UNDP-CIMMYT Global Research Project

UNDP - CIMMYT
L RESEARCH PROJECT GLO
(Phase III)

CIMMYT

Centro Internacional de Mejoramiento de Maíz y Trigo
International Maize and Wheat Improvement Center
Lisboa 27, Apdo. Postal 6-641, 06600
México, D. F. México

UNDP - CIMMYT

GLOBAL RESEARCH PROJECT GLO - 75 - 007

(Phase III)

CIMMYT PROGRESS REPORT

to

August 1977

REPORT OF UNDP - CIMMYT GLOBAL RESEARCH PROJECT

CONTENTS | Page

REPORT OF UNDP - CIMMYT GLOBAL RESEARCH PROJECT GLO - 75 - 007

(Phase III)

August 1977

I.- INTRODUCTION

The progress made in the various aspects of the UNDP-CIMMYT Global Research Project "Research and training in the development of High Lysine Maize" during the period September 1976 to August 1977 is presented in this report. The major emphasis in CIMMYT's high protein quality maize program has been to exploit genetic modifiers of o_2 locus to remedy undesirable kernel characteristics and improve the agronomic performance of opaque-2 converted maize. Good progress has been made in this direction. We now have maize opaque-2 materials that are very similar in kernel appearance and performance to normal materials. A number of quality protein maize varieties exhibited performance in terms of yield and production that was equal or even superior to normal maize varieties or hybrids used as checks in these trials.

Considerable progress has also been made in improving the stability of the hard endosperm o_2 maize kernel in different environments. Wider scale testing of the superior quality protein varieties is necessary to know whether the levels of ear rot and insect resistance and stability of hard endosperm achieved to date will be sufficient to allow commercial production of these types. CIMMYT scientists are quite hopeful that newly developed opaque-2 materials will soon be able to fulfil the expectations to some extent that had been raised following the discovery of the biochemical and nutritional effects of the opque-2 gene.

II. - GENETIC AND BREEDING RESEARCH

A. INTRODUCTION

Considerable interest exists all around the world to upgrade the quality of protein in maize and other major cereal crops to improve their nutritional value. In some crops such as maize, barley and sorghum the quality of protein can be enhanced genetically by manipulation of known mutant genes while in other crops the search for such mutant genes is still underway.

In maize only half of the actual protein content present in the endosperm is of importance from the nutritional standpoint. This is so because roughly 50% of the protein of maize endosperm is constituted by zein fraction which practically lacks lysine in its amino-acid profilie. The mutant genes that affect the quality of protein in maize can reduce the synthesis of zein in protein thereby resulting in increased proportion of other protein fractions that have good levels of lysine and tryptophan. This alteration in the proportion of different protein fractions in maize endosperm is thus responsible for giving a boost in protein quality in maize.

Breeding for improved protein quality of maize endosperm through the use of different mutant genes is underway for the past thirteen years. Though several genes are known to increase the levels of lysine and tryptophan in protein to almost double, only opaque-2 gene has been used extensively to convert normal maize genotypes to opaque-2.

It may be of interest to point out some of the developments and the progress that has taken place ever since the biochemical effects of opaque-2 gene were first discovered. Historically, the years 1963-1964 generated considerable interest among maize breeders all around the world to develop maize materials with superior protein quality of maize endosperm. Straight opaque-2 versions of normal open-pollinated varieties and the parental inbred lines involved in hybrid combination were obtained during the first 6-7 years of intensive research efforts. Some of these materials moved into commercial production in the early seventy's in different countries but by and large these materials failed to give comparable performance with their normal counterpart maize materials.

Problems confronting opaque-2 maize are known for a long time but serious considerations that something must be done to solve these problems was realized much later. Also as soon as some of the opaque-2 materials moved into commercial production in some countries, the importance of problems associated with opaque-2 maize became still more evident. Some of the problems that need to be high-lighted include: 1) Reduced kernel weight, 2) unacceptable kernel appearance, 3) greater vulnerability to ear rot organisms, 4) more infestation by weevils during storage, 5) slower drying of grain following physiological maturity.

The research thrust to solve the aforesaid problems is underway in many breeding programs. Though minor problems still exist, a major break-through in remedying some of these problems has already been made. Also a series of other developments have taken place in the last 5-6 years and as such I consider this period to be of tremendous significance in breeding of quality protein maize materials for the following reasons:

1) Seed increase and commercial production of opaque-2 materials started in some countries during this period.

2) The relative importance of different problems affecting opaque-2 maize were further assessed.

3) Attempts to solve problems associated with quality protein maize were initiated.

4) Basic information on the effects of opaque-2 gene was gathered in greater depth.

5) Genetical and biochemical information of opaque-2 modifiers in modifying undesirable effects of opaque-2 gene was accumulated.

6) Interaction of opaque-2 gene with other endospermic mutants was studied to solve problems confronting opaque-2 maize.

7) Refinement in analytical techniques and new methods to detect the presence of protein quality were devised.

8) Biochemical laboratories were established in many national programs to support breeding programs to develop quality protein maize materials.

9) Biological tests on acceptable type opaque-2 materials were continued and produced encouraging results that protein quality was being maintained and was of superior biological value.

In breeding opaque-2 materials with acceptable characteristics, one must consider in the first place as to what kinds of materials can be accepted in different countries. Depending on the need, one must, therefore, put emphasis on the following points:

i) In areas where soft opaque-2 materials can be accepted without any problem, the major emphasis in the program should be placed on increased yield and greater resistance to ear rot organisms.

ii) In countries where the interest lies mainly in the soft floury types, the breeding focus should primarily be on ear rot resistance. Use of Ninhydrin test to sort out quality protein segregates should be used extensively to accelerate the development of quality protein opaque-2 versions.

iii) In areas where hard flints and dents are preferred, the emphasis should be to develop hard endosperm opaque-2 materials comparable in performance to their normal counterparts. The merits and demerits of various breeding approaches should be considered before their use in the breeding program.

The major emphasis in CIMMYT's maize program has been to exploit genetic modifiers of opaque-2 locus to remedy undesirable kernel characteristics and the agronomic performance of opaque-2 converted materials. Considerable progress has already been made in developing quality protein materials that approach more nearly in kernel appearance and performance to normal materials. It is hoped that newly developed opaque-2 materials can once again revive the same enthusiam and interest that existed in the first few years following discovery of the biochemical effects of the opaque-2 gene.

B. OBJECTIVES

In the development of quality protein opaque-2 materials, the major emphasis was placed on the following aspects:

i) Convert all maize materials in CIMMYT's maize improvement program to opaque-2 as rapidly as possible.

ii) Continue development and improvement of broadbased opaque-2 source populations of tropical, temperate and highland origin.

iii) Improve yield, agronomic characteristics and adaptation of advanced unit opaque-2 populations over a range of environments.

iv) Continue emphasis on accumulation of favorable genetic modifiers in opaque-2 materials at all stages of maize improvement.

v) Place major thrust in future on stabilizing modifier genes over a range of environments through multilocation, progeny tests.

vi) Select for ear rot resistance and better stalk quality through artificial inoculation with ear and stalk rot organisms.

vii) Increase emphasis on the transfer of opaque-2 gene into floury-1 backgrounds to serve areas in the Andean region.

viii) Develop and study the potential of sugary-2/opaque-2 composite for future use.

ix) Develop stronger international cooperation in testing and evaluation of materials.

x) Encourage germplasm distribution and utilization by the national programs.

A detailed account of the progress that has been made on the above mentioned aspects is discussed in the following sections:

C. CONVERSION PROGRAM

Efforts to obtain opaque-2 versions of all normal maize materials in the advanced and back-up units of maize improvement program were continued. Also, some opaque-2 versions that had good kernel appearance were backcrossed to transfer improvements made in normal populations to the counterpart opaque-2 versions. Most of the conversions, in general, look fairly good with respect to kernel appearance and other agronomic characteristics. It is probably time now to concentrate and screen for those families that are rather stable for hard endosperm opaque-2 character in different environments. The progress that has been made with respect to each material individually will be discussed in the following sub-sections.

i) Conversion of advanced unit materials

From the harvest of 1976A at Poza Rica and Tlaltizapan, 3594 ears were saved from 19 different advanced unit materials of tropical and subtropical origin. The selected ears were shelled individually and the best looking vitreous segregates were sorted out from each ear separately for planting during 1976B The materials during this cycle were handled differently in different ways. Opaque-2 versions of subtropical type materials such as Amarillo Subtropical, Blanco subtropical, Eto x Illinois and Compuesto de Hungria were handled in a full sib manner. Attempt was made to cross plants from each family to as many other families as possible. Of the tropical conversions, four materials such as Tuxpeño-1 H.E.o_2, Blanco Cristalino H.E.o_2, Ant. x Republica Dominicana H.E.o_2, and Eto Blanco H.E.o_2 were handled in a half sib recombination block, three materials namely La Posta H.E.o_2, Tuxpeño Caribe H.E.o_2 and Amarillo Cristalino H.E.o_2 were subjected to selfing; and others were handled in a manner to generate new set of full sibs resulting from plant to plant crosses among families. The number of ears harvested from each population is given in Table No. 1. Only hard endosperm opaque-2 ears free of ear rots were selected from good type plants. As can be seen from the table a total of 2,857 ears were saved from 1976B harvest. These ears were shelled individually and seed prepared exactly in the same manner as in 1976A for planting during 1977A. Ten kernel sample of each family from all the materials was sent to the laboratory for analyses. The data coming from the laboratory was used in rejecting families before pollination.

The materials during 1977A were also handled in different ways. S_1 lines developed from Tuxpeño Caribe and La Posta were handled separately in two separate H.S. recombination blocks. Also two other materials namely Tuxpeño-1 and Eto Blanco H.E.o_2 were handled in two separate half sib crossing blocks. Rest of the advanced unit opaque-2 conversions were handled in a full sib manner. Very intense selection for plant and ear type was practiced at harvest time. A total of 3,474 ears were saved at harvest time to continue further selection and improvement in these materials.

The harvest of 1977A was really good and in fact very encouraging so far as the quality and appearance of ears was concerned. For the first time, it was noticed that in some of the materials there was not a single ear that was segregating for soft endosperm. It was felt that in many opaque-2 converted materials, opaque-2 modifiers have probably accumulated to a fairly highly frequency. It was, therefore, considered desirable to follow a different strategy during 1977B to put a strong pressure for screening families that have stable modifiers over a number of environment. So it was decided to plant hard endosperm opaque-2 segregates from each family in at least two locations. The families from tropical materials were planted in Poza Rica and Obregon while those from subtropical materials were planted at Tlaltizapan and Obregon. At flowering time, the pollination will be made only in Poza Rica and Tlaltizapan. Reckprocal plant to plant pollinations will be made within each family to capitalize on plant and ear variation within each family. At harvest, the pollinated ears from only those families that show stability for kernel hardness will be saved for next season planting. This new strategy will help to achieve the following objectives:

1) Planting same families in two or more locations will permit screening and selection of families that are stable for vitreous endosperm.

2) Will help in reducing the bulk of experimental material that has been built up in the last 4-5 years.

3) While families for modified endosperm character are being identified reciprocal plant to plant sib pollinations within a family will be helpful in capitalizing within family variation for height, ear rots and kernel characteristics.

4) This procedure will help in increasing area of adaptation of these materials to other environments.

A number of opaque-2 versions of different advanced unit materials were also backcrossed to corresponding normal populations. The number of backcrossed ears saved from each cross is given in Table 2. These backcrossed ears were planted on family basis next to hard endosperm opaque-2 families from the same material. Bulk pollen from the latter was used to pollinate the BC_1 families. At harvest good segregating ears were saved. In most of the selected ears there was no segregation for soft opaque-2 kernels. Selected ears were shelled separately and from each ear normal and modified opaque-2 kernels were sorted out. One hundred kernel weight of normals and modofied opaque-2 kernels from each ear was recorded and compared. Based on this data, some families were rejected where the difference between opaques and normals was over 10%. Kernel weight, volume and density comparisons of normal and hard endosperm opaque-2 segregates recovered from segregating populations are given in

Tables 3 and 4. The number of families rejected on the basis of weight comparisons are given in Tables 5 and 6. In general it can be seen from tables 3 and 4 that opaque-2 segregates were lower in kernel weight, volume and density. Variation, however, exists and it will ,therefore, be advisable to select families from the higher kernel weight class where the differences between opaques and normals are the least.

ii) <u>Conversion of back-up materials</u>

Conversion of all tropical and temperate gene pools to hard endosperm opaque-2 is underway. Some conversions have reached as far as F_4 or F_5 generation. All tropical opaque-2 conversions are being handled at Poza Rica. From the harvest of 1976A, 1,454 ears were saved. These ears were shelled individually and sorted out for good looking hard endosperm opaque-2 segregates. Selected segregates from each material were planted on family basis in 1976B. Four pools namely Pool 23 H.E.o_2, Pool 22, Pool 24, and Pool 26 were handled in half sib recombination separate blocks while in the rest of the pools plant to plant crosses were made between different families to generate full sibs.

From the harvest of 1976B at Poza Rica, 1,209 good looking ears with modified endosperm were selected. The selected ears were planted on family basis in 1977A. Plant to plant crosses were made between selected plants among selected families. At harvest, 1,144 ears were saved. The selected ears will be planted at Poza Rica and Obregon to select for modified endosperm stable families during 1977B.

Full sib ears saved from 1976A harvest at Tlaltizapan were planted on family basis during 1976B. Full sib crosses between selected plants among selected families were made. One hundred and ninety two selected ears were further advanced by one more generation in 1977A to continue improvement of kernel hardness and other agronomic characteristics. At harvest 486 vitreous ears were selected. These were shelled and good vitreous segregates were sorted out from each for planting during 1977B.

All the eight tropical pools were backcrossed during 1977A. The number of ears harvested from each backcross are indicated in Table 7. The BC_1 families from each cross will be planted by the side of hard endosperm opaque-2 families of the same pool in 1977B. The pollinations will be done in the same manner as indicated earlier for the advanced unit materials.

Four tropical early pools and four temperate pools have been formed recently. One or more sources of opaque-2 donors were crossed with these pools in 1976 or 1977. The number of ears saved from each cross are indicated in Table 8. The F_1 crosses with three temperate pools were advanced during 1977A. 209 F_2 segregating ears saved from three pools were shelled and sorted out separately for normal and opaque-2 segregates. One hundred kernel weight comparison of normals and opaques was also made to eliminate families with differences of the order of more than 10%. F_1 or F_2 families from these pools will be advanced to next generation in 1977B.

Conversion of highland gene pools to opaque-2 was continued. Excepting Pools 3 and 8, the emphasis in the highland materials has been to select for vitreous opaque-2 kernels. Most of the conversions from the highland pools so far do not have very good modifiers. A total of 2,095 F_2 families were planted during 1976 from different pools. Plant to plant crosses were made among different families. The number of ears selected from each pool is indicated in Table 9. Other than Pool 3 and Pool 8, intense selection was exerted on modified opaque-2 ears. In Pool 3 and Pool 8, the selection pressure was exerted on selecting ears with large kernels. The selected ears from 1976 harvest have been planted both at Batan and Toluca.

iii) Conversions of populations that are being selected for earliness, plant efficiency and adaptation.

Number of hard endosperm opaque-2 families saved from each population during different seasons is given in Table 10. Most of these materials excepting selección precoz look very good. The families from these materials have also been planted in Tlaltizapan and Obregon to exert more pressure for stability of genetic modifiers controlling kernel hardness in opaque-2 materials.

iv) The protein content and quality of opaque-2 converted materials.

The ears selected in each generation further undergo selection for best vitreous segregates that are available in each ear. In general 10 seeds from each family are analyzed for protein and tryptophan content. The families that do not meet the minimum acceptable levels are eliminated before pollination. This means the pollinations are restricted among selected families The mean values of families analyzed in each population from different cycles for both protein content and quality are given in Tables 11, 12, 13 and 14. It can be seen from these tables that mean values for protein and tryptophan in protein of hard endosperm opaque-2 versions were in general fairly good.

In some materials DBC analysis was made. The quality of protein in such materials has been indicated by quality index value which was calculated by dividing DBC value by % protein in the whole grain. Values above 3.5 represent good quality of protein. In Table 13, it can be seen that most of the materials analyzed by this method had good quality of protein.

D. DEVELOPMENT OF BROADBASED HARD ENDOSPERM OPAQUE-2 SOURCE POPULATIONS AND OTHER OPAQUE-2 MATERIALS AT BACK-UP STAGES OF DEVELOPMENT.

Intensive research efforts are underway for the last four years to develop hard endosperm opaque-2 materials with modifiers accumulated from a wide range of maize materials being grown in different areas of the world. The major emphasis in all such materials has been to increase kernel vitreosity while maintaining the same protein quality as that of soft opaque-2 materials. The pressure in these materials has been somewhat mild for other characters in the initial cycles but as these materials have already got fairly good kernel type and acceptable appearance, considerable pressure is now being exerted for all important agronomic traits, in addition to improving kernel vitreosity and maintaining protein quality. Also in some materials where kernel appearance has reached a point of acceptance, it is proposed to exert more pressure on the stability of opaque-2 modifiers responsible for changing soft endosperm to hard endosperm. A brief description and stage of development of some materials of tropical and temperate origin is given in Table 15.

i) White opaque-2 back-up pool.

This material has white flint and dent grain type with appealing hard endosperm texture. Two more cycles of genetic mixing were achieved in a half-sib crossing block during 1976B and 1977A at Poza Rica. Following each cyle of recombination, half-sib ears with good appearance were selected from short disease-free plants. Selection of modified opaque-2 kernels from each ear separately for next planting, and elimination of families with low protein quantity and quality was continued like the previous cycles.

This pool has been further broadened by the addition of some very good hard endosperm opaque-2 families identified from advanced and back-up conversions. These materials were added only as female rows in the recombination block of 1977A. The selected ears from these families will enter both as male and female families in the next season recombination block.

A number of good families from this pool were taken out and handled separately in the breeding nursery. In 1976A, 250 full sibs were developed in a reciprocal manner. These will be evaluated in progeny trials as described in a separate section.

ii) Yellow opaque-2 back-up pool.

This material is of yellow color with a mixture of flint and dent grain types. Two additional cycles of recombination were completed during 1976B and 1977A. The number of families saved after each cycle of recombination is given in Table 15. The ears were shelled individually and sorted out for best modified opaque-2 segregates from each ear separately for the next planting.

In addition to enhancing the frequency of favorable modifiers and maintaining the protein quality, a very intense selection pressure was exerted for shorter plant type both in male and female rows.

During the year 1977A, some additional hard endosperm opaque-2 materials were added into this pool only as female entries. The selected ears from these newly added materials will enter into next year's recombination block in exactly the same way as half-sib ears from the core of the pool.

A few outstanding families from yellow opaque-2 back-up pool after the third cycle of recombination were handled separately in the breeding nursery. Full sib pollinations were made during 1976A and 1976B and the ears saved in each generation are given in Table 15 . In 1977A, 108 full sib ears saved during 1976B were planted on family basis. Only short and disease-free plants in good families were self-pollinated. At harvest, a total of 82 good looking S_1 ears were saved for further selection in the next season. Since the harvested ears were fairly good, these have been planted at Poza Rica and Obregon during 1977B to put more pressure on the stability of modifiers.

iii) Yellow flint H.E.o_2 .

This material has resulted from the recombination of 207 hard endosperm opaque-2 families from five different materials. The recombinations were made in a full sib mating system among families of different groups. At harvest, 237 full sib ears were saved that had very good endosperm hardness. The selected ears have been planted both at Poza Rica and Obregon to screen families that are stable in modified endosperm character. Reciprocal plant to plant crosses within family will be made to exploit variation for plant and ear characteristics.

iv) Late white dent H.E.o_2

White dent hard endosperm opaque-2 families from a number of materials were genetically mixed to form this population. From the harvest in 1976B, 176 full sib ears were saved. The selected ears were subjected to second cycle of recombination during 1977A at Poza Rica. Following second cycle of recombination, 146 full sibs were selected which have been planted in Poza Rica and Obregon for increasing the frequency of favorable modifiers stable over environments.

v) PD(MS) 6 H.E.o_2 .

In terms of kernel hardness and appealing grain type, this is one of the best materials in the program. Following four cycles of half-sib recombinations coupled with simultaneous selection for modifiers and protein quality, 467 ears with good vitreous appearance were saved. These were planted on family basis at Poza Rica during 1976A to develop 250 reciprocal full sibs. These full sibs were tested in different locations within Mexico. Based on the performance of these families, the selected ones will give rise to IPTT-38.

vi) CIMMYT H.E.o_2.

This is another one of the best looking materials in the quality protein program. Genetically this represents a combination of so many different hard endosperm opaque-2 materials. Also, with respect to genetic modifiers this is probably more broadbased material in the program. Like PD(MS)6, this material has undergone four cycles of recombination to improve the frequency of favorable modifiers without sacrificing protein quality. Development of full sibs and their evaluation in progeny trial are discussed separately in population improvement section. This material may either give rise to new IPTT or may replace the old IPTT-39.

vii) Temperate x Tropical H.E.o_2.

In subtropical-temperate program, this is perhaps the most advanced opaque-2 population. This has excellent plant type, good yielding ability and acceptable ear and kernel characteristics. Two additional cycles of recombination were achieved in a half-sib crossing block during 1976B and 1977A. The number of half-sib ears saved in each cycle of recombination is given in Table 15. The harvested ears from 1977A cycle have been separated into flint and dent groups. These have been planted into two separate recombination blocks during 1977B. Also, the half-sib families from flint and dent groups have been planted at Poza Rica and Obregon for observation to examine the stability of modifiers and reaction to some of the leaf diseases that normally do not occur at Tlaltizapan.

Good families from this population are also being handled separately in a full sib selection scheme. This selected fraction of Temperate x tropical H.E.o_2 population may give rise to new advanced unit population.

viii) Highland opaque-2 materials in the back-up stages of the program.

A number of highland composites and other highland opaque-2 materials have been developed over the past few years. Three highland opaque-2 composites namely Composite I, High altitude opaque-2 Composite and Puebla opaque-2 Composite completed the fourth cycle of recombination during 1976. The number of families involved in recombination in these materials is given in Table 16 . The half-sib ears selected from the fourth cycle of recombination have been planted both at Batan and Toluca to undergo fifth cycle of genetic mixing and to increase adaptation of these materials. Further since two of the highland composites are very similar in plant type, maturity and ear characteristics, 242 families of Composite I and 174 families of high altitude o_2

composite have been planted in the same recombination block to achieve the fifth cycle of mixing and selection.

In addition to the above composites, a new composite namely highland modified opaque-2 composite was formed from F_2 hard endosperm opaque-2 families identified from the conversion of different highland pools to opaque-2. From the first cycle of recombination in Batan, 205 ears completely modified or at least segregating for modified kernels were saved. The vitreous segregates were sorted out very carefully from each ear separately and these have been planted both in Batan and Toluca to undergo second cycle of mixing.

For very high altitude areas above 2,500 meters, there is a need for some early opaque-2 materials. The cross of Puebla o_2 composite with Barraza was made with this objective in mind. The F_1 was advanced to F_2 at Toluca. From 200 selected segregating ears, opaque-2 kernels were sorted out and planted in a half-sib crossing block at Toluca during 1976. A total of 157 F_3 H.S. ears were selected which have been planted at Toluca in 1977 to undergo another generation of mixing and selection for earliness and other agronomic characters.

A number of modified hard endosperm opaque-2 families are also being handled from a number of materials by full sib crossing. The number of families planted in each one of these materials is given in Table 16. Sooner or later, these materials will be merged with other appropriate materials.

ix) Protein content and quality of back-up opaque-2 materials.

The number of families analyzed for protein and tryptophan in protein in several opaque-2 materials at back-up stages of the program is given in Table 17. The mean values for protein and tryptophan in protein are also given in the above table. It can be seen from this table that the mean of analyzed families had a protein content above 7% and tryptophan in protein .70% and above in endosperm.

E. POPULATION IMPROVEMENT PROGRAM.

During 1976A at Poza Rica, 250 full sib families were developed in four opaque-2 populations namely Tuxpeño opaque-2, PD(MS)6 H.E.o_2, CIMMYT H.E.o_2, and White opaque-2 back-up pool. The full sibs plus six check entries were tested in a 16 x 16 simple lattice with 2 replications at three locations within Mexico during 1976B (Table 18). The performance of 250 full-sibs from each of the four populations is presented in Table 19.

i) PD(MS)6 H.E.o_2.

On the basis of progeny trial data, 93 full sib families were selected. The mean of selected families showed a superiority of 8.17%, 9.62%, 11.37% and 9.97% in Poza Rica, Tlaltizapan, Obregon, and across location data respectively. The mean of selected families was 1-2 cms. shorter and a day earlier than the mean of tested population.

The selected families were planted in 1977A at Poza Rica to generate new set of 250 reciprocal full sibs. 250 full sibs along with six checks have been sent out to six different countries including one in Mexico as IPTT-38.

ii) CIMMYT H.E.o_2.

Considering grain yield, plant height, kernel hardness and other agronomic characters, 96 full sib families were selected based on the data of three locations. The mean of selected families showed selection differential of 8.62%, 7.56%, 12.69% and 9.66% in Poza Rica, Tlaltizapan, Obregon and across location data respectively. With regards to plant height and days to flower, the mean of selected families was 2-3 cms. shorter and about one day earlier than the mean of tested families.

The selected families were planted in Poza Rica during 1977A to generate a new set of 250 full sibs. It was interesting to note at harvest that not a single ear in this population was segregating for soft endosperm. The new full sibs have been planted in progeny trials within Mexico at three locations (Table 20). Based on the progeny trial data, the selected families may replace old IPTT-39.

iii) White opaque-2 bakc-up pool (full sibs).

The mean of 250 tested families for yield and other characters is given in Table 19. Based on the performance of 250 families, 99 full sibs were selected. The mean of selected families showed grain yield superiority of 7.54%, 10.92%, 8.30% and 9.12% over the mean of tested families in Poza Rica, Tlaltizapan, Obregon and across location data respectively. The selected families were also on the average about one centimeter shorter and a day earlier.

The selected families were used to generate new 250 full sib families in Poza Rica during 1977A. The families of this material have been sent out to six different locations in replacement of white hard endosperm opaque-2 (IPTT-40). The distribution of progeny trials is given in Table 20.

iv) Tuxpeño opaque-2.

This is the only soft opaque-2 material in the tropical-lowland program. The full sib families generated in Poza Rica during 1976A, were tested at three locations within Mexico (Table 18). Based on the performance of 250 full sibs, 84 families were selected. These were planted in Poza Rica during 1977A to generate a set of new 250 reciprocal full sibs. The new full sibs along with six check entries have been planted in progeny trials at Poza Rica and Tlaltizapan during 1977B.

v) Yellow H.E.o_2 (IPTT-39).

During 1976, 250 full sib families from Yellow H.E.o_2 were sent out in six different countries for evaluation. The distribution of progeny trial is given in Table 21. In the absence of results from some locations, the selection of families with good performance has not yet been finalized. Consequently, the results will be reported in the next report.

F. BIOCHEMICAL ANALYSES OF SOME PROMISING HARD ENDOSPERM OPAQUE-2 MATERIALS.

Some of the best looking hard endosperm opaque-2 materials have been analyzed for Protein, Lysine and Tryptophan content in the whole grain. The results are given in Table 22. It can be seen from the data, that all materials had acceptable levels of lysine and tryptophan in protein.

The same six materials were analyzed for different protein fractions in the endosperm. The results of the analysis are presented in Table 23. It can be seen from the data that in general alcohol soluble fraction formed about one-third of the total protein in the endosperm. The other two fractions each also constituted about one-third of the total protein.

A complete amino-acid analysis of some promising materials was also done. The results are given in Table 24. It can be seen from the table that the levels of lysine in all hard endosperm opaque-2 materials were considerably higher than the normal Tuxpeño. Also, the hard endosperm opaque-2 materials had less glutamic acid compared to Tuxpeño normal.

G. DEVELOPMENT OF EXPERIMENTAL VARIETIES.

On the basis of 1976 progeny trial data, four experimental varieties were developed from Yellow H.E.o_2. The experimental varieties are listed in Table 25. The table also shows the mean grain yield and other agronomic traits of experimental varieties developed by recombining the best 10 families on the basis of site-specific and across location data. Four experimental varieties developed from Yellow H.E.o_2 showed superiority over the mean of the population and also over the mean of check entries. The superiority of experimental varieties in yield ranged from 60.2% to 22.3% over the mean of the population and 174.6% to 16.5% over the mean of the checks. Regarding days to silk, the experimental varieties were either equal or one day earlier than the mean of the population. All the experimental varieties were, however, taller by 1-3 cms. over the population mean. The ear rot incidence in all the experimental varieties was less compared to mean of 250 tested families.

The experimental varieties developed above will be included in EVT-15 during 1977.

H. FLOURY OPAQUE-2 CONVERSION PROGRAM.

Conversion of soft floury types of materials to opaque-2 has received considerable emphasis in CIMMYT's quality protein maize breeding program in the last three years. Though a wide range of materials varying in kernel color, maturity and cooking characteristics, are being grown in different countries of the Andean region, the most prominent types are white and yellow large seeded floury varieties of different maturity range. The research efforts are, therefore, concentrated in transferring opaque-2 gene into those genetic backgrounds that will have wider use.

Conversion of two floury pools in the highland program is underway. Crosses of Pool 3 and Pool 8 with a number of soft opaque-2 donors were advanced to F_2 in 1975. From the segregating ears, large kernels were selected and subjected to Ninhydrin test. The selected segregates having quality protein were planted either as bulks or on family basis at Batan during 1976. Plant to plant sib pollinations were made among families. At harvest only ears with large kernels were selected. Some other materials such as Cacahuacintle, Amarillo harinoso and some promising varieties from the Andean countries are being converted to opaque-2 in the same way.

The number of ears saved collectively from opaque-2 versions of Pool 3 and Cacahuacintle is given in Table 26. From each of the 393 ears, large kernels were selected to plant in a half sib recombination block both at Batan and Toluca during 1977. The selected ears from Pool 8 have been planted in the same way as Pool 3.

Families with distinctly very large seeds were taken out separately during 1976 harvest. Fifty three such families have been planted at Batan for recombination during 1977.

Recombination of half-sib families coupled with simultaneous selection for plant and ear characteristics was continued in floury-opaque-2 composite. At harvest and seed preparation time, considerable pressure is being exerted for large seeds of floury types. From the third cycle of recombination, 479 ears were saved during 1976. The selected half-sib ears have been planted at Batan and Toluca to undergo the fourth cycle of recombination and selection.

A bulk sample of floury-opaque-2 composite was analyzed for percent protein, different protein fractions and complete amino-acid analysis of protein. The results of such analyses are presented in Tables 27 and 28. It can be seen from the table that the alcohol soluble fraction (zein) formed 34.3% of the protein. The other fractions such as acid soluble and glutenins constituted 28.4% and 28.3% of the protein respectively.

Complete amino-acid analyses of endosperm and whole grain in floury-opaque-2 composite indicated that the levels of lysine and tryptophan in protein were fairly high.

I. SUGARY-2/OPAQUE-2 CONVERSION PROGRAM

Considering certain advantages of sugary-2/opaque-2 double mutant combination pointed out by Purdue scientists, a conversion program was started in 1975. All important normal and opaque-2 materials existing in CIMMYT's maize improvement program were crossed to sugary-2/opaque-2 source in a half-sib crossing block. The resulting F_1 crosses were harvested from both normal and opaque-2 materials. From this point onwards F_1 crosses of normal and opaque-2 materials were handled slightly different to recover sugary-2/opaque-2 segregates.

From the crosses of normal and sugary-2/opaque-2, the double mutant segregates were recovered in a two-step program. The F_1's were advanced to F_2 and then from segregating ears soft opaque-2 kernels were selected from each F_2 ear separately. The recovered segregates were planted on family basis during the next season. A number of plants were selfed in each family. At harvest only those selfed ears were saved that were segregating for sugary-2 kernels.

In the second group that involved crosses between opaque-2 and sugary-2/opaque-2 materials, the sugary-2/opaque-2 segregates were recovered in an easy fashion. From the F_1 crosses, hard endosperm opaque-2 segregates were sorted out on family basis in each material separately. These were planted next season and the pollinations were made in a full sib manner. At harvest, good looking ears segregating for sugary-2 kernels were selected. The selected ears from each materials were shelled individually and then opaque-2 and sugary-2/opaque-2 segregates were sorted out. Detailed observations were recorded on several characters to compare opaque-2 segregates with sugary-2/opaque2. The conclusions drawn from this data are discussed in the following paragraphs.

Comparisons of one-hundred kernel weight, volume in c.c., and kernel density of opaques and sugary-2/opaque-2 from several materials are presented in Table 29. It can be seen that sugary-2/opaque-2 segregates had, in general, lower kernel weight and reduced kernel volume compared to opaque-2 segregates. The segregates of double mutant combination, however, registered a higher kernel density over the counterpart opaques.

The two kinds of segregates from each material were also subjected to protein, lysine and DBC analyses of the whole grain. The results are given in Table 30. It can be seen from the table that two types of segregates, in general, did not differ very much from each other. The same was true for lysine and DBC as well. In some materials, however, differences were apparent but no consistent trend could be noticed.

A complete amino-acid analysis in the whole grain of opaque-2 and sugary-2/opaque-2 segregates was performed in eight selected materials. The results are shown in Table 31. The results indicated that sugary-2/opaque-2 segregates had somewhat higher protein content than the soft opaque-2 segregates. In some materials, however, the differences were of negligible order. The two important amino-acids namely lysine and tryptophan did not differ very much in the two types of segregates. Some other amino-acids such as glutamic acid, leucine and tryosine were present in somewhat larger amounts in opaque-2 segregates over the sugary-2/opaque-2 segregates.

Correlation coefficients (r) among several characters of opaque-2 and sugary-2/opaque-2 segregates recovered from 27 segregating populations were worked out separately for each type of segregates. The results are presented in Table 32. It can be seen from the table that kernel weight and kernel volume were positively correlated while kernel volume and density were negatively correlated in both types of segregates. The other correlation which was negative and significant was between protein and lysine levels in the endosperm.

The protein fractions in the endosperm of eight sugary-2/opaque-2 materials were also determined. The results of such an analysis are presented in Table 33. It can be seen from the table that alcohol soluble, and acid soluble fractions each constituted about one-fourth of the total protein. The glutenin fraction was present in much higher amounts and formed about one-half of the total protein.

On the basis of data and observations made in the field, the following general conclusions can be drawn about sugary-2/opaque-2 segregates recovered from different materials:

i) Sugary-2/opaque-2 segregates vary considerably in their phenotypic appearance in different genetic backgrounds.

ii) The segregates of double mutant combination exhibited variation in size. In general, they were smaller than their counterpart opaques. Exceptions to this were, however, observed in many instances.

iii) Sugary-2/opaque-2 segregates in dent backgrounds were dented but failed to show soft starch in the dented portion.

iv) The double mutant segregates have vitreous appearance but in many instances the inner soft endosperm characteristic of opaque-2 gene was still evident.

v) In some backgrounds, the sugary-2/opaque-2 segregates had intensified color.

vi) Mosaic phenotypic appearance in sugary-2/opaque-2 segregates was also observed in some segregates.

vii) Ears homozygous for sugary-2/opaque-2 tended to shell easily.

viii) Spaces between and within rows were clearly visible as a result of the failure of sugary-2/opaque-2 segregates to attain normal grain size probably due to early curtailing of dry matter accumulation.

ix) The protein content and protein quality of sugary-2/opaque-2 segregates was as good or even better than the soft opaque-2 segregates.

x) In developing double mutant combination, it was felt that due consideration should be paid to selecting segregates that have acceptable appearance and are comparable in size to the normal counterparts.

The sugary-2/opaque-2 segregates of families originating from normal and opaque-2 materials were recombined during 1977A at Tlaltizapan to result into sugary-2/opaque-2 composite. About 800 families from several materials were included in the first cycle of recombination. The ears selected from the first cycle of recombination have been planted at Tlaltizapan during 1977B to undergo the second cycle of recombination. Following additional one or more cycles of recombination, the potential of this combination for future work will be assessed.

J. INTERNATIONAL TESTING - 1976

During this year, CIMMYT.s international program with opaque-2 materials consisted of three major aspects, namely:

a) International progeny testing trials

In the year 1976, the 23 advanced unit materials were split into two groups in an effort to make full and effective use of data from all the locations. Following this division, Yellow H.E.o_2 will be handled in one group while the other two populations i.e. White H.E.o_2 and Tuxpeño opaque-2 will form part of the other group. This grouping will permit the handling of opaque-2 materials in each group every other year.

During the year 1976A, new set of full sib families were developed in Yellow H.E.o_2 (IPTT-39). The resulting full sibs were sent out for evaluation in six different countries (Table 21).

b) Experimental Variety Trial No. 15

A total of 15 experimental varieties were developed on the basis of 1975 IPTT data from three advanced unit populations. These EVT's along with others developed on the basis of late arrival data formed EVT-15 which has been sent to 36 different locations as shown in Table 34. The trial consisted of 25 entries replicated four times.

The results of the trial are presented in Table 35. It is clear from the data that the experimental varieties derived from IPTT-37 were top performers in many locations. The experimental varieties derived from IPTT-39 in general did fairly well, the good yielders in the order of their performance were Across 7539, La Máquina 7539 and Cotaxtla 7439. Of the experimental varieties derived from White H.E.o_2, Across 7440 and La Máquina 7540 were better performers. Amarillo Dentado H.E.o_2 and CIMMYT H.E.o_2 as populations also did fairly well.

It can also been seen from the table that there were a number of entries in each location that performed equal to or better than the local checks.

c) Elite experimental variety trial (ELVT-19)

Also on the basis of 1975 data of experimental variety trial 15, seven varieties were selected as elites. The seven elites plus three checks formed elite experimental variety trial (ELVT-19) which has been sent to 60 different locations in different parts of the world. The trial consisted of 10 entries replicated four times and four row plots.

The distribution of the trial is shown in Table 34 and the results are presented in Table 36. The results available from 29 out of 60 locations indicate that experimental varieties derived from IPTT-37 were the top yielders and in many locations outyielded the local opaque-2 check entry. In some locations, however, the performance of these two varieties was either equal or better than the normal check entry. The performance of two elite experimental varieties from Yellow H.E.o_2 was fairly similar though the superiority of one over the other differed in different locations. The performance of Across 7441 (Composite K), San Andres 7440 and Poza Rica 7441 was also fairly good. It can also be seen from the data that in many locations, the opaque-2 entries in the trial were either equal or at least comparable to both normal and check entries included in the trial.

K. INTERNATIONAL TESTING - 1977

The international testing during the year 1977 consists of the following trials:

a) Progeny trials

During this year, 250 full sib families of three different opaque-2 materials have been sent out to different countries for evaluation. The names of the populations are PD(MS)6 H.E.o_2 (IPTT-38), White H.E.o_2 (IPTT-40) and Temperate x tropical H.E.o_2 (IPTT-41). The first and the third populations are new additions to the advanced unit. The distribution of the trials is shown in Table 20.

b) EVT-15

This trial consists of 11 entries Thirty-eight sets of this trial have been distributed to different countries. The distribution of the trial is shown in Table 37.

c) ELVT-19

This trial consists of 10 entries and has been distributed to 55 sites for planting. The distribution of this trial is shown in Table 37.

L. DISTRIBUTION OF OPAQUE-2 MATERIALS

In addition to progeny and experimental variety trial seed shipments, opaque-2 maize samples in experimental quantities have been shipped to different countries. During the period January to June 1976, 84.3 kilos of opaque-2 maize seed was shipped to 29 different countries. The distribution of materials to different countries is listed in Table 38.

For the period July to December 1976, 352.42 kilos of opaque-2 maize seed was shipped to 24 different countries as shown in Table 39.

M. SUMMARY

During the year under report, the major emphasis in CIMMYT's quality protein maize program consisted in remedying some of the most important problems confronting opaque-2 maize. Genetic modifiers of opaque-2 locus were used as the principal approach to improve the undesirable characteristics of this type of maize. The progress and the status of presently existing materials in the program are discussed in the report.

Conversion of advanced and back-up normal materials to opaque-2 was continued. The ears saved from nineteen advanced unit populations during 1976A were subjected to further selection during 1976 and 1977. The number of families involved in planting during 1976B, 1977A and 1977B were 3594, 2857 and 3474 respectively. The materials in each season were handled in different schemes of S_1, half-sib and full sib selection. In addition to selection for kernel hardness and maintenance of protein quality, intense selection pressure was exerted for plant and ear characteristics. Hard endosperm opaque-2 versions of most of the advanced unit materials look very good so far as quality and appearance of ears is concerned. Starting 1977B, a new strategy has been started in planting hard endosperm opaque-2 families in different locations to screen families stable for modified opaque-2 appearance. A number of opaque-2 versions were also backcrossed to corresponding normal materials. The BC_1 crosses were advanced and a number of segregating BC_1 (F_2) ears were rejected on the basis of kernel weight comparison of normal and opaque-2 segregates.

In eight tropical pools, 1454, 1209 and 1144 hard endosperm opaque-2 families were handled during 1976B, 1977A and 1977B respectively. In four temperate pools, 192 and 486 families were involved in planting during 1977A and 1977B respectively. The improvement of kernel hardness without sacrificing protein quality was continued in all opaque-2 versions of different gene pools. Hard endosperm opaque-2 families of different tropical pools have been planted at Poza Rica and Obregon to select for stable modified endosperm opaque-2 families. The existing versions of all tropical pools were also backcrossed. These have been planted to advance to BC_1 (F_2). The conversion program has also been started in four tropical and four temperate pools that have been formed recently.

Conversion of highland gene pools to opaque-2 was continued. A total of 2095 F_2 families were planted during 1976. Except pools 3 and 8, the major emphasis was placed on selection for modified opaque-2 endosperm.

Conversion program of special project populations for earliness, plant efficiency and adaptation was continued. A total of 916 ears were saved during 1977A. These have been planted at Tlaltizapan and Obregon during 1977B.

Research efforts for the development and improvement of broadbased hard endosperm opaque-2 populations were continued. Twelve tropical and temperate materials completed one or more additional cycles of recombination and selection. Four materials from this program have been promoted to advanced unit. These materials are PD(MS)6 H.E.o_2, CIMMYT H.E.o_2, Temperate x tropical H.E.o_2 and full sib families from White opaque-2 back-up pool.

In addition to tropical and temperate materials in the back-up stages of the program, twelve highland opaque-2 materials were subjected to further mixing and selection. Excepting five soft opaque-2 populations, the major emphasis in these highland materials was placed on changing the endosperm from soft to hard endosperm. Most of these materials are in different stages of development.

Families from several opaque-2 materials were analyzed for protein and tryptophan in endosperm. The mean values for protein and tryptophan in protein in most opaque-2 materials were, in general, very good.

Population improvement program was carried out with five materials. 250 full sib families from Tuxpeño opaque-2, PD(MS)6 H.E.o_2, CIMMYT H.E.o_2 and White opaque-2 back-up pool were evaluated in three locations within Mexico. The selection differential in percent was of the order of 10.44, 9.97, 9.66 and 9.12 in across location data of Tuxpeño opaque-2, PD(MS)6 H.E.o_2, CIMMYT H.E.o_2, and White opaque-2 back-up pool respectively. The mean of selected families in all populations was shorter and a day earlier than the mean of tested population. The full sibs from Yellow H.E.o_2(IPTT-39) were evaluated in six sites. However, in the absence of results from some locations, the selection of families with good performance has not yet been finalized.

On the basis of 1976 progeny trial data, four experimental varieties were developed. These experimental varieties have been included in EVT-15 during the year 1977.

In floury-opaque-2 conversion program, a number of floury-opaque-2 materials have been developed. These materials are floury-opaque-2 composite, opaque-2 versions of Pools 3 and 8, and some very large seeded opaque-2 families selected from different materials. The emphasis in floury 1/opaque-2 materials was placed on selection for large kernels. A complete amino-acid analysis of endosperm and whole grain in floury-opaque-2 composite indicated that the levels of lysine and tryptophan in protein were fairly high.

Sugary-2/opaque-2 conversion program is in very early stages. The double mutant segregates have been recovered from many normal and opaque-2 genetic backgrounds. 800 sugary-2/opaque-2 families originating from different materials entered in the first cycle of recombination during 1977A to form a sugary-2/opaque-2 composite. The selected ears have been planted to undergo second cycle of recombination. Biochemical analyses of sugary-2/opaque-2 segregates indicated the presence of higher protein content than the soft opaque-2 segregates. The two essential amino-acids, however, did not differ very much in the two types of segregates. Differences in glutamic acid, leucine and tryosine were observed in the two types of segregates. The glutenin fraction of the protein was present in much higher amounts in sugary-2/opaque-2 segregates and it formed about one-half of the total protein.

Biochemical analyses of many promising hard endosperm opaque-2 materials indicated the presence of acceptable levels of lysine and tryptophan. An analysis of protein fraction showed that alcohol soluble, acid soluble, and alkali soluble fraction each constituted about one-third of total protein. The hard endosperm opaque-2 materials, in general, had less glutamic acid.

During 1976, EVT-15 and ELVT-19 were sent to 36 and 60 different locations respectively. The results from EVT-15 showed that experimental varieties derived from IPTT-37, in general, performed very well in different locations. Across 7539; La Maquina 7539 and Cotaxtla 7439 also did fairly well. From White H.E.o_2, across 7440, and La Maquina 7540 were better performers. Amarillo Dentado H.E.o_2 and CIMMYT H.E.o_2 as populations also performed fairly well. In ELVT-19, the experimental varieties from IPTT-37 were top yielders. In many locations, the opaque-2 entries were either equal or at least comparable to both normal and opaque-2 check entries included in the trial.

The international testing program during the year 1977 consists of progeny trials, EVT-15 and ELVT-19. 250 full sibs from 3 different populations have been set out to different countries for evaluation. EVT-15 and ELVT-19 have been sent out to 38 and 55 locations respectively.

TABLE 1 .- Conversion of Advanced Unit materials to opaque-2.

IPTT No.	Pedigree	No. of hard endosperm o_2 ears saved		
		1976A	1976B	1977A
21	Tuxpeño-1	93	211	401
22	Mezcla tropical blanca	320	126	154
23	Blanco Cristalino-1	256	361	266
24	Ant. x Ver. 181	295	225	233
25	Mix.-1-Col. Gpo.1 x Eto	160	79	189
26	Mezcla amarilla	254	191	162
27	Amarillo Cristalino-1	399	212	148
28	Amarillo Dentado	256	144	228
29	Tuxpeño Caribe	336	175	233
30	Blanco Cristalino-2	-	-	49*
31	Braquíticos	109	-	-
32	Eto Blanco	240	293	334
33	Amarillo Subtropical	271	226	243
34	Blanco Subtropical	96	56	165
35	Ant. x Rep. Dominicana	199	312	209
36	Cogollero	-	-	36*
42	Eto x Illinois	29	90	74
43	La Posta	216	114	288
48	Compuesto de Hungria	65	42	62

* F_2 families.

TABLE 2.- No. of segregating ears saved from Advanced generation of BC_1 families in some advanced unit materials.

IPTT No.	Population	No. of BC_1 ears saved during 1976	Ears saved from advanced generation of BC_1
21	Tuxpeño-1	50	61
22	Mezcla tropical blanca	64	37
23	Blanco Cristalino-1	80	91
24	Ant. x Ver. 181	50	22
25	Mix.1- Col. Gpo.1 x Eto	50	65
26	Mezcla Amarilla	44	35
27	Amarillo Cristalino	81	-
28	Amarillo Dentado	50	62
29	Tuxpeño Caribe	49	57
33	Amarillo Subtropical	37	18
42	Eto x Illinois	61	38
43	La Posta	45	29
48	Compuesto de Hungria	29	44

TABLE 3.- Kernel weight, volume and density comparisons of normal and hard endosperm opaque-2 segregates recovered from segregating populations.

Population	Origin	No. of ears	100 kernel weight in gms. normal	opaques	diff. (%)	Volume in ml. normal	opaques	diff. (%)	Density (gms/ml) normals	opaques	diff. (%)
	PR-77A										
Amarillo Dentado H.E.o_2	308	62	34.08	29.70	12.51**	27.12	25.29	6.38**	1.26	1.17	6.46**
Mix.1-Col.Gpo.1 x Eto H.E.o_2	309	65	31.32	28.43	8.78**	25.53	24.34	4.18**	1.23	1.17	4.59**
Mezcla Amarilla H.E.o_2	311	35	30.85	27.57	9.98**	23.89	23.21	2.06	1.29	1.19	7.98**
Cogollero H.E.o_2	329	28	27.77	24.77	10.27**	22.51	21.53	3.91**	1.23	1.15	6.45**
(Blanco Cristalino x Blanco Cristalino H.E.o_2)-F_2	330	49	31.79	26.92	15.15**	25.76	23.71	7.81**	1.24	1.14	7.86**
Tuxpeño 1 H.E. o_2	Lote 93	61	34.17	30.52	10.54**	27.32	26.51	2.69**	1.25	1.15	7.91**
Tuxpeño Caribe H.E.o_2	Lote 94	57	35.61	32.79	7.72**	29.00	28.03	3.10**	1.23	1.17	4.65**

** Significant at 1% level of probability.

TABLE 4.- Means of 100-kernel weight, volume, and density of normals and opaques from segregating ears of different populations.

Population	Origin	No. of ears	100-kernel weights in grams: normal	100-kernel weights in grams: opaques	100-kernel weights in grams: diff. (%)	Volume in ml.: normals	Volume in ml.: opaques	Volume in ml.: diff. (%)	Density (gms/ml.): normals	Density (gms/ml.): opaques	Density (gms/ml.): diff. (%)
	TL-77A										
Pool 27 H.E.o_2	1304	27	30.97	28.82	6.66**	25.96	25.04	3.28**	1.19	1.15	3.44**
Pool 34 H.E.o_2	1305	12	34.02	31.63	6.90**	28.08	28.05	0.04	1.21	1.13	6.82**
Blanco subtropical H.E.o_2	1312	96	35.86	32.02	10.53**	29.29	28.63	2.15**	1.23	1.12	8.52**
Hungarian Composite H.E.o_2	1316	44	31.91	29.62	7.02**	26.38	26.32	0.23	1.21	1.13	6.99**
Pool 30 H.E.o_2	1317	14	33.41	31.69	5.03**	28.04	27.91	0.47	1.19	1.14	4.53**
Pool 33 H.E.o_2	1318	31	32.60	30.27	6.96**	26.40	26.06	1.17	1.24	1.16	5.78**
Pool 29 H.E.o_2	1319	34	29.79	27.84	6.50**	24.31	23.58	2.92**	1.23	1.18	3.59**
(Pool 31 x Temp. Trop. H.E.o_2)F_2	1320	66	33.38	30.10	9.68**	27.09	26.84	0.94	1.23	1.12	8.72**

** Significant at the 1% level of probability.

TABLE 5 .- Number of families rejected on the basis of kernel weight comparison of normals and opaques in different segregating populations.

Material	Origin	No. of segregating ears	No. of ears rejected in each population*
	PR-77A		
Amarillo Dentado H.E.o_2	308	.62	19
Mix.1-Col.Gpo.1 x Eto H.E.o_2	309	65	18
Mezcla Amarilla H.E.o_2	311	35	11
Cogollero H.E.o_2	329	28	11
(Blanco Cristalino-2 x Blanco Cristalino H.E.o_2) -F_2	330	49	24
Tuxpeño 1 H.E.o_2	Lote 93	61	22
Tuxpeño Caribe H.E.o_2	Lote 94	57	15

* Kernel weight difference in normals and opaques more than 10%.

TABLE 6 .- No. of ears with more than 10% difference in 100-kernel weight between normals and opaques in segregating materials.

Material	Origin	Total No. of ears	No. of ears with more than 10% diff. between normals and opaques
	TL-77A		
Pool 27 H.E.o_2	1304	27	6
Pool 34 H.E.o_2	1305	12	2
Blanco subtropical H.E.o_2	1312	96	40*
Hungarian Comp. H.E.o_2	1316	44	9
Pool 30 H.E.o_2	1317	14	1
Pool 33 H.E.o_2	1318	31	6
Pool 29 H.E.o_2	1319	34	12
(Pool 31 x Temp. x Trop. H.E.o_2)-F_2	1320	66	28*

* Ears with more than 11% difference between normals and opaques.

TABLE 7.- Conversion of tropical and temperate gene pools to opaque-2.

Pool No.	Name	No. of hard endosperm opaque-2 ears saved			No. of BC_1 ears saved during 1977A
		1976A	1976B	1977A	
A) TROPICAL POOLS					
19	Tropical intermediate white flint	208	87	99	31
20	Tropical intermediate white dent	157	92	86	26
21	Tropical intermediate yellow flint	154	97	97	30
22	Tropical intermediate yellow dent	211	178	145	30
23	Tropical late white flint	221	268	264	28
24	Tropical late white dent	151	154	163	30
25	Tropical late yellow flint	112	71	86	17
26	Tropical late yellow dent	240	262	204	30
	TOTAL	1454	1209	1144	222
B) TEMPERATE POOLS					
27	Temperate early white flint	74	43	109	-
28	Temperate early white dent	-	-	14*	-
29	Temperate early yellow flint	-	19*	61**	-
30	Temperate early yellow dent	-	30*	47**	-
31	Temperate intermediate white flint	-	39*	101**	-
32	Temperate intermediate white dent	96	60	165	-
33	Temperate intermediate yellow flint	21	24	86	-
34	Temperate intermediate yellow dent	109	65	126	-
	TOTAL	300	280	709	

* F_1 ears
** F_2 ears

TABLE 8 .- Conversion of new gene pools to opaque-2.

Pool No.	Name	No. of o_2 donors used	No. of F_1 ears saved in 1976 or 1977	No. of F_2 ears saved in 1977A
15	Tropical early white flint	2	15	-
16	Tropical early white dent	3	31	-
17	Tropical early yellow flint	2	9	-
18	Tropical early yellow dent	2	15	-
28	Temperate early white dent	1	14	-
29	Temperate early yellow flint	1	19	61
30	Temperate early yellow dent	1	30	47
31	Temperate intermediate white flint	1	39	101

TABLE 9 .- Conversion of highland gene pools to opaque-2.

Pool No.	Name	No. of ears selected for planting next year 1975	1976
1	Highland early white flint	147	68
2	Highland early white dent	198	91
3	Highland early white floury	205	393
4	Highland early yellow flint	270	226
5	Highland early yellow dent	292	129
7	Highland intermediate white dent	107	63
8	Highland intermediate white floury	238	185
9	Highland intermediate yellow flint	202	158
10	Highland intermediate yellow dent	273	132
11	Highland late white flint	24	9
12	Highland late white dent	55	40
13	Highland late yellow flint	71	47
14	Highland late yellow dent	13	54
	TOTAL	2095	1595

TABLE 10.- Conversions of populations that are being selected for earliness, plant efficiency and adaptation.

Material	No. of ears saved during		
	1976A	1976B	1977A
Amarillo Bajío	408	190	280
Amarillo Bajío x varios templados	83	73	131
Amarillo Bajío x Mezcla Tropical	63	88	144
Mezcla Amarilla P.B. x Lin. Ill.	204	97	131
Planta pequeña mazorca grande	21	21	30
Amarillo Bajío x Maíces Argentina	41	51	92
Selección Precoz	42*	41	28
Maíces Tropicales Sel. Batan	40	45	80
TOTAL	902	606	916

* F_1 ears.

TABLE 11 .- Mean values for protein and tryptophan in endosperm of quality protein hard endosperm opaque-2 materials.

Pedigree	Origin	No. of families	Mean values: Protein (%)	Mean values: Tryptophan in protein (%)
	PR-76B			
Mezcla tropical blanca H.E.o_2	825	42	7.9	0.78
Ant. x Ver.181 H.E.o_2	806	178	8.6	0.82
Mix.1-Col.Gpo.1 x Eto H.E.o_2	827	21	7.7	0.82
Mezcla amarilla H.E.o_2	828	29	7.7	0.80
Amarillo Cristalino H.E.o_2	807 ⊠	188	8.5	0.77
Tuxpeño Caribe H.E.o_2	808 ⊠	144	8.0	0.86
Eto Blanco H.E.o_2	837	-	8.1	0.77
Ant. x Rep. Dominicana	PR-76B Lote 99	319	7.8	0.80
La Posta H.E.o_2	809	85	7.8	0.91
Amarillo subtropical H.E.o_2	TL-76B 1811	178	8.7	0.73
Blanco subtropical H.E.o_2	1812	86	8.7	0.78
Eto x Illinois H.E.o_2	1813	48	8.8	0.76
Amarillo Pakistan H.E.o_2	1814	68	9.0	0.75
Blanco Pakistan	1815	13	8.2	0.80
Hungarian Composite H.E.o_2	1816	42	8.7	0.76
Pool 19 H.E.o_2	PR-76B 813A	70	8.8	0.78
Pool 20 H.E.o_2	814	92	8.4	0.80
Pool 21 H.E.o_2	815	97	8.2	0.78
Pool 25 H.E.o_2	816	52	8.3	0.78
Pool 27 H.E.o_2	TL-76B 1804	50	8.6	0.78
Pool 34 H.E.o_2	1805	65	8.3	0.82
Amarillo Bajío H.E.o_2	1802	190	8.8	0.73
Mezcla amarilla P.B.x Lin. Ill. H.E.o_2	1803	97	8.3	0.74
Amarillo Bajío x Maices Argentina H.E.o_2	1806	51	8.6	0.84
Amarillo Bajío x varios templados H.E.o_2	1807	73	9.2	0.74
Amarillo Bajío x Mezcla tropical H.E.o_2	1808	25	9.1	0.72
Amarillo Bajío x Pl. peq. maz. grande H.E.o_2	1809	21	8.9	0.72
Maíz tropical selección Batan H.E.o_2	1810	45	8.4	0.71

TABLE 12.- Mean values for protein and tryptophan in endosperm of some highland quality protein hard endosperm opaque-2 materials.

Pedigree	Origin	No. of families	Protein (%)	Tryptophan in protein (%)
Pool 1 H.E.o_2	BA-76 2601	42	10.0	0.80
Pool 2 H.E.o_2	2602	53	9.6	0.82
Pool 4 H.E.o_2	2603	132	10.0	0.85
Pool 5 H.E.o_2	2604	33	10.4	0.78
Pool 7 H.E.o_2	2605	31	9.6	0.80
Pool 9 H.E.o_2	2606	60	10.3	0.81
Pool 10 H.E.o_2	2607	15	10.3	0.79
Pool 11 H.E.o_2	2608	13	9.6	0.92
Pool 12 H.E.o_2	2609	29	9.9	0.82
Pool 13 H.E.o_2	2610	38	9.5	0.75
Pool 14 H.E.o_2	2611	12	9.4	0.94
Mezcla amarilla P.B. x Lin. Ill. H.E.o_2	2613	52	9.7	0.83
Mezcla amarilla P.B. x Lin. Ill. x precoces H.E.o_2	2614	36	10.2	0.82
Planta Peq.Maz. Grande H.E.o_2	2615	56	9.9	0.80

TABLE 13.- Mean values for protein and quality index in some hard endosperm opaque-2 materials.

(Whole kernel analyses)

Pedigree	Origin	No. of families	Mean values Protein (%)	Quality index
Mezcla tropical blanca H.E.o_2	PR-76B 803	134	9.8	4.0
Mix. 1-Col. Gpo. 1 x Eto H.E.o_2	802	58	9.3	3.9
Mezcla amarilla H.E.o_2	805	162	9.8	3.6
Amarillo Dentado H.E.o_2	801	96	7.8	4.1
White o_2 B.U. Pool	PR-76B Lote 91	443	7.0	3.7
Yellow o_2 B.U. Pool	Lote 92	430	9.3	4.7

TABLE 14.- Mean values for protein and tryptophan in some hard endosperm opaque-2 materials of tropical and temperate origin (1977A harvest).

(Endosperm Analyses)

Pedigree	Origin	No. of families	Protein (%)	Tryptophan in protein(%)
	PR-77A			
Mix. 1-Col. Gpo. 1 x Eto H.E.o_2	309	122	8.1	0.77
Mezcla Amarilla H.E.o_2	311	125	8.4	0.78
Amarillo Dentado H.E.o_2	308	166	8.0	0.79
Blanco Cristalino H.E.o_2	316	266	8.2	0.74
Pool 23 H.E.o_2	321	264	8.0	0.79
	TL-77A			
Amarillo Subtropical H.E.o_2	1311	243	8.7	0.72
Blanco Subtropical H.E.o_2	1312	69	8.7	0.78
Eto x Ill. H.E.o_2	1313	74	9.0	0.70
Amarillo Pakistan H.E.o_2	1314	55	8.5	0.70
Blanco Pakistan H.E.o_2	1315	12	8.4	0.80
Hungarian Composite H.E.o_2	1316	68	9.3	0.72
Pool 27 H.E.o_2	1304	61	9.0	0.66
Pool 29 H.E.o_2	1319	23	8.7	0.74
Pool 30 H.E.o_2	1317	14	9.2	0.79
Pool 33 H.E.o_2	1318	28	9.4	0.71
Pool 34 H.E.o_2	1305	75	8.2	0.73
Amarillo Bajío H.E.o_2	1302	280	9.0	0.71
Mezcla Amarilla P.B. x Lin. Ill. H.E.o_2	1303	131	9.1	0.69
Amarillo Bajío x Maíces Argentinos H.E.o_2	1306	92	8.4	0.77
Amarillo Bajío x varios templados H.E.o_2	1307	131	8.7	0.80
Amarillo Bajío x Mez. Trop. Amarilla H.E.o_2	1308	144	9.2	0.77
Amarillo Bajío x Pl. Peq. Maz. Grande H.E.o_2	1309	30	9.5	0.66
Maíces tropical selección Batan H.E.o_2	1310	80	8.6	0.69

TABLE 15.- Tropical and temperate opaque-2 materials in the back-up stages of the program.

Population	Breeding scheme	Recombination or sel. cycle	No. of families saved 1976A	1976B	1977A
White opaque-2 back-up pool	H.S.	C_6	624	443	624
Yellow opaque-2 back-up pool	H.S.	C_6	720	430	667
Temperate x tropical H.E.o_2	H.S.	C_6	507	774	615
Yellow flint H.E.o_2	F.S.	C_1	-	-	237
Late White dent H.E.o_2	F.S.	C_2	-	176	146
F.S. from Yellow o_2 B.U. Pool (C_3)-##	S_1	C_1	-	108	82
F.S. from White o_2 B.U. Pool (C_3)	F.S.	C_3	-	250	220
PD(MS)6 H.E.o_2 (H.S.)C_4	F.S.	C_2	250	Progeny trial	250
CIMMYT H.E.o_2 (H.S.)C_4	F.S.	C_2	250	"	250
F.S. from Temperate x Trop. H.E.o_2 (H.S.) C_4	F.S.	C_1	318*	264	250

* H.S. ears

TABLE 16.- Highland opaque-2 materials in the back-up stages of the program.

Population	Method of recombination	Cycle of recombination	No. of fam. involved in recombination 1976	1977
Highland modified opaque-2 composite	H.S.	C_2	205	288
Floury opaque-2 composite	H.S.	C_4	365	479
Puebla opaque-2 composite	H.S.	C_5	287	384
Composite I	H.S.	C_5	359	242
Highland altitude opaque-2 composite	H.S.	C_5	234	174
Puebla o_2 x Barraza	H.S.	F_3	200	157
Mezcla Amarilla P.B. x Lin.Ill.H.E.o_2	F.S.	F_3	57	79
Mezcla Amarilla P.B.-Lin.Ill. x precoces H.E.o_2	F.S.	F_3	42	53
Planta pequeña mazorca grande H.E.o_2	F.S.	F_3	70	46
Composite I H.E.o_2	F.S.	F_5	114	122
Modified o_2 families resulting from intercrosses among different fam.	F.S.	F_2	58	77
Highland White H.E.o_2 families	F.S.	F_1	-	57

TABLE 17.- Protein and tryptophan content of some opaque-2 materials in the back-up stages of the program.

Pedigree	Origin	No. of fam.	Protein (%)	Tryptophan in protein (%)
Yellow o_2 B.U. Pool (H.S.) C_3	PR-76B 811	108	7.7	0.81
White o_2 B.U. Pool Pool (H.S.)C_3	832	93	7.8	0.78
Late White Dent H.E.o_2	810	133	7.9	0.87
Yellow flint H.E.o_2	812	55	9.2	0.74
Temperate x tropical H.E.o_2	TL-77A 1301	250	8.7	0.70
Temperate x tropical H.E.o_2(flint)	Lote 191	242	7.7	0.72
Temperate x tropical H.E.o_2(dent)	Lote 191	434	7.5	0.75
Highland modified o_2 comp.	BA-76 Lote 295	312	9.3	0.81
Floury opaque-2 Composite	Lote 291	324	8.9	4.5*

* Quality index

TABLE 18.- Progeny trials conducted within Mexico during the year 1976

Population	No. of families	Type of families	Locations: Poza Rica	Locations: Tlaltízapan	Locations: Obregón	Total
Tuxpeño opaque-2	250	Full sibs	x	x	x	3
PD(MS) 6 H.E.o_2	250	"	x	x	x	3
CIMMYT H.E.o_2	250	"	x	x	x	3
Full sibs from white o_2 back-up pool	250	"	x	x	x	3

TABLE 19 .- Summary of performance of full-sib families from four different opaque-2 populations.

Population	test site	No. of families tested	No. of families selected	Mean yield in ton/ha tested	Mean yield in ton/ha selected	Selection differential (%)	C.V.	L.S.D. (.05)	Plant height in cms. tested	Plant height in cms. selected	Days to flower tested	Days to flower selected
Tuxpeño opaque-2 (IPTT-37)	Poza Rica	250	84	1958	2117	8.12	26.9	1051	193	190	59	59
	Tlaltizapan	250	84	3870	4373	13.00	27.0	2083	172	170	73	72
	Obregón	250	84	4372	4772	9.15	18.9	1647	220	216	63	63
	Across	250	84	3400	3755	10.44	-	-	195	193	66	65
PD(MS)6 H.E.o_2 (IPTT-38)	Poza Rica	250	93	1677	1814	8.17	27.1	915	200	197	57	56
	Tlaltizapan	250	93	3751	4112	9.62	23.3	1742	201	200	67	66
	Obregón	250	93	3174	3535	11.37	20.9	1329	230	229	61	60
	Across	250	93	2868	3154	9.97	-	-	211	209	62	61
CIMMYT H.E.o_2	Poza Rica	250	96	1832	1990	8.62	31.7	1163	203	200	58	58
	Tlaltizapan	250	96	3942	4240	7.56	18.2	1429	213	210	68	67
	Obregón	250	96	3326	3748	12.69	17.8	1191	235	232	62	61
	Across	250	96	3034	3327	9.66	-	-	217	215	63	62
White opaque-2 Back-up Pool	Poza Rica	250	99	2760	2968	7.54	26.5	1458	214	212	58	58
	Tlaltizapan	250	99	4003	4440	10.92	26.7	2130	182	183	72	71
	Obregón	250	99	3867	4188	8.30	17.4	1348	226	223	63	63
	Across	250	99	3543	3866	9.12	-	-	208	207	65	64

TABLE 20 .- Distribution of progeny trials during the year 1977. (Quality protein materials).

IPTT	Population	South America		Central America		Mexico			Africa			Asia				Total
		Bolivia	Colombia	Guatemala	Panama	Poza Rica	Tlaltizapan	Obregón	Egypt	Ivory Coast	Tanzania	India	Nepal	Philippines	Thailand	
38	PD(MS)6 H.E.o_2			x	x	x		x				x			x	6
41	Temperate x Tropical H.E.o_2	x	x				x		x			x	x			6
40	White H.E.o_2					x	x	x		x	x			x		6
37	Tuxpeño opaque-2					x		x								2
-	CIMMYT H.E.o_2					x	x	x								3
	TOTAL															23

TABLE 21.- 1976 IPTT distribution of quality protein materials

IPTT No.	Population	No. of sets distributed						Total
		Peru	Honduras	Nicaragua	Mexico(PR)	Ivory Coast	Nigeria	
39	Yellow H.E.o_2	1	1	1	1	1	1	6

TABLE 22.- Protein, lysine and tryptophan in the whole grain of some promising hard endosperm opaque-2 materials

Material	Protein (%)	Lysine in protein (%)	Tryptophan in protein (%)
PD(MS)6 H.E.o_2	10.8	3.4	0.83
Amarillo dentado H.E.o_2	11.2	3.5	0.88
CIMMYT H.E.o_2	10.9	3.8	0.97
White opaque-2 Back-up Pool	10.4	3.5	0.89
Ant.x Ver.181 H.E.o_2	11.2	3.6	1.00
Temperate x tropical H.E.o_2	9.2	3.8	1.12

TABLE 23.- Percent protein, tryptophan and different protein fractions in the endosperm.

Material	% Protein in endosperm	% Tryptophan in protein in endosperm	Protein fractions in endosperm protein (%)		
			Acid soluble	Alcohol soluble	Glutenin
PD(MS)6 H.E.o_2	8.9	0.70	28.4	34.3	28.8
Amarillo dentado H.E.o_2	8.7	0.77	31.5	36.0	30.0
CIMMYT H.E.o_2	8.8	0.73	29.4	34.8	30.6
White opaque-2 back-up pool	8.4	0.83	30.3	29.8	28.8
Temperate x tropical H.E.o_2	8.0	0.88	32.2	33.7	31.6
Ant. x Ver.181 H.E.o_2	8.4	0.83	32.0	37.4	30.2

TABLE 24.- Complete amino-acid analysis of the endosperm in some promising hard endosperm opaque-2 materials.

Amino-acid	PD(MS)6 H.E.o_2	Amarillo Dent. H.E.o_2	CIMMYT H.E.o_2	White opaque-2 Back-up pool	Ant. x Ver.181 H.E.o_2	Temp.x Trop. H.E.o_2	Tuxpeño Normal
Lysine	2.98	3.13	3.09	2.85	3.14	3.04	1.90
Histidine	4.15	4.19	4.30	3.94	4.66	3.93	2.45
Arginine	3.99	5.22	4.78	4.75	4.69	4.53	3.28
Aspartic acid	7.35	8.01	7.50	7.02	7.51	7.75	5.92
Threonine	3.99	4.06	3.99	3.76	4.08	3.94	3.15
Serine	4.28	5.12	4.83	4.76	4.95	5.06	3.47
Glutamic acid	20.08	20.12	19.64	18.10	20.22	18.96	24.89
Proline	11.79	13.06	11.68	11.23	11.75	11.06	11.21
Glycine	4.36	4.47	4.42	4.25	4.51	4.29	2.92
Alanine	8.06	8.13	7.89	7.18	8.06	7.49	9.26
Cystine	2.07	2.25	1.94	2.14	2.17	2.01	0.76
Valine	5.69	5.74	5.93	4.94	5.95	5.31	4.01
Methionine	1.70	1.55	1.35	1.37	1.51	1.40	1.43
Isoluicine	3.82	3.91	3.94	3.19	4.02	3.46	3.17
Leucine	13.07	13.02	12.77	11.39	13.05	11.66	14.58
Tryosine	4.18	4.61	4.38	4.25	4.52	3.96	4.15
Phenylalanine	4.91	5.33	5.02	4.71	5.33	4.56	5.17
Tryptophan	0.70	0.77	0.73	0.83	0.83	0.88	- -
% Protein	8.9	8.7	8.8	8.4	8.4	8.0	9.2

TABLE 25.- Development of experimental varieties from Yellow H.E.o_2 (IPTT-39) on the basis of 1976 data.

IPTT No.	Population	Experimental Variety	Grain yield Kg/ha. Pop. $\bar{x}$	Sel. fam. $\bar{x}$	Checks $\bar{x}$	% superiority of sel. fam. $\bar{x}$ Pop. $\bar{x}$	Check $\bar{x}$	Days to flower Pop. $\bar{x}$	Sel. fam. $\bar{x}$	Plant ht. in cm. Pop. $\bar{x}$	Sel. fam. $\bar{x}$	% ear rot Pop. $\bar{x}$	Sel. fam. $\bar{x}$
39	Yellow H.E.o_2	Santa Rosa 7639	4262	5634	2052	32.2	174.6	56	55	209	211	30.0	20.2
		Tocumen 7639	4293	5250	4507	22.3	16.5	55	55	209	210	17.4	9.4
		Poza Rica 7639	1949	3123	1645	60.2	89.8	60	59	197	199	2.5	2.1
		Across 7639	3501	4298	2735	22.8	57.0	57	57	205	208	-	-

TABLE 26.- Development of floury-opaque-2 materials.

Population	Selection procedure	Cycle or generation	No. of fam. planted during 1977
Floury-opaque-2 Composite	H.S.	C_4	479
Pool 3 (opaque-2)-#-#	H.S.	C_1	393
Pool 8 (opaque-2)-#-#	H.S.	C_1	185
Large seeded floury-opaque-2 families	F.S.	C_1	53

TABLE 27.- Percent protein, tryptophan and different protein fraction in the endosperm.

Material	Protein (%)	Trytophan in protein (%)	Protein fraction in endosperm protein (%) Acid soluble	Alcohol soluble	Glutenin
Floury 1-opaque-2 Comp.	8.9	0.70	28.4	34.3	28.3

TABLE 28.- Complete amino-acid analysis of Floury-opaque-2 Composite.

Amino Acid	Whole grain	Endosperm
Lysine	4.1	3.5
Histidine	2.9	3.3
Arginine	5.6	4.9
Aspartic acid	10.2	10.9
Threonine	3.5	3.9
Serine	4.6	5.2
Glutanic acid	15.9	18.9
Proline	8.0	9.5
Glysine	4.4	4.3
Alanine	6.8	7.7
Cystine	1.1	1.6
Valine	5.0	5.3
Methionine	1.5	1.7
Isoluicine	3.1	3.7
Leucine	8.6	11.2
Tryosine	3.7	4.5
Phenylalanine	4.2	5.0
Tryptophan	1.0	1.1
% Protein	9.7	7.2

TABLE 29.- Kernel weight, volume and density comparison of opaques and sugary-2-opaque-2 segregates in different opaque-2 backgrounds.

S.No.	Pedigree	No. of samples	100 kernel wt. in grammes			Volume (C.C.)			Density*		
			o_2o_2	$su_2su_2o_2o_2$	Difference (%)	o_2o_2	$su_2su_2o_2o_2$	Difference (%)	o_2o_2	$su_2su_2o_2o_2$	Difference (%)
1	(Ver.181-Ant.Gpo.2xVen.1o_2 x su_2o_2)-#	56	28.8	26.7	7.3	24.5	21.9	10.6	1.179	1.221	3.6
2	(Yellow H.E.o_2 x ")-#	37	28.1	26.5	5.7	23.6	21.5	8.9	1.191	1.232	3.4
3	(White H.E.o_2 x ")-#	27	29.0	26.6	8.3	24.6	21.1	14.2	1.214	1.260	3.8
4	(Yellow o_2 B.U.Pool x ")-#	33	27.4	25.7	6.2	23.4	20.5	12.4	1.170	1.254	7.2
5	(White o_2 B.U.Pool x ")-#	24	29.3	25.6	12.6	25.3	20.6	18.6	1.206	1.246	3.3
6	(Temperate-tropical H.E.o_2 x ")-#	47	28.1	26.2	6.8	24.0	20.8	13.3	1.170	1.255	7.3
7	(Ant.xVer.181 H.E.o_2 x ")-#	27	28.4	26.7	6.0	24.5	21.2	13.5	1.158	1.253	8.6
8	(Mezcla amarilla H.E.o_2 x ")-#	31	27.8	25.9	6.8	23.8	20.4	14.3	1.168	1.267	8.5
9	(Amarillo Cristalino H.E.o_2 x ")-#	35	26.3	24.7	6.1	22.6	19.5	13.7	1.160	1.268	9.3
10	(Amarillo dentado H.E.o_2 x ")-#	33	27.5	26.0	5.5	24.1	21.0	12.9	1.144	1.241	8.5
11	(Tuxpeño Caribe H.E.o_2 x ")-#	36	30.5	28.6	6.2	26.6	22.7	14.7	1.148	1.263	10.0
12	(Mezcla tropical blanca HEo_2 x ")-#	45	28.7	27.0	5.9	24.8	21.5	13.3	1.157	1.253	8.3
13	(Blanco Cristalino H.E.o_2 x ")-#	26	28.5	26.5	7.0	24.4	21.6	11.5	1.167	1.232	5.6
14	(La Posta H.E.o_2 x ")-#	20	27.3	25.7	5.9	22.5	20.4	9.3	1.214	1.262	3.9
15	(Pool 21 H.E.o_2 x ")-#	37	27.3	25.4	7.0	23.5	20.1	14.5	1.163	1.267	8.9
16	(Pool 22 H.E.o_2 x ")-#	42	29.5	27.5	6.8	25.4	21.8	14.2	1.163	1.263	8.6
17	(Pool 23 H.E.o_2 x ")-#	27	27.8	25.4	8.6	23.6	19.9	15.7	1.178	1.275	8.2
18	(Pool 24 H.E.o_2 x ")-#	35	28.9	26.1	9.7	24.0	20.5	14.6	1.170	1.271	8.6
19	(Pool 25 H.E.o_2 x ")-#	32	28.4	25.7	9.5	23.9	20.5	14.2	1.155	1.251	8.3
20	(Pool 26 H.E.o_2 x ")-#	24	28.0	26.1	6.8	24.4	20.7	15.2	1.148	1.256	9.4
21	(PD(MS)6 H.E.o_2 x ")-#	36	27.6	24.9	9.8	23.7	19.5	17.7	1.199	1.280	6.8
22	(CIMMYT H.E.o_2 x ")-#	35	28.8	26.0	9.7	24.3	21.1	13.2	1.152	1.238	7.5
23	(Tuxpeño C_2-La Posta H.E. x ")-#	14	29.7	26.6	10.4	25.8	20.7	19.8	1.154	1.285	11.4
24	(Líneas El[11] Salvador H.E.o_2 x ")-#	36	29.1	26.5	8.9	24.5	21.1	13.9	1.190	1.257	5.6
25	(Thai Comp.#1-PD(MS)6 H.E. o_2 x ")-#	35	27.1	25.2	7.0	23.0	20.1	12.6	1.177	1.252	6.4
26	(Amarillo Bajío H.E.o_2 x ")-#	20	28.5	26.6	6.7	24.4	21.1	13.5	1.167	1.259	7.9
27	(Amarillo Bajío x Mezcla Tropical Am.H.E.o_2 x ")-#	33	27.3	25.3	7.3	23.0	19.8	13.9	1.184	1.276	7.8
	AVERAGE**	-	28.3	26.1	7.8	24.2	20.8	14.0	1.172	1.257	7.3

* Specific gravity with respect to water at room temperature.

** Average for 100 kernel weight, volumes and specific gravities of all materials.

TABLE 30.- Percent protein, lysine and DBC values in the whole kernel of opaque-2 and sugary-2 opaque-2 segregates recovered from different materials.

S.No.	Material	Protein (%)		Lysine in protein (%)		DBC	
		o_2o_2	$su_2su_2o_2o_2$	o_2o_2	$su_2su_2o_2o_2$	o_2o_2	$su_2su_2o_2o_2$
1	Ver. 181-Ant. Gpo. 2 x Ven. 1 o_2	11.8	10.8	3.9	3.9	54	54
2	Yellow H. E. o_2	11.1	11.1	4.4	3.8	56	59
3	White H. E. o_2	10.6	11.1	4.0	3.4	51	57
4	Yellow opaque-2 back-up pool	10.8	11.4	3.8	4.0	52	59
5	White opaque-2 back-up pool	11.5	11.5	4.2	3.9	56	60
6	Temperate x tropical H. E. o_2	11.4	11.4	4.2	3.9	57	62
7	Ant. x Ver. 181 H. E. o_2	11.6	11.3	4.0	4.1	57	60
8	Mezcla amarilla H. E. o_2	11.5	11.1	3.8	3.7	52	58
9	Amarillo Cristalino - 1 H. E. o_2	11.3	11.0	3.7	4.0	52	57
10	Amarillo dentado H. E. o_2	11.1	10.9	3.6	4.0	54	59
11	Tuxpeño Caribe H. E. o_2	10.6	10.6	4.6	4.2	53	57
12	Mezcla tropical blanca H. E. o_2	11.1	11.8	4.0	3.8	52	58
13	Blanco Cristalino H. E. o_2	11.0	11.2	4.4	3.5	53	58
14	La Posta H. E. o_2	11.2	10.9	4.2	4.4	52	66
15	Pool 21 H. E. o_2	11.0	11.2	3.9	4.1	52	60
16	Pool 22 H. E. o_2	11.0	10.9	4.1	4.3	52	62
17	Pool 23 H. E. o_2	10.6	10.8	4.2	4.4	50	64
18	Pool 24 H. E. o_2	11.0	11.1	4.2	3.9	52	54
19	Pool 25 H. E. o_2	11.0	11.3	4.0	4.0	54	58
20	Pool 26 H. E. o_2	11.1	11.2	3.7	4.0	54	58
21	PD(MS)6 H. E. o_2	11.1	11.4	3.6	4.1	52	62
22	CIMMYT H. E. o_2	10.5	11.4	3.7	4.1	50	60
23	Tuxpeño C_{11} x La Posta H. E. o_2	10.6	10.7	3.8	4.0	50	56
24	Lineas El Salvador H. E. o_2	10.8	10.3	4.2	4.2	51	57
25	(Thai Composite # 1 x PD(MS)6 H. E. o_2)-#	11.3	12.0	3.6	4.2	52	66
26	Amarillo Bajío H. E. o_2	11.8	11.2	-	4.1	53	61
27	Amarillo Bajío x Mezcla tropical amarilla	10.5	10.7	4.0	4.6	50	57

TABLE 31.- Amino acid composition of the whole grain in opaque-2 and sugary-2 opaque-2 segregates recovered from different materials.

Amino acid	Ver.181-Ant.Gpo. x Ven. 1 o_2		Yellow H.E.o_2		Temperate x tropical H.E.o_2		Mezcla amarilla H.E.o_2		Amarillo dentado H.E.o_2		Tuxpeño caribe H.E.o_2		Pool 24		PD(MS) 6 H.E.o_2	
	o_2o_2	$su_2su_2o_2o_2$	o_2o_2	$su_2su_2o_2o_2$	o_2o_2	$su_2su_2o_2o_2$	o_2o_2	$su_2su_2o_2o_2$	o_2o_2	$su_2su_2o_2o_2$	o_2o_2	$su_2su_2o_2o_2$	o_2o_2	su_2su_2	o_2o_2	$su_2su_2o_2o_2$
Lysine	3.7	3.8	4.0	3.8	3.7	3.9	3.7	3.9	3.8	3.7	4.0	3.9	3.5	3.8	3.7	3.8
Histidine	3.4	3.0	3.1	3.0	2.7	2.8	2.5	2.8	2.9	2 8	3.0	2.9	2.8	2.9	2.9	2 9
Arginine	6.0	6.2	6.2	6.1	6.0	5.9	5.6	5.6	6.1	5.6	6.4	5.9	5.7	5.8	6.0	5.8
Aspartic acid	9.0	9.0	9.3	8.9	9.3	8.9	9.9	9.8	9.5	8.9	10.6	10.2	8.6	9.1	9.7	9.1
Threonine	3.7	3.6	3.7	7.3	3.7	3.6	3.3	3.5	3.6	3.5	3.7	3.6	3.5	3.5	3.4	3.5
Serine	5.2	5.9	5.2	5.1	5.1	5.0	4.7	4.7	5.1	4.8	5.3	5.0	5.0	4.9	5.0	4.7
Glutamic acid	16.6	15.4	16.0	16.0	16.8	15.3	15.2	15.2	16.6	14.8	17.2	15.5	15.5	14.7	16.7	14.9
Proline	9.3	8.5	7.8	8.6	8.9	8.4	8.3	8.4	8.8	8.2	8.8	8.6	8.2	8.6	8.5	8.8
Glycine	4.9	4.6	4.8	4.7	4.5	4.6	4.4	4.6	4.8	4.6	4.8	4.7	4.5	4.7	4.7	4.5
Alanine	7.1	6.3	6.9	7.0	7 0	6.9	6 6	6.7	6.8	6.7	7.1	6.8	6.6	6.7	6.6	6.6
Cistine	1.7	1.6	1.9	2.0	1 7	1.6	1.7	1.3	1.5	1.6	1.4	1.7	1.4	1.5	1.4	1.6
Valine	3.9	3.7	3.9	3.8	3.8	3.7	3 4	4.0	3.8	3.7	3.9	3.8	3.7	3.6	3.6	3.6
Methionine	1.6	1.6	1.4	1.7	1.7	1.6	1.6	1.3	1.6	1.4	1.4	1.6	1.4	1.5	1.4	1.4
Isoleucine	2.4	2.2	2.5	2.3	2.5	2.2	2.1	2.5	2.3	2.2	2.4	2.2	2.1	2.1	2.1	2.2
Leucine	9.2	8.4	9.1	8.7	9.3	8.3	8.2	7.9	8.7	8.3	9.0	8.5	8.3	8.1	8.1	8.3
Tyrosine	4.5	3.9	4.1	3.8	4.1	3.8	4.0	3.6	4.0	3.6	3.9	3.8	3.5	3.5	3.8	3.6
Phenylalanine	5.1	4.2	4.7	4.4	4.7	4.4	4.5	4.0	4.3	4.0	4.5	4.3	4.2	4.1	4.2	4.1
Tryptophan	0.9	0.8	0.9	0.8	0.9	0.9	1.0	0.9	0.9	0.9	1.0	0.9	0.9	0.8	1.1	0.8
% Protein	11.8	12.6	13.0	13.1	13.5	13.1	12.1	13.0	12.6	12.9	12.4	12.8	12.5	12.9	2.1	13.4

TABLE 32.- Correlation coefficients (r) among several characters of opaque-2 and sugary-2 opaque-2 segregates recovered from 27 segregating populations.

	Character		2	3	4	5	6	7
1	100 kernel weight	o_2o_2	0.940**	-0.186	-0.244	-0.207	0.190	0.047
		$su_2su_2o_2o_2$	0.942**	-0.221	-0.181	-0.300	-0.172	0.001
2	Kernel volume	o_2o_2		-0.504**	-0.278	-0.190	0.217	0.106
		$su_2su_2o_2o_2$		-0.535**	-0.164	-0.190	-0.220	-0.052
3	Kernel density	o_2o_2			0.180	0.030	-0.153	-0.130
		$su_2su_2o_2o_2$			0.006	-0.210	0.213	0.155
4	Protein content of endosperm	o_2o_2				0.257	-0.611**	0.077
		$su_2su_2o_2o_2$				0.188	-0.440*	0.168
5	Protein content of whole kernel	o_2o_2					-0.192	-0.448*
		$su_2su_2o_2o_2$					-0.059	-0.242
6	Lysine in protein of endosperm	o_2o_2						0.266
		$su_2su_2o_2o_2$						0.050
7	Lysine in protein of whole kernel	o_2o_2						
		$su_2su_2o_2o_2$						

* Significant at 0.05 probability level.
** Significant at 0.01 probability level.

TABLE 33.- Percent protein, lysine and different protein fractions in the endosperm of eight sugary-2/opaque-2 materials.

S. No.	Pedigree	Protein (%)	Lysine in protein (%)	Protein fractions in protein (%) Acid soluble	Alcohol soluble	Glutenin
1	Ver.181-Ant.Gpo.2x Ven. 1 o_2	9.3	3.7	28.6	26.6	44.5
2	Yellow H.E.o_2	9.4	3.6	28.7	28.4	42.8
3	Temperate x Tropical H.E.o_2	10.2	3.6	26.5	29.4	39.6
4	Mezcla Amarilla H.E.o_2	9.4	4.3	28.3	26.8	44.4
5	Amarillo Dentado H.E.o_2	9.2	3.7	29.4	29.1	41.3
6	Tuxpeño Caribe H.E.o_2	9.4	3.4	26.4	29.5	44.0
7	Pool 24 H.E.o_2	9.0	3.8	28.0	25.7	46.0
8	PD(MS)6 H.E.o_2	9.5	3.5	26.5	28.9	44.4

TABLE 34.- Distribution of EVT-15 and ELVT 19 during the year 1976.

Trial No.	No. of entries	No. of sets distributed in different countries							Total
		South America	Central America	Caribe	Mexico	Africa	Asia	North America	
EVT-15	25	6	8	4	3	9	6	-	36
ELVT-19	10	8	12	6	5	12	16	1	60

TABLE 35 .- Results of Experimental Variety Trial No. 15 during the year 1976. (Grain yield in kgs/ha. at 15% moisture).

Entry No.	Populations	Tocumen Panamá	Bodles Jamaica	Sakha Egypt	Pantnagar India	Pichilingue Ecuador	Palmira Colombia	San Andres El Salvador	Guanacaste Costa Rica	Sn.Cristóbal Rep. Dom.	Omonita Honduras	Pirsabak Pakistan	Suwan Thailand	Poza Rica Mexico	Obregón México	Tlaltizapan Mexico	Means
1	Guanacaste 7437	4429	5784	2625	2303	5025	4794	4079	2060	3206	2630	4345	1958	1701	4291	7103	3756
2	Cotaxtla 7437	5240	4356	2840	2331	4420	4507	4291	1818	3012	2106	3751	3258	1812	4462	6437	3631
3	Sids 7537	5278	5088	2258	2871	4798	4861	4185	2287	3476	2273	4276	2791	1215	4699	7275	3842
4	Cotaxtla 7537	5091	5465	2201	2422	4820	4794	4024	2089	3003	2061	4464	1491	2219	4455	6366	3664
5	Poza Rica 7537	5473	4759	3085	3083	5097	4910	4000	2209	3612	2997	3904	2655	1440	4327	6748	3557
6	Across 7537	5070	5060	3302	2879	4783	4696	3709	2088	2649	2679	4229	1618	2241	4532	6475	3734
7	Pichilingue 7439	4654	5076	3129	2538	5333	4446	3512	1549	2667	2136	3558	2712	1453	4032	5679	3429
8	Suwan 7439	4907	4726	3317	2493	4781	3885	3394	1736	2691	2442	3820	2476	1146	4279	5709	3457
9	Cotaxtla 7439	5029	4338	3361	2286	4558	3939	3636	1823	2746	2230	3660	3033	1356	4305	6143	3534
10	Across 7439	4511	4359	3190	2653	4722	4077	3849	1625	2652	2042	3724	2558	1080	4277	5634	3437
11	La Máquina 7539	4179	4808	3354	2320	4579	3915	3949	1803	2882	2442	3158	2979	1936	4197	6127	3512
12	Amarillo Dentado H.E.o_2	4357	4464	3387	2472	3917	4492	3339	1771	3279	2649	3806	3227	1946	4591	6235	3599
13	CIMMYT H.E.o_2	4403	5581	3033	2639	4168	2973	3624	1473	2673	2533	3006	2636	1438	3338	5937	3301
14	Across 7539	5007	4701	3384	2933	4469	3834	4039	1851	2785	2794	3122	2467	1468	4137	6349	3556
15	Temp. x Trop. H.E.o_2	4074	3783	2312	2445	3463	2841	3164	989	2079	1827	3244	2206	692	3763	5307	2313
16	Across 7440	4306	5010	3392	2811	4222	3830	3321	2088	2646	1706	3411	3191	1758	4179	6043	3461
17	La Máquina 7540	5042	4775	3836	2314	4841	3786	3630	1570	2676	2206	3668	2573	1914	3903	5707	3503
18	San Andres 7440	3749	4271	3157	2475	4074	3258	3527	1654	2403	2158	3141	3133	1066	3613	5323	3134
19	Ferke 7537/2	5395	5067	2400	2718	4678	3951	3858	1986	2342	2906	3306	1397	1632	4391	6753	3622
20	Tuxpeño opaque-2	4916	5015	3012	2287	4142	4953	3933	1697	2303	2424	2952	1661	1228	4029	7113	3473
21	Yellow H.E.o_2	4397	4681	3467	2417	4546	3813	3488	1353	2342	2036	3492	1639	1753	4137	5883	3237
22	White H.E.o_2	4178	4546	2881	2187	4311	3317	3497	1526	2776	2032	3443	1900	1251	3907	5124	3128
23	PD(MS)6 H.E.o_2	3875	4093	3770	2367	4338	3653	3330	1756	2570	2173	2747	2321	1535	3693	5023	3153
24	Check 1*	3301	4780	1722	775	3293	2953	3912	451	3288	1391	2108	4315	1713	4307	6131	2967
25	Check 2*	4631	5241	3395	2491	5979	5321	3970	1559	3146	1576	2603	6573	2243	4303	6732	3988
Means		4640	4813	3052	2480	4534	4072	3730	1712	2836	2260	3498	2693	1602	4167	6148	
LSD (.05)		638	969	947	828	676	971	815	642	536	715	912	832	642	514	1008	
C.V.		9.7	14.2	21.9	23.6	10.5	16.9	15.4	22.4	13.4	22.4	18.4	21.9	28.4	3.7	11.6	

* not the same checks at each location.

TABLE 36 .- Results of ELVT No. 19 during the year 1976. (Grain yield in kgs/ha. at 15% moisture).

Entry No.	Pedigree	Cuyuta Guatemala	La Máquina Guatemala	Sta. Rosa Nicaragua	Tocumen Panamá	Guarare Panamá	Danli Honduras	Guanacaste Costa Rica	Alajuela Costa Rica	San Andres El Salvador	San Cristóbal Rep. Dom.	Cayes Haiti	Bodles Jamaica	Texaco Trinidad	Poza Rica Mexico	Obregón Mexico
1	Poza Rica 7437	3692	4904	4330	4804	2133	8018	3673	5206	3873	5007	5124	4667	1677	2518	4167
2	Across 7437	3318	4753	4358	4739	1488	7352	3358	4791	3879	5120	4982	4038	1347	2218	4003
3	Delhi 7439	3465	4561	4412	4897	1391	7158	3842	5900	3688	4383	4167	4650	1883	2342	3764
4	Poza Rica 7439	3361	3808	3618	5042	1704	6055	3484	4894	2088	4343	4803	4588	1585	2230	3939
5	San Andres 7440	3235	4222	3855	4255	1103	6579	2827	4618	2452	3590	4394	3915	1265	2230	3891
6	Poza Rica 7441	3455	3886	4179	4779	1685	6346	3558	3991	3355	4127	4149	3452	1302	2009	3621
7	Across 7441	2927	4546	4261	5155	1442	7130	3670	5800	3612	4457	5121	4433	1711	2303	3939
8	Check 1 PD(MS)6 H.E.o$_2$	2977	4056	4088	4442	1455	6473	3370	3808	3258	3977	4321	3948	1552	2839	3700
9	Check 2 (opaque-2)	3114	4351	2670	4115	1636	7364	4697	2355	3097	2907	2230	5767	1110	2924	3897
10	Check 3 (normal)	4316	5184	2624	4621	1976	8185	4330	7533	3700	4727	4467	7618	923	3164	6421
	Means	3386	4427	3840	4694	1610	7157	3600	4801	3390	4324	4376	4713	1436	2478	4034
	LSD (.05)	838	706	1133	414	665	852	873	1672	904	766	1624	986	602	728	773
	C.V.	17.3	12.8	20.7	8.2	28.9	8.3	16.6	23.9	18.7	12.4	26.0	14.7	29.3	20.6	13.4

Entry No.	Pedigree	Tlaltizapan Mexico	Cotaxtla Mexico	Saavedra Bolivia	Pichilingue Ecuador	Porto Viejo Ecuador	Kawanda Uganda	Sids Egypt	Delhi India	Pantnagar India	Pirsabak Pakistan	Khumaltar Nepal	Rampur Nepal	Site not men. Nepal	Suwan Thailand	Mea
1	Poza Rica 7437	6627	4888	4812	5206	5976	2692	6612	1367	4452	2742	5133	1502	6252	1800	427
2	Across 7437	7440	4761	5146	4291	6388	2029	5849	1061	5170	3049	4176	2705	6021	1976	420
3	Delhi 7439	6376	3915	4358	5079	5036	2614	6700	1230	5214	2700	4655	2411	5988	2110	410
4	Poza Rica 7439	5246	3591	4321	4806	5242	2373	6439	1594	4488	3406	4109	2264	5364	1682	359
5	San Andres 7440	4842	3639	4091	3024	4691	2350	5675	1370	4614	3103	4861	2566	5374	1006	362
6	Poza Rica 7441	5927	3761	4642	4158	5067	2361	6399	1855	4218	3558	4197	2163	5150	1749	375
7	Across 7441	6197	4185	4652	4455	6158	2076	6759	1839	4696	2424	4197	2241	5961	2500	403
8	Check 1 PD(MS)6 H.E.o$_2$	5861	3912	4267	4036	4406	2224	6614	1197	4427	3183	4018	2355	5152	1700	371
9	Check 2 (opaque-2)	6378	4403	5235	5539	6527	3138	7337	1570	5592	1768	3561	1598	4149	3321	367
10	Check 3 (normal)	6739	5056	5600	6570	5455	2212	8707	985	3609	2392	4270	2125	3509	4669	453
	Means	6104	4301	4717	4708	5405	2487	6709	1497	4648	2834	4318	2164	5355	2349	
	LSD (.05)	1287	721	927	703	944	562	1221	848	816	847	1074	566	1359	795	
	C.V.	14.6	11.7	13.8	7.3	8.5	15.8	12.7	39.6	12.3	20.9	17.4	10.0	17.8	23.7	

1/ Check 2 and Check 3 did not have the same pedigree at all locations.

TABLE 37.- Distribution of EVT-15 and ELVT-19 during the year 1977.

Trial No.	No. of entries	No. of sets distributed						Total
		South America	Central America	Caribe	Mexico	Africa	Asia	
EVT-15	11	6	7	5	6	8	6	38
ELVT-19	10	9	10	7	6	12	11	55

TABLE 38.-Quantity of opaque-2 maize seed shipped to different countries (January-June, 1976)

Country	Yellow H.E.o_2	White H.E.o_2	Comp.K H.E.o_2	Tuxpeño opaque 2	Ver.181-Ant. Gpo.2xVen.1o_2	Comp.I o_2	Mat.o_2 Comp.	CIMMYT H.E.o_2	PD(MS)6 H.E.o_2	Puebla Comp. o_2	M.Altitude temperate	Tropical x Temp.o_2	Miscellaneous
Açores (Atlantic Is.)	0.500	0.500							0.500				0.500
Bangladesh	0.75	0.75		0.75					0.75				
Canada	0.15	0.15		0.15	0.15			0.15	0.15				
Colombia	2.00	2.400		1.00									10.00
Denmark													0.730
Germany												0.300	0.600
Ghana	0.75			2.00									0.300
Gilbert Is.(W.P.)	0.75	0.75		0.75					0.75				
Greece	0.60								0.60			0.60	0.60
Guatemala									5.00				
Haiti	0.300	0.300							0.500				
India	0.500	0.500	0.500		0.500				0.500				
Ivory Coast	0.350	0.350			0.350								0.330
Korea						0.500				0.500			
Mexico		1.00		13,700			2.00		1.150	5.00	5.00	0.620	0.900
Nicaragua									2.500				
Nigeria	0.750	2.250		0.750					0.250				
New Zealand							0.75						0.75
Peru	0.250	0.250		0.250	0.250					0.150		0.150	
Philippines		0.150						0.150	0.300				0.600
Puerto Rico	0.60	0.60							0.60				
Romania												0.60	0.240
Swaziland	0.500				0.500							0.500	
Sri Lanka	0.320	0.320		0.320					0.320				
Trinidad & Tobago	0.300	0.300							0.450				0.300
Uganda	0.60	0.60		0.60					0.60				
U.S.A.	1.00	1.00	0.310	0.300	0.300				0.240			3.60	0.620
Venezuela					0.75								
Yugoslavia												0.30	0.100
TOTAL IN KG.	**7.190**	**9.605**	**0.810**	**18.545**	**1.990**	**0.500**	**2.075**	**0.165**	**12.055**	**5.650**	**5.000**	**5.320**	**15.395**

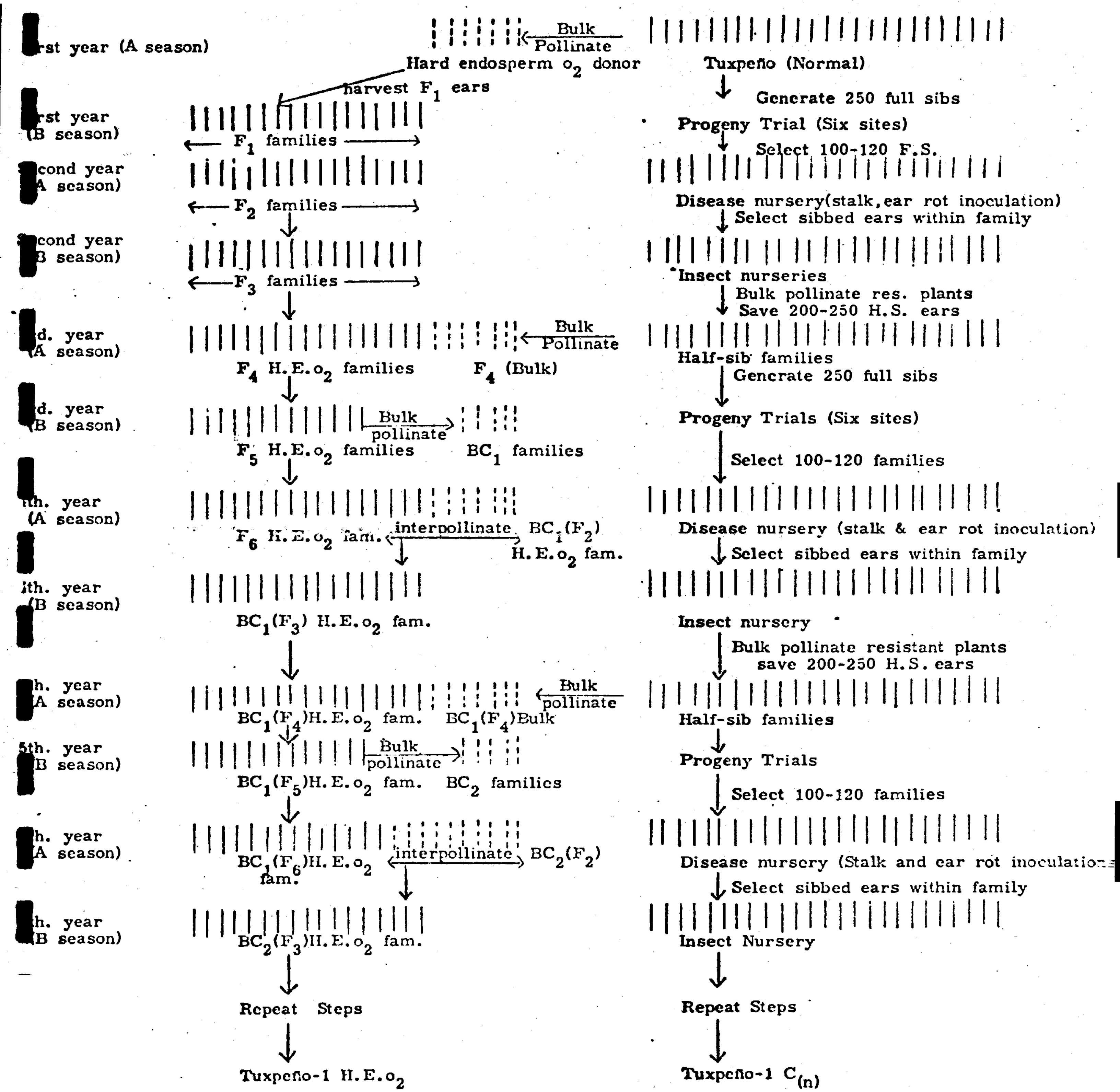
GRAND TOTAL OF OPAQUE-2 MAIZE SEED SHIPPED: 84.300

TABLE 39. Quantity of opaque-2 maize seed shipped to different countries (July-December, 1976)

Country	Yellow H.E.o_2	White H.E.o_2	Comp.K H.E.o_2	Tuxpeno opaque 2	Ver.181-Ant. Gpo.2xVen.1o_2	Comp.I o_2	Mat o_2 Comp.	CIMMYT H.E.o_2	PD(MS)6 H.E.o_2	Puebla Comp. o_2	M.Altidude temperate o_2	Tropical x Temp.o_2	Miscellaneous
Argentina									.500			.500	1.000
Bolivia									.250				
Brasil	.500	.500	.500	.500	.500								
China								.600	.600			.600	.600
Colombia				1.000					4.500				
Ecuador						10.000							1.000
Ethiopia	.500	.500				1.500			.500	.500	.500	.500	
Germany												1.000	1.000
Grenada (W.I.)	5.000		5.000										
Guatemala		115.000		116.000				1.000	1.000				10.000
India				1.000	1.000			1.000	1.000				10.000
Korea												.120	
Mexico	.700	.500		.200	.500								.500
Peru						1.000							1.000
Philippines	1.000	1.000		1.300	1.000			1.000	1.800				14.000
Puerto Rico	.260	.260		.260					.260	.520		.260	.260
Spain												.130	
Saint Vincent (W.I.)	.250								.250				
Sri Lanka	.260							.260	.260				.520
Thailand	1.000			1.000	1.000			1.000	1.000				10.000
Trinidad	1.000	1.000							1.000				2.000
Uruguay									1.000				
U.S.A.										2.000			.750
Venezuela									.060				.260
Zaire		.130		.130									.780
TOTAL IN KG.	**10.470**	**118.890**	**5.500**	**121.390**	**4.000**	**12.500**		**4.860**	**13.980**	**3.020**	**.500**	**3.110**	**54.200**

GRAND TOTAL OF OPAQUE-2 MAIZE SEED SHIPPED : 352.420 KG.

SCHEME FOR MAKING PARALLEL IMPROVEMENT IN NORMAL AND OPAQUE-2 COUNTERPART POPULATION



III.- CHEMICAL RESEARCH AND ANALYTICAL SERVICE

A. INTRODUCTION

The protein quality laboratory has provided during the last year a continuous service to the breeding programs. In order to assist the breeders with the nutritional improvement of their materials, screening methodologies have been applied to thousands of samples from different experimental stations and cycles of selection.

The genetic improvement of hard endosperm opaque-2 and floury-1 opaque-2 maize lines has been only possible with the aid of the chemical data provided by the laboratory.

Biological experiments with the best promising maize materials are now underway in cooperative institutions like INIP (National Institute of Animal Nutrition) in Mexico City and the Agriculture Experiment Laboratory in Denmark.

Great effort has been also directed into the training of young scientists from developing countries which return home at the end of a three month period to establish a service laboratory for their agricultural national program.

B. LABORATORY SERVICE

The improvement of maize protein quality has been detected and followed up after each cycle of selection by using protein and tryptophan analysis of the endosperm of each genetic family. During the past year approximately 14,000 samples have been analyzed for these two parameters. Lysine content has been quantitatively determined only in selected promising lines either by the 2-chloro 3-5, dinitropyridine colorimetric method (Villegas, E. & Mertz, E.T., 1971) or by ion exchange chromatography in a Beckman 120 C aminoacid analyzer especially in colored endosperm samples when problems are encountered with the colorimetric procedure (Spackman, D. et al, 1958). Complete aminograms using the Beckman 117 aminoacid analyzer with the single column methodology (Benson, R.J., 1972) were performed for the best advanced high quality materials with hard endosperm or floury opaque-2 samples.

The dye binding capacity method (DBC) (Mossberg, R., 1969) along with the protein analysis have been used in screening for protein quality in whole kernel maize samples. The quality index (Q.I.) obtained for each sample is really the value of DBC per gram of protein. This Q.I. correlates well with % of lysine in protein of the materials. The whole kernel samples are ground in a Udy cyclone mill with a 0.5 mm screen in order to obtain a fine and homogeneous flour. The ground materials are not required to be deffated as in the case of tryptophan analysis. This allows us to save great time and to have a better continuous system.

Different methodologies have been studied for the quick identification of materials with high protein quality using the ninhydrin test (Mertz, E.T., et al, 1974). We have observed that more reliable results can be obtained for the qualitative identification of materials that carry on the opaque-2 gene either on single kernel without destruction of the germ or ground sample of genetic family, by performing the test without any heating for color development during the reaction of the free aminoacids with the ninhydrin reagent. Out of 397 genetic families; 45 kernels of each were tested for the presence of the opaque-2 gene. The percentage of kernels with positive reaction varied from genotype to genotype. These selected seeds were returned to the breeders for their propagation.

We have been testing successfully a new method for protein hydrolysis (Liu, T.Y. and Chang, Y.H., 1971). This technique utilizes an organic acid (p-toluene-sulfonic) instead of hydrochloric acid with the advantage that we don't have to evaporate the excess of acid as it's normally done when HCl is used. Accuracy and reproducibility is adequate and time is greatly saved. This has been valuable to us when lysine analysis of a large number of samples must be reported to the breeders in a short time period.

The best promising hard endosperm opaque-2 materials as well as some sugary-2 - opaque-2 lines were subjected to fractionation of their endosperm proteins. Three fractions were separated on the basis of protein solubility (Mertz, E.T. and Bressani R., 1957). Four opaque-2 samples were fractionated into five fractions by a more recent method (Landry, J. and T. Moureaux, 1970). A comparison between both methodologies was made in basis of the results obtained.

In all the high quality samples fractionated, the decrease in the prolamine fraction was observed (Table 1) with the concomitant increase in the other protein fractions with the consequent increase in the lysine content of the total endosperm protein.

Data of analysis of most materials has been presented in the breeding section.

The Plant Nutrition Laboratory analyzed approximately 2,000 samples which include grain, stems, leaves and corn cob for nitrogen content.

The main objectives are to explore the genetic variability in maize for ability to take up nitrogen from soil and to determine the proportion of the nitrogen taken up that is moved into the grain.

In addition 300 stem samples were analyzed for total sugar content as a guide to the potential for yield increase.

C. BIOLOGICAL EVALUATION

At present time CIMMYT with the collaboration of the INIP and the Agricultural Experiment Laboratory (Denmark) has evaluated biologically the most promising advanced materials that were previously selected through chemical analysis. The animal test used for this evaluation was the white rat.

The material evaluated is identified as follows:

Sample No.	IDENTIFICATION
1	HE O_2, PR-76 B, Bh-101
2	PD (MS) 6 HE O_2, IPTT-38
3	Yellow HE O_2, IPTT-39
4	Tuxpeño O_2 (soft) PR-76 A # (IPTT-37)
5	Amarillo Dentado HE O_2 PR 76-13, 801
6	Ant. x Ver. 181 HE O_2, 806 #
7	Ant. x Rep. Dom. HE O_2, Lote 9.9

Note: Samples 1 to 3 and 5 to 7 = hard endosperm types.
Sample 4 - soft endosperm type.

The grain samples were analyzed for nutrients (Table 2) as well as for aminoacid composition (Table 3). In table 4 are shown the results of the nutrition studies.

The response criteria are: True Digestibility (TD), Biological Value (BV) and Net Protein Utilization (NPU), where:

TD is the percentage of nitrogen intake which is absorbed by the organism (nitrogen intake minus fecal nitrogen of dietary origin).

BV expresses the percentage of the absorbed nitrogen that is retained in the body (digested nitrogen minus nitrogen eliminated in the urine).

NPU indicates the actual nitrogen retention in the organism. It is thethe product of TD and BV expressed in percent.

The TD of cereal grain protein in general, is known to be between 80 and 90%. The CIMMYT maize samples instead show higher values (95.3 to 96.6%). Less than 5% of the dietary nitrogen was not absorbed by the rats.

Since the Biological Value (BV) is the part of absorbed nitrogen which is retained in the organism, it indicated protein quality. The respective values are fairly high between 72 and 78%, the BV values agree very well with the lysine values of the respective samples; samples 4, 5 and 6, which show the highest BV (77.6, 74.5 and 76.2% respectively) are also at the top in lysine content (higher than 4%). It has to be mentioned, that in the group of these three top samples, one is a soft endosperm type, the others are hard endosperm types. The samples 1,2,3, and 7 also performed well, they are placed fairly closed behind. It is satisfying to see that the nutritional quality of the hard endosperm types is as good as the quality of the soft type. This was already observed in previous experiments.

Since there is almost no variation between TD values, the differences in NPU values agree with the respective BV values.

Dr. Eggum from Agricultural Experiment Laboratory (Copenhagen, Denmark) is preparing a more detailed report on his evaluation with the comparison of the data obtained with normal, opaque-2 hard and soft endosperm. We wish to acknowledge Dr. Eggum for his desinterested and helpful cooperation in the evaluation of these materials.

At INIP laboratory the same samples are now under evaluation using rats and Tribolium castaneum. The results of these assays will be included in the next year report.

REFERENCES

Benson, R. J. "Single column analysis of amino acids". Durrum Resin Report No. 4, 1972

Landry, J. and T. Moureaux. "Heterogeneity of the glutelins of the grain of corn: Selective extraction and composition in aminoacids of the three isolated fracions. Bull. Soc. Chim. Biol. 52:1021 (1970).

Mertz, E. T. and R. Bressani. "Studies of Corn Proteins" I. A new method of extraction. Cereal Chemistry 34: 63 (1957).

Mertz, E. T.; D. S. Misra and Jambunathan R. "Rapid ninhydrin color test for screening high lysine mutants of maize, sorghum, barley and other cereal grains". Cereal Chemistry 51:304-307 (1974).

Mossberg, R. "Evaluation of protein quality and quantity by dye-binding capacity. A tool in plant breeding in new approaches to breeding for improved plant protein Ñ (1969). FAO/IAEA Division of Atomic Energy in Food and Agriculture, IAEA. Vienna.

Spackman, D.; W. Stein and S. Moore. Analytical Chemistry 30, 1190 (1958).

Villegas, E. and E. T. Mertz. "Chemical Screening Methods for Maize Protein Quality at CIMMYT". International Maize and Wheat Improvement Center. Research Bulletin No. 20. Apdo. 6-641, México 6, D. F.

Liu, T. Y. and Y. H. Chang, Hydrolysis of proteins with p-Toluen sulfonic acid., The Journal of Biological Chemistry, Vol. 246, No. 9, Issue of May 10th, U.S.A., 1971, pp. 2842-2848.

TABLE 1.

Protein Fraction		% TOTAL PROTEIN				
		Tuxpeño Normal	CIMMYT O_2	TEMP. X TROP. ~~HE-O_2~~		
				Modified	x su$_2$o$_2$ (hard) seg.	x su$_2$o$_2$(soft) seg.
(Mertz-Bressani)	I	21 - 25	31 - 35	32.2	26.5	28.6
	II	45 - 55	26 - 30	33.7	29.4	39.2
	III	16 - 20	31 - 35	31.6	39.6	31.1

Protein Fraction		% TOTAL NITROGEN			
		CIMMYT O_2	TEMP. X TROP. HEO_2		
			Modified	x su$_2$o$_2$ (hard)	x su$_2$o$_2$ (soft)
(Landry - Moureaux)	I	18.6	11.7	20.0	20.6
	II	11.2	15.5	16.6	19.5
	III	14.7	20.7	14.4	18.2
	IV	16.1	17.8	14.8	11.8
	V	39.2	34.0	34.0	29.7

TABLE 2.- NUTRIENT CONTENT OF MAIZE SAMPLES USED IN NUTRITION STUDIES *

Nutrient %	SAMPLE NUMBER 1	2	3	4	5	6	7
Dry matter	88.8	88.8	89.1	88.4	89.0	89.3	89.0
Nitrogen	1.58	1.69	1.73	1.50	1.67	1.76	1.79
Ash	1.58	1.27	1.61	1.60	1.60	1.60	1.64
Fat	4.84	4.55	4.94	4.79	5.43	5.21	5.12
Starch	63.07	64.14	64.44	64.76	62.69	63.69	62.52
Crude Fibre	2.25	2.43	2.38	2.32	2.56	2.47	2.61

* Data obtained by Dr. B. O. Eggum, Denmark

TABLE 3.- AMINO ACID COMPOSITION OF MAIZE SAMPLES USED IN NUTRITION STUDIES*

	SAMPLE NUMBER						
	1	2	3	4	5	6	7
AMINO ACIDS (g / 16g NITROGEN)							
Aspartic Acid	7.04	6.98	7.57	7.82	7.71	7.74	7.39
Threonine	3.45	3.47	3.66	3.63	3.76	3.56	3.50
Serine	3.94	3.98	4.27	4.24	4.40	4.13	4.05
Glutamic Acid	16.59	17.70	17.06	16.82	17.41	17.19	17.58
Proline	9.25	9.95	9.34	8.72	9.82	9.74	9.59
Glycine	4.48	4.39	4.78	4.82	4.87	4.80	4.57
Alanine	5.66	6.06	5.99	5.96	6.10	5.92	6.02
Valine	5.08	5.15	5.26	5.22	5.39	5.33	5.22
Isoleucine	3.08	3.25	3.23	3.29	3,29	3.25	3.25
Leucine	8.45	9.58	8.84	8.63	9.02	8.74	9.32
Tyrosine	3.40	3.56	3.54	3.55	3.62	3.47	3.56
Phenylalanine	3.80	4.01	4.02	3.99	4.11	3.99	4.05
Lysine	3.79	3.54	3.98	4.18	4.09	4.04	3.76
Histidine	3.67	3.75	3.81	3.58	3.89	3.82	3.70
Arginine	6.46	6.18	7.00	6.86	7.10	7.19	6.69
Methionine	1.65	1.78	1.79	1.88	1.82	1.76	1.70
Cystine	2.54	2.73	2.65	2.56	2.75	2.67	2.59
Tryptophan	0.91	0.95	1.35	0.96	1.16	1.03	0.92

* Data obtained by Dr. B. O. Eggum, Denmark.

TABLE 4. - TRUE DIGESTIBILITY (TD), BIOLOGICAL VALUE (BV) AND NET PROTEIN UTILIZATION (NPU) FOR SEVEN MAIZE TYPES*

	RESPONSE CRITERIA					
Sample	TD		BV		NPU	
Number	%	(s)	%	(s)	%	(s)
1	95.6	0.4	73.5	.8	70.2	.9
2	95.7	0.5	71.8	1.4	68.7	1.3
3	95.3	1.0	74.0	1.4	70.5	1.9
4	96.0	1.8	77.6	2.1	74.5	1.3
5	95.8	1.4	74.5	0.8	71.4	1.4
6	96.6	1.1	76.2	1.5	73.6	1.2
7	95.5	0.9	74.3	1.0	71.0	0.9

* Data obtained by Dr. B. O. Eggum, Denmark.

IV.- TRAINING

A. TRAINING AND GUIDANCE IN PROTEIN QUALITY ANALYSIS

Continuous support of technical advisement and laboratory equipment has been provided to service protein quality laboratories of national agricultural programs, among which must be mentioned the following countries: Brazil, Colombia, Ecuador, Egypt, Guatemala, India, Pakistan, Peru, Philippines, Romania and Thailand. The CIMMYT laboratory staff visited some former trainees and generally worked with them for a few days looking out at specific problems.

During the period under report the following persons have received training in our laboratory:

NAME	COUNTRY
Mr. Luis Humberto Andrade Badillo	Ecuador
Mr. Sabir Hussain Shah	Pakistan
Miss Ratana Punsawat	Thailand
Miss Redia N. Gicana	Philippines
Mrs. Rosario Montenegro de Nevado	Peru

B. TRAINING IN MAIZE IMPROVEMENT AND PRODUCTION

During the period under report (September 1976 to August 1977) 74 trainees received training in maize production and improvement at CIMMYT. 57 in maize production and 17 in maize improvement. Of these 18 trainees were funded by UNDP. The names of the in-service trainees, country of origin and the field of specialisation are listed in the attached table.

We consider training as a very important factor in developing strong national programs with adequately trained young scientists to exploit the new technology and materials coming out of the quality protein maize international breeding program. This ever-expanding group of highly motivated young scientists is necessary to accelerate maize production at a rate necessary to significantly influence the food production in many of the developing countries.

[redacted]IZ[redacted]PR[redacted]U C[redacted]OI[redacted]R[redacted]E[redacted]

Country	Name	Country	Name
Bolivia	Florian Rodríguez	Pakistan	Ata-Ur-Rahman
			Ahmad Nawaz
Costa Rica	Jorge Luis Ulate Murillo		Gulfam Khan Jahangire
Dom. Rep.	Adelina Montolío Barranco	Panama	Andrés Eloy González
	Antonio Calderón Reyes	Papua	Kado Wudrag
	Pedro Rodríguez Alvarez		
Dominica	Derrick Zamore	Perú	Roberto Julio Contreras Málaga
Ecuador	Galo Joaquín Bruque Chiriboga	Tanzania	Ross Francis Mawkyoma
	Santiago B. Crespo Orellana		Timothy Maembe
			Dudley Lameck
El Salvador	José Ernesto Portillo		Seraphin Fulko Antapa
Ethiopia	Tassew Gobezayehu		Sharif Nurdin Katuli
Grenada	Kenneth Rush		Esther Elisafisha Lyimo
			Gabriel Nick Lyimo
Haiti	Eddy Salador		Joseph Mwangeni Gallus
	Claude Philogene Wroy		David Mfaume Mwanjali
	Joseph Saint Phard		Harold Zephaniah Ngowi
Honduras	Diego Alvarado Sevilla		Awon Honsia Ngowo
	Ricardo Cerrato		Stanely Gondwe
	José Manuel Aguilar Maradiaga		Abbas Hussein
	Ramón Osorio Rodríguez		Samuel E. Munuo
	Wilfredo Córdova Escoto		Yahya A. Sudi
México	Antonio Castillo Guillén	Thailand	Teerasak Manupeerapunt
	Celso Gutiérrez Macías		Sakol Petchmanee
	José Luis Molano	Tunisia	Mohamed Kraoua
	Leoncio Quintanilla Cobián		Mustapha Limame
	Isidoro Oscar González Enciso	Yemen	Ismail Al-Haddad
	José David Michel Padilla		
	Gerardo Salgado Sotelo	Zambia	Mulele Russell Mulele
Nepal	Bimal Kumar Baniya		
	Krishna Lall Rauniyar	Total	57 trainees
	Prakash Shrestha		
Nicaragua	Wilfredo Méndez		

MAIZE IMPROVEMENT TRAINEES

Country	Name
Colombia	José Evers Vargas Sánchez
Egypt	Boshra Nagib Ayad
	Sadek El-Shahat Sadek
Guatemala	Fidel Rangel
Honduras	José Antonio Márquez Figueroa
	Antonio E. Osorio Bárcenas
Korea	Seok Dong Kim
Nepal	Leashab Prasad Shrestha
Pakistan	Mohammad Aslam
Peru	Víctor de la Colina Kalinowski
	Luis Narro León
Philippines	Emmanuel M. Serrano
Tanzania	Hugh Banjamin Sonje
Thailand	Bunponte Tasanasuwan
	Nipon Iamsupasit
Venezuela	Jesús Ma. Llavaneras Torres
Yemen	Fadil A. Maflahi
Total	17 trainees