of service and left the GGDP in 1995.

Regional Maize Program for Central America and the Caribbean

*J. Bolaños and Jerome Fournier**

The PRM is a collaborative network of maize researchers from nine countries and CIMMYT with full-fledged governing statutes and bodies and funding from Swiss Development Cooperation (SDC). CIMMYT acts as the executing technical agency from regional offices in Guatemala and San José. Research is focused on germplasm development, sustainable crop management research, adoption and impact socioeconomic studies, in-service and regional training, participation in scientific fora and annual publication of research results. Important regional trends include: 1) many projects aim to "improve agricultural sustainability for resource-poor farmers" (many funded by SDC); 2) a continuing decline in the capacity of traditional, public agricultural research programs; and 3) an increasing role and presence of non-government organizations (NGOs).

Specific achievements in 1995 include:

1. Selection and appointment of a new Regional Coordinator--Elio Durón, Ph.D. Tropsoils-NCSU, based in Honduras;
2. Posting of a Swiss associate expert (Jerome Fournier) in Guatemala to promote validation and links to NGOs;
3. An active role in acquiring supplementary Swiss funds to support CIMMYT socioeconomic activities in the region; and
4. The promotion of a common agenda and effective inter-institutional partnership and participation in the system-wide ecoregional hillside initiative.

For 1995, the PRM programmed 257 activities in breeding, agronomy and socioeconomics (see POA-96). Although more than 75% of programmed activities were executed, reliable results were obtained from about half. The PRM continued to perform with high standards of quality, efficiency, productivity and professional and personal behavior, providing a high sense of pride to CIMMYT. Undoubtedly, the PRM is considered one of the best research 'networks' in Central America. Future directions call for increased inter-institutional collaboration on strategic agronomic research and increased links with selected NGO's and OPD's for increased validation, transference and impact of generated PRM technologies.

Germplasm Development

This comprised 120 activities; around 40% of the collaborative budget.

* Appointed in 1995.

Hybrid Development: White and Yellow Maize. 100-150 S_4-S_8 inbreds were evaluated *per se* across 3-5 locations. 40-45 elite lines were topcrossed to two PRM hybrids. 80-100 topcrosses were evaluated in 6-8 locations to identify superior 25-30 crosses. 3-4 hybrid yield trials were conducted across 3-4 locations. A trial of 20-30 entries was evaluated across 10-15 locations, as part of the uniform trials of the Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos y Animales (PCCMCA); several recombination, crossing and selfing blocks as well as dialels were planted (source germplasm both CIMMYT and PRM).

PRM hybrids outyield most commercial entries and participating institutions are generating hybrids relatively quickly through collaborative breeding. New experimental hybrids will be released soon.

Drought Tolerance: S_2 Recurrent Selection in TS6 x BS-19 (Sint. Reg. Sequía). We recombined C_5 Sint. Reg. Sequía and increased seed for testing. 12-15 variety trials comprising white and yellow early materials (mostly OPVs) were evaluated. We also evaluated topcrosses from S_4s TS6. The latest cycle of Sint. Reg. Sequía has been formed, increased, validated, and will also be released in several countries.

Corn Stunt Tolerance: Recurrent Selection in P73 (Nicaragua) and P76 (El Salvador) Under High Levels of Natural Infestation. Populations C5 P73 and C_3 P76 (latest selection cycles) were formed, advanced, recombined, and merged. We formed and advanced experimental synthetics from P79 and Cesda-88, and from Pop76xMIR x Pop21xAntigua. New experimental varieties (EVs) from P73 and P76 which outperform the commercial varieties NB-6 (P73) and NB-12 (P76) are soon to be released and both white populations have been merged. Experimental synthetics from P79 and Cesda-88 with improved performance have also been formed. Adoption studies reveal 80% of farmers in the Pacific area of Nicaragua use NB-6 or NB-12.

Ear-rot Tolerance: Recurrent Selection in Population RPM. We evaluated 225 S_1 lines from Population *Resistencia a Pudrición de Mazorca* (RPM) x TuxPBC17 under natural disease pressure and controlled inoculation; we also formed experimental synthetics and conducted cycles-of-selection trials.

Research for Sustainable Maize-Based Systems

This comprises 120 activities; around 40% of the collaborative budget.

Density x N Responses. We tested 3-4 elite cultivars x 1-2 N levels x 2-3 densities x 3 replications in 5-row plots of 5 m each at 2-3 locations in each of 4-6 PRM countries. The density optima were higher for hybrids than for OPVs. There was no apparent difference between 75 or 150 kg N/ha for most PRM germplasm, and most cultivars do not tolerate densities above 8.0 pl/m^2, and the method of Duncan has proven ineffective.

Interseeding, Relay and/or Rotation of Legumes into Maize Production Systems. We planted 12-15 trials evaluating *Phaseolus* and/or *Vigna* spp. intercropped with maize in local designs. There were 10-12 uniform regional trials evaluating maize-legume topological arrangement (doble-surco). We conducted 15-20 adaptation (validation) trials with canavalia planted in alternate maize rows. PRM researchers also performed 2-3 strategic agronomic trials (factorial of 3 rotation systems [no legume, canavalia, mucuna] x 2 tillage [incorporated vs no-incorporated] x 3 N levels [0, 75, 150 kg N/ha] x 3 management [foliage only, roots only, all residue] x 3 replications) maintained for the 2nd and 3rd year at the same sites.

Through the above, we obtained local information on *Phaseolus* and *Vigna* spp. that adapt to intercropping with maize. Our work validated the use of double-rows of maize intercropped with legumes and of simultaneous intercropping of alternate rows of canavalia with maize. Finally, we obtained agronomic information of regionwide value on the N-substitution and fodder value of legumes.

Mulch and N Interactions. These comprise strategic long-term trials, the oldest of which is in its 4th sequential year. We are studying the response of maize to combinations of amounts and types of mulch x inorganic N levels: 1) mulch x N (4 trials of 2x2 = 0, 5 t/ha mulch x 0, 100 kg N/ha and 6 trials of 3x3 = 0, 5, 10 t/ha mulch x 0, 75, 150 kg N/ha); and 2) 5 trials with 5 t/ha of types of mulch (maize, legume, or 50:50) in factorial combination with 0, 75 and 150 kg N/ha. As a result, we are obtaining information on maize responses to organic and inorganic sources of N and their interactions that will be of use regionwide. We have evidence of a strong negative mulch x N interaction (when N>75-100 kg yield increases 20 kg per ton of mulch, but at low N levels yield is depressed 100 kg per ton of mulch).

Efficient Nutrient Use in Maize Production Systems. Repeats of studies conducted in 1994, these comprised 12 trials evaluating the response of maize to urea-N fractionating. Data show that average uptake is only about 25% of applied urea-N (at doses of 100 kg N/ha), and subsurface application in three doses improves efficiency only by 10% (300 kg grain yield gain). For each kg of urea-N applied (over the range 0-100 kg N/ha), 30 kg of grain are produced. Ear-leaf SPAD values at flowering have high predictive value for grain yield.

Products

Varietal Releases and Source Germplasm. The following materials will be released in 1996:

- Sint. Reg. Sequía in Honduras and Nicaragua.
- Ac8328 BN C5 in Panamá substituting Guararé (Ac8128).
- Omonita 9243 substituting B-102 in Honduras.
- Hybrids H-30 in Honduras and HN-911 in Nicaragua.
- PRM germplasm (progenies, inbreds, bulks, etc.) with tolerance to corn stunt disease and drought have been used by other programs.

Prototype Technologies to Increase Productivity While Conserving the Resource-Base

- Use of simulation modeling to evaluate agronomic strategies in selected maize production systems.
- Information on responses to density and N for many PRM cultivars.
- Recommended practices for interseeding, relay and/or rotation of legumes (canavalia, mucuna, etc.) in maize-based systems.

- Identification of *Phaseolus* and/or *Vigna* spp. for intercropping with maize in specific regions.
- Strategic agronomic information on relationships, responses and interactions between amounts and type of mulch and applied inorganic N (dataset with >25 locs).
- Identification of a strong negative interaction between mulch and N (mulch depressing yields under low N).
- Robust calibration of SPAD chlorophyll meters across a wide range of maize leaves, and identification of a strong and positive relationship between ear-leaf chlorophyll concentration at flowering and final grain yield (19 locs).
- The finding that crop uptake of applied urea-N averages 25-30% and can be improved 10% with sub-surface placement.
- The development of strategic agronomic information and robust recommendations when linked to environmental, biophysical and socioeconomic characterization of maize production systems.

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Specific Achievements

- SDC's manifest satisfaction with their investment in the PRM (presentation to SDC's Director, Walter Fust)
- PRM's active role in the promotion of a common agenda and effective inter-institutional partnership and participation in the system-wide ecoregional hillside initiative.
- Successful negotiation with SDC for relocation of the Regional Coordinator--Elio Durón—to Guatemala (approved U$50k)
- JB had an active role in acquiring supplementary Swiss funds to support CIMMYT activities in the region (G.Sain's);

For 1996, the PRM programmed 323 activities in breeding, agronomy and socioeconomics (see POA-96). Although more than 75% of programmed activities were executed, reliable results were obtained from about half.

Germplasm Development

This comprised 144 activities, around 40% of collaborative budget.

Hybrid Development. (applies to both white and yellow sets) 100-150 S_4-S_8 inbreds evaluated per se across 3-5 locations; 40-45 elite lines topcrossed to two PRM hybrids; 80-100 topcrosses evaluated in 6-8 locations to identify superior 25-30 crosses; 3-4 hybrid yield trials across 3-4 locations; uniform PCCMCA trial (20-30 entries) across 10-15 locations; several recombination, crossing and selfing blocks as well as diallels (source germplasm both CIMMYT and PRM). PRM hybrids outyield most commercial entries and participating institutions are generating hybrids relatively fast through collaborative breeding schemes. New experimental hybrids will be released soon.

Drought Tolerance. Focus on S_2 recurrent selection in TS6 x BS-19 (Sint.Reg.Sequía). We recombined C_5 Sint. Reg. Sequía and multiplied seed for testing. More than 30 validation trials involving Sint. Reg. Sequía were conducted in Guatemala, Honduras, and Nicaragua. Sint. Reg. Sequía has been released as NBS (Nic. Blanco Sequia) in Nicaragua and will be released next year in Honduras.

Corn Stunt Tolerance. Recurrent selection was conducted in P73 (Nic) and P76 (Salv) under high levels of natural stunt infestation. We advanced C_5 P73 and C_3 P76 (latest selection cycles) to F_2, recombined and merged Pop. 73 and Pop. 76 into PRAC's, and evaluated synthetics from Pop. 79 and Cesda-88 in Panama, where the disease has spread. Results: a) new EV's from P73 and P76 outperform commercial NB-6 (P73) and NB-12 (P76) soon to be released; b) experimental synthetics from P79 also were formed.

Ear-Rot Tolerance. We conducted recurrent selection in RPM (Resistencia a Pudrici6n de Mazorca). Honduras assumed leadership for this research. Seed of all experimental synthetics and populations was regenerated and evaluated extensively across the region. Data will be presented next year.

Research for Sustainable Maize-Based Systems

This comprised 163 activities, around 40% of collaborative budget.

Density x N Responses. Elite 2-4 PRM cultivars were sown at 2-3 locations in each of 4-6 PRM countries: 3-4 elite cultivars x 1-2 N levels x 2-3 densities x 3 reps, plots 5 rows x 5 m, 2-3 locs each. Density optima were higher for hybrids than OPVs, with no apparent difference between N levels for most PRM germplasm; most cultivars do not tolerate densities above 8.0 pl m^2, and the method of Duncan has proven ineffective.

Interseeding, Relay and/or Rotation of Legumes into maize. Activities in 1996: a) 12-15 trials evaluating *Phaseolus* and/or *Vigna* spp. intercropped with maize in local designs; b) 10-15 validation trials with canavalia planted in alternate maize rows; c) the PRM initiated evaluation of legume cover crops for highland maize systems, 4 trials conducted (2 in Guatemala and 2 in Honduras); d) 2-3 strategic agronomic trials (factorial of 3 rotation systems (no legume, canavalia, mucuna) x 2 tillage (incorporated vs no-incorporated) x 3 N levels (0, 75, 150 kg N/ha) x 3 management (foliage only, roots only, all residue) x 3 reps maintained for 2nd and 3rd year at same sites. Results include: a) local information on *Phaseolus* and *Vigna* spp. that adapt to intercropping with maize; b) validation of simultaneous intercropping of alternate rows of canavalia with maize; c) information on legumes adapted to intercropping with maize in highland environments, d) strategic agronomic information of N-substitution and fodder value of legumes.

Mulch and N Interactions. These are strategic, long-term trials; the oldest is in the 5th sequential year of evaluation. In 1996, we tested the response of maize to combinations of amounts and types of mulch x inorganic N levels : a) mulch x N (3 trials of 2x2 = 0, 5 t/ha mulch x 0, 100 kg N/ha and 6 trials of 3x3 = 0, 5, 10 t/ha mulch x 0, 75, 150 kg N/ha); and b) 5 trials with 5 t/ha of types of mulch (maize, legume, or 50:50) in factorial combination with 0, 75 and 150 kg N/ha. As a result, we obtained strategic agronomic information on maize responses to organic and inorganic sources of N and their interactions; strong negative mulch x N interaction (when N>75-100 kg yield increases 20 kg per ton of mulch, but at low N levels yield is depressed 100 kg per ton of mulch).

Efficient Nutrient Use in Maize Production Systems. These comprise urea-N trials. Activities in 1996 involved 16 trials evaluating the response of maize to urea-N fractionating; activities started in maize-legume intercrop systems for improving P recycling (4 activities in collaboration with CIAT-Hillsides) . We found that: a) average N uptake is only around 25% of applied urea-N (at doses of 100 kg N/ha), and subsurface application in three doses improves efficiency only by 10% (300 kg grain yield gain); b) 30 kg of grain are produced per each applied kg of urea-N (over the range 0-100 kg N/ha); c) ear-leaf SPAD values at flowering have high predictive value for grain yield.

Products

Variety Releases and Source Germplasm. Releases included a) Sint. Reg. Sequía in Nicaragua; b) release of DICTA-Guayape (Omonita 9243) and hybrid H-30 in Honduras; c) release of hybrids HA-46 and HA-48 in Guatemala; d) and PRM germplasm (progenies, inbreds, bulks, etc.) with tolerance to corn stunt disease and drought have been increasingly demanded by other programs.

Prototype Technologies to Increase Productivity While Conserving the Resource-Base. These included: 1) use of simulation modeling to evaluate agronomic strategies in selected maize production systems; 2) response to density and N for many PRM cultivars; 3) recommended practices for interseeding, relay and/or rotation of legumes (canavalia, mucuna, etc.) in maize-based systems; 4) identification of *Phaseolus* and/or *Vigna* spp. for intercropping with maize in specific regions; 5) strategic agronomic information on relationships, responses and interactions between amounts and type of mulch and applied inorganic N (dataset with >25 locs); 6) identification of a strong negative interaction between mulch and N (mulch depressing yields under low N); 7) robust calibration of SPAD chlorophyll meters across a wide range of maize leaves, and identification of a strong and positive relationship between ear-leaf chlorophyll concentration at flowering and final grain yield (19 locs); 8) crop uptake of applied urea-N average 25-30% and can be improved 10% with sub-surface placement; 9) develop strategic agronomic information and robust recommendations when linked to environmental, biophysical and socioeconomic characterization of maize production systems.

Selected CIMMYT Maize Publications

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General Interest and Research Reports

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