UNDP-CIMMYT Global Research Project

# UNDP - CIMMYT

# GLOBAL RESEARCH PROJECT

## (Phase III)

CIMMYT

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CIMMYT PROGRESS REPORT

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## REPORT OF UNDP-CIMMYT GLOBAL RESEARCH PROJECT

## GENETIC AND BREEDING RESEARCH

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# GENETIC AND BREEDING RESEARCH

## 1. INTRODUCTION

Within the past fourteen years, the task of breeding for nutritionally superior maize types has been greatly facilitated by the discovery of the biochemical effects of the opaque-2 and floury-2 genes. Through manipulation of these two genes, it has been possible to produce biochemical alterations in various protein fractions. These alterations can boost the concentration of lysine and tryptophan in maize endosperm protein to levels almost double those found in normal maize. The enhancement of these two amino acids make the maize protein better balanced and nutritionally superior. Since these discoveries maize breeders in maize growing countries of the world have introduced these genes into their most promising maize stocks. However, there seems to have been a decline in interest and resources devoted to the breeding and development of this type of maize, with considerably reduced research emphasis in this area of maize breeding. This unfortunate reduction has resulted partly from the difficulties encountered in breeding and developing quality protein maize populations or hybrids that can compete equally with the normal maize types. Problems differ both in degree and magnitude in different areas around the world.

## 2. REVIEW OF DEVELOPMENTS AND BREEDING APPROACHES RELATING TO QUALITY PROTEIN MAIZE.

Before reviewing the development of opaque-2 maize, it seems appropriate to cite the maize breeders' traditional fascination with new genes or gene combinations that cause drastic alterations in plant or seed characteristics. Usually, these genes have been most difficult to manipulate and exploit effectively in practical maize breeding programs. The discovery of new gene(s) usually generates tremendous initial excitement and this enthusiasm lasts for some time and then starts declining when several other problems are found associated with the exploitation of these new genes or gene combinations. The direct exploitation or utilization of these genes in the breeding program is no longer an easy task. Several thousand years of natural evolution coupled with mild human selection has evolved different maize genotypes in different ecological regions which have assembled different constellation of genes or gene combinations that favor certain wild alleles to function more efficiently at the biochemical level. When the mutant alleles of more recent origin are introduced in such evolved genotypes, the whole series of genes and gene combinations of this genotype no longer favor the recessive alleles in the same way as did the wild alleles. A considerable amount of ground work may thus be necessary before such genes can be exploited to advantage. Though there are some good examples of direct usefulness of such genes with dramatic effect in other cereal crops, the straight introduction of such genes in maize rarely, if ever, has resulted into genotypes that can be accepted directly.

In the mid-1960's, both opaque-2 and floury-2 mutants sparked considerable enthusiasm. The use of these genes gained tremendous momentum in developing quality protein maize types in all maize growing countries of the world. Attempts were made by all interested breeders to incorporate these genes into the most promising inbred lines and the open-pollinated maize varieties. At this point most researchers were interested in obtaining opaque-2 versions of their best normal genotypes as rapidly as possible. To achieve this objective, several short-cuts were used in converting normal materials to opaque-2. (This was more often the case in hybrid development programs where the interest was to have opaque-2 versions of lines involved in hybrid combinations). This approach did help to produce opaque-2 hybrids somewhat earlier but unfortunately most of these hybrids failed to compare in performance to the normal counterparts. This straighword backcrossing procedure has a disadvantage in that in the absence of segregating generations, it does not permit selection for favorable modifiers if such modifiers are present in the stock under conversion. In the late 1960's and early 1970's, the intent of most breeders was to introduce this gene without being concerned to overcome some of the undesirable side-effects associated with this gene. Most of the breeders did not expect that opaque-2 materials will suffer from such complex and interrelated problems that could act as a bottleneck in the commercial production and utilization of these materials.

The initial era of conversion programs produced a number of opaque-2 maize hybrids and open-pollinated opaque-2 maize varieties. Some of these appeared on the commercial scene. The early seventy's saw the spread of the opaque-2 materials in some countries. The greatest enthusiasm and spread was seen in Brasil, Colombia and the U.S.. The area grown in this maize steadily increased. This trend, however, did not continue. Very soon the short-comings of opaque-2 materials were realized, which slowed further spread of opaque-2 materials in these countries. The area grown started declining and in some countries this maize was soon completely out of production. Now, very few countries are growing opaque-2 maize, and there is very insignificant maize acreage. Unless the problems are solved soon, the debate whether or not to grow opaque-2 maize will continue. For bringing opaque-2 maize into prominence it seems imperative to allocate the available resources to solve the problems.

The introduction and spread of opaque-2 maize in some countries clearly demonstrates some of the most important weaknesses of these materials. At this stage, economic and acceptability surveys were carried out in some countries. The results of such surveys proved beyond doubt that the problems from which this maize suffers were of considerable concern and acted as a major hurdle in the acceptance of this maize. The problems considered most serious included: reduced grain yield, unacceptable soft chalky lustreless appearance,greater vulnerability to ear-rots and stored grain pests, and inability to lose moisture fast following physiological maturity of the grain. The underlying causes of some of the problems are now somewhat better understood, and will be discussed in a separate section below.

Realizing the complexity of problems involved in the breeding of opaque-2 maize, relatively little effort has been devoted to the understanding and to the solution of problems confronting opaque-2 maize. Some research effort in this direction was started as early as the 1970's. The approaches or the methodology used, however, were different in various research programs. Some of the developments that have taken place in this area are described next along with the relative merits and demerits of some of these approaches.

i) Search for new mutants:

A sustained search has been underway to find new and better high-lysine mutants. Such efforts have resulted in identifying new mutants such as opaque-7 ($o_7$), opaque-6 ($o_6$) and floury-3 ($fl_3$). Like opaque-2 or floury-2, these new mutants have an ability to manifest themselves fully in triploid endosperm with three doses of recessive alleles. Also, the kernel phenotype of these mutants is soft and chalky. These new mutants do not offer any advantages over opaque-2 or floury-2, rather both $o_6$ and $fl_3$ have additional problems with seed development and maintenance.

ii) Recurrent selection for high-lysine in normal populations

There is variation in lysine content in different normal materials and this can be exploited by various recurrent selection schemes to upgrade the nutritional quality of normal maize without the use of mutant genes. Encouraging results have been reported by some research workers. This approach was tried at CIMMYT in the late sixty's. Based on experience CIMMYT breeders have recognized that there are several problems in developing high-lysine maize populations with this approach, at least for use in the developing countries. Some of the drawbacks that prevent the use of this approach in the developing world are: lack of well equipped laboratories, a narrow range in lysine values for selection, difficulty in transferring this trait to other materials and lack of assurance about its superior biological value.

iii) Increasing germ size

Increasing germ size is another way of improving both the quantity and quality of maize grain protein. This method also has limitations, because the size of germ can be increased up to only a certain point without adversely affecting other traits. Also, it is practically impossible to attain lysine levels anywhere near those of the opaque-2 maize. The increased germ size might have another disadvantage, particularly in those areas where the germ is discarded in maize food preparations.

iv) Developing double mutant combinations

Two double-mutant combinations have been of interest in changing the soft endosperm to hard endosperm: opaque-2/floury-2 and opaque-2/sugary-2. Little success has been reported with floury-2/opaque-2, because the two genes interact favorably to give vitreous kernels only in rare genetic backgrounds.

The interaction between sugary-2 and opaque-2 results in vitreous kernels with protein quality that is either equal to or slightly better than the opaque-2 alone. Reduced kernel size and grain yield, however, are the major barriers to the successful exploitation of this combination. (This double mutant is discussed further in the section entitled sugary-2/opaque-2).

v) Exploitation of genetic modifiers of opaque-2 locus

This approach has been tried at several institutions,including CIMMYT. Sufficient information and data have been accumulated at CIMMYT to demonstrate that the kernel appearance and some other major problems confronting opaque-2 maize can be overcome speedily and effectively through careful and systematic selection for vitreous kernels. Information on different aspects of genetic modifiers is discussed in appropriate sections of this report.

## 3. PROBLEMS, UNDERLYING CAUSES, AND RESEARCH EMPHASIS IN DEVELOPING ACCEPTABLE TYPE OPAQUE-2 MATERIALS.

i) Reduced grain yield

Reduced kernel weight in opaques is one of the most serious problems in developing acceptable materials. The opaques, in general, cease accumulating dry matter in the grain somewhat earlier than do the normal maize. This inherent defect in opaques is the primary cause of reduced kernel weight. Through accumulation of favorable modifiers, it is possible to overcome this yield barrier in the opaques. Variation for kernel weight and density exists in materials segregating for the opaque-2 gene and it is possible to capitalize on this variation through accumulation of favorable modifiers.to close the gap between the opaques and normals.

It has been observed that selection for increased kernel hardness results in spacing between the kernel rows due to smaller kernel size. The width of spacing varies from material to material and also from family to family within the same material. The occurrence of spacing between kernel rows provides a good measure for evaluating kernels or ears that fail to reach their full potential because of early cessation of dry matter accumulation. This character can be used as one of the criteria in selecting for better kernel weight in the hard endosperm opaque-2 materials.

ii) Unacceptable kernel appearance

Interspersed air-spaces between starch granules produces an opaque appearance with soft floury endosperm. The soft kernel texture of the opaques can be altered so as to appear more translucent with more normal looking endosperm without sacrificing protein quality. Shiny, translucent hard endosperm opaque-2 materials can be developed through exploitation of genetic modifiers.

iii) Ear rots

The opaques, in general, show greater ear rot damage than do the normals. The higher incidence of ear rots in opaques can be attributed to several causes, including the use of unadapted opaque-2 donor stock, a thicker pericarp, a popped kernel tendency, the soft floury endosperm of opaques, and the slower drying, in addition to genetic differences among materials. The ear rot incidence in opaques can be reduced through the use of a backcrossing program, the exploitation of genetic modifiers, and by capitalizing on variation that exists for various factors contributing to ear rots.

iv) Greater moisture content at harvest

Opaques have a higher kernel moisture percentage at harvest as compared to their normal analogues. Poor permeability of pericarp, thicker pericarp and probably greater concentration of some of the hydrophilic compounds can affect the ability of grains to lose moisture. This problem can be overcome by exploiting variation for this character that is found in opaque-2 converted materials. Ears that show better ability for drying can be separated visually by harvesting opaque-2 materials 5 to 6 days earlier than usual. To practice selection for this character at family level, the plants within a family that have flowered on about the same day can be marked. At harvest, only those ears that appear to be drier can be selected. In materials undergoing population improvement, the problem of slower drying can be overcome effectively by selecting and recombining families that have higher grain yield and lesser moisture content in the grain at harvest.

## 4. CIMMYT'S RESEARCH RATIONALE AND OBJECTIVES IN DEVELOPING QUALITY PROTEIN MAIZE MATERIALS.

Key points in CIMMYT's rationale for research are:

a) The initial boost in lysine level resulting from the introduction of opaque-2 gene is of sufficient magnitude to improve the nutritional quality of maize considerably. Thus, following incorporation of opaque-2 gene, no major emphasis is placed on further enhancing the level of lysine. Rather effort is made to maintain the protein quality at a protein level of 9-10% in the whole grain.

b) CIMMYT recognizes that protein quality maize materials must perform competitively with normals, otherwise their acceptance and commercial exploitation by the farmers will be difficult.

c) Major emphasis is placed on breeding agronomically superior, high-yielding, quality-protein materials to obtain the same calories as found in normal maize, with quality protein as a bonus.

d) Several genetic backgrounds are being converted to hard endosperm opaque-2 so that these materials can serve either as donors or source genetic stocks for further selection in many countries that do not have the facilities to do the initial basic work.

e) Simple qualitative and quantitative biochemical analyses are used for preliminary screening, followed by more complete analyses on the bulk samples for more accurate information and to assess changes occurring in the population from year to year.

In developing quality protein opaque-2 materials, the major emphasis is placed on the following research activities:

a) Converting all advanced populations and back-up gene pools in CIMMYT's maize improvement program to opaque-2.

b) Continuing research emphasis on the development and improvement of opaque-2 back-up pools with tropical, temperate and highland adaptation.

c) Improving yield, agronomic traits and adaptation of advanced unit opaque-2 populations over a range of environments.

d) Continuing principal strategy on the accumulation of favorable genetic modifiers in the opaque-2 materials at all stages of maize improvement.

e) Placing major emphasis on stabilizing genetic modifiers over a range of environments through multilocation observational nurseries and progeny tests.

f) Selecting for ear rot resistance through natural and artificial inoculations with ear rot organisms.

g) Continuing emphasis on the development and improvement of floury-1/ opaque-2 maize materials for countries in the Andean region.

h) Continuing improvement of sugary-2 opaque-2 population to examine its potential for future use.

i) Evaluating different generations or cycles of materials at all levels for progress.

j) Distributing materials in the form of progenies, experimental varieties, and populations to develop stronger international cooperation in the testing and evaluation of materials.

k) Evaluating promising more advanced materials for biological assay and feeding trials.

5. CONVERSION PROGRAM

Conversion of normal maize materials to hard endosperm opaque-2 continues in the Advanced and Back-up units. Conversions of some of the promising materials in Special Projects and Collaborative Research are also being developed. In converting these wide range of materials to opaque-2, the major emphasis is on selection for modified opaque-2 kernels to accumulate the frequency of favorable modifiers. Laboratory analysis are usually performed on all hard endosperm opaque-2 families in different materials to eliminate those families in which the protein quality may have been affected adversely as a result of selection for vitreous endosperm. Hard endosperm opaque-2 materials with good kernel characteristics and with a high frequency of modifier genes are used in additional backcrosses to the most advanced cycle of the recurrent parent population. Also, since most of the materials have gone through several cycles of selection for genetic modifiers, the conversion scheme includes a procedure for screening the stability of hard endosperm opaque-2 families over environments. A backcrossing-cum-recurrent selection was designed to meet this need. This approach provides the following unique features:

a) An improved version or the latest cycle of selection of the recurrent parent undergoing population improvement is used in each backcross.

b) The appearance of hard endosperm opaque-2 kernels determines the next backcross. It is often necessary to advance the $F_2$ segregates to $F_3$ or $F_4$ to accumulate the frequency of modifiers necessary, before actually making the next backcross.

c) The scheme permits selection in homozygous backgrounds, though it slows the recovery of the recurrent parent genotype.

d) Continuous improvement of modifiers, in addition to other characters, is done cycle after cycle. The backcrossed families are handled so as to prevent dilution of accumulated modifiers.

e) The scheme permits selection for stable modifiers in one season and recombination in the next.

f) After each backcross, it is not necessary to begin the process anew. Thus the research effort in accumulating modifiers and maintaining protein quality is not lost.

g) Selection for kernel weight and density can be made in each segregating generation. Those advanced generation backcrossed families are retained that show only small differences in the kernel weight of opaques and normals.

h) During the recombination process, each family is crossed with as many other families as possible. The crossing program resembles mating design-1, except that interfamily pollinations are made.

i) At any stage materials that look good can be used in evaluation trials, or for other purposes, irrespective of whether one or more backcrosses have been made.

During the conversion program, some characters are ~~given~~ particular emphasis, because they will ultimately aid in improving the performance of hard endosperm opaques for yield, kernel appearance, reduced ear rot incidence, and ability to lose moisture quickly. Several direct and indirect field criteria are used to alleviate problems associated with opaque-2 maize. Some of these criteria are:

a) Spaces between kernel rows

This criterion provides a good measure for evaluating the ability of kernels or ears in reaching their full potential because of reduced amount of dry matter accumulation in the grain. This criterion has been found to facilitate selection for better kernel weight in translucent, hard-endosperm, opaque-2 materials.

b) Dull modifiers

Some ears show kernels with dull expression. Ears or families showing this undesirable trait are eliminated during the selection process.

c) Popped kernels

The individual ears or the families showing popped kernels or the tendency for popping are eliminated, since such popped kernels are more prone to ear rots. Also when such kernels rot, they promote ear rots in the neighboring kernels. Selection against this defect should reduce the incidence of ear rots in the long run.

d) Early harvesting to enable selection for fast drying genotypes.

Progress in converting different materials to hard endosperm opaque-2 is outlined below:

a) Conversion of advanced populations

Seventeen advanced unit populations are being converted to hard endosperm opaque-2. From the 1977A harvest of Poza Rica and Tlaltizapan, a total of 3325 ears were saved. Since most of the materials showed a very high frequency of hard endosperm opaque-2 ears, it appears that these materials have accumulated a high frequency of modifier genes. A change in breeding and selection strategy was made at this point to place major emphasis on screening for families that would show stability across sites. In the new strategy, one season will be devoted completely to identify families that are stable over environments. Also, in the same season, effort will be made to capitalize on within-family variation for such attributes as plant height, ear height, maturity, foliar diseases, ear rots, and kernel modification of the opaque-2 ears. In the following season, the stable families identified on the basis of at least two location data will be recombined.

These new changes have been incorporated in the backcrossing-cum-recurrent selection scheme described earlier.

The 3325 selected hard endosperm opaque-2 ears from the 1977A harvest were shelled individually. The best looking hard endosperm opaques were sorted out on illuminated glass screens, for planting during 1977B at different stations. The tropical lowland hard endosperm opaque-2 populations were planted at Poza Rica and Obregon. Similarly, the temperate-subtropical populations were planted at Tlaltizapan and Obregon. To capitalize on within family variation for various traits, reciprocal plant-to-plant sibs were made in all the families that had an acceptable level of both protein quantity and quality. The pollinations were restricted only to Poza Rica and Tlaltizapan. The Obregon planting was used as an observational nursery to aid selection of stable and better adapted families in Poza Rica and Tlaltizapan.

Some of the several advanced unit materials were handled in a half-sib recombination block during 1977B. In Obregon, however, these materials were planted in the observational nursery, as with most other materials. These materials were Amarillo Dentado H.E. $o_2$, Mix.1-Col. Gpo. 1 x Eto H.E.$o_2$, Mezcla Amarilla H.E.$o_2$ and Blanco Cristalino H.E.$o_2$.

From the harvest of 1977B, the hard endosperm opaque-2 ears were saved only from those families that performed well in both locations. Thereafter, the best looking within-family sibbed pairs were saved only from the selected families. Table 2 shows the number of families evaluated and the number found stable in each of the several advanced unit populations. From a total of 3325 families evaluated in two locations, 1725 families were found to be stable, with a good rating for endosperm hardness.

The within-family sibbed ears saved from 1977B harvest were shelled separately. Better kernels with more normal appearance were selected from each ear separately, for planting and for analysis in the protein laboratory. The selected sibbed ears from different materials were planted on a family basis at Poza Rica or Tlaltizapan, depending on the material. Before pollination, families were rejected on the basis of genetic spotting, or for segregation for some of the deleterious genes, in addition to elimination of families on the basis of laboratory data. Following rejection of undesirable families, the best looking plants were marked within each selected family. The full-sibs were made among different families by plant-to-plant pollinations. During this recombination process, each family was crossed to at least 4 or 5 different families. The materials were harvested prematurely to permit separation of families with faster drying ability. At harvest, good modified ears were selected from different families. The performance of each family in the crosses with other families was taken into consideration at the selection time. The selected ears were shelled as described above and the best modified kernels were used for planting during 1978B. The number of families grown during 1978A are listed in Table 1.

During 1978A, the bulks of H.E.$o_2$ families from different materials were used for making backcrosses with the selected families of the latest cycle of selection of the corresponding recurrent parent population. Table 3 shows the number of backcrossed ears harvested in each population. The backcrossed ears were planted on a family basis next to hard endosperm opaque-2 families of the same material. Plant-to-plant sibs were made within each family at flowering time. At harvest, only those ears that failed to show segregation for soft kernels were selected. After shelling each ear separately, the modified kernels were selected from each ear and their weight was compared with the normal kernels from the same ear. Table 3 shows the number of ears that were selected based on the quality of segregates and their comparable weight to that of the normals.

The full-sibs and advanced generation backcrossed ears selected in 1978A harvest were planted at least at two stations during 1978B. Only families from four materials (Populations 33, 34, 42 and 48) were planted at Tlaltizapan and Obregon. The rest of the materials were planted in Poza Rica and Obregon. Following rejection of families based on the criteria mentioned earlier, the within-family sibs were made only in promising families. At harvest, the endosperm-hardness data was considered from both locations in deciding families that would undergo recombination in the next cycle. Table 2 indicates that less than 50% of the families were selected on the basis of stability data. This table also shows that some of the better materials had higher proportions of the stable families.

The within family sibs, plus the advanced generation backcrossed families were planted in Poza Rica or Tlaltizapan during 1979A. The number of families planted from each station and from each material is shown in Table 1.

**b)** Conversion of gene pools

Twelve tropical gene pools and eight temperate gene pools were included in the conversion program. The scheme for converting the pools is exactly the same as that of the advanced populations.

Table 4 lists the number of families grown in each tropical pool in each season. A total of 1214 hard endosperm opaque-2 families from 12 pools were grown at Poza Rica during 1977B. The same families, except families from the early pools, also were grown at Obregon. On the basis of performance of families in two locations, the within family sibbed ears were selected only from the stable families that performed well.

The backcrosses of intermediate and tropical late gene pools made during 1977A also were advanced to $F_2$ by crossing $BC_1$ families of each pool with the bulk pollen of the hard-endosperm opaque-2 families of the same pool. Good hard-endosperm opaque-2 segregates were selected from each $BC_1(F_2)$ ear separately for planting in the next season. Some families were rejected on the basis of quality of hard-endosperm opaque-2 segregates and their kernel weight as compared with that of normals.

The within-family sibs and the advanced $BC_1(F_2)$ families were grown during 1978A at Poza Rica. Table 4 shows the number of families grown during this cycle. Plant-to-plant crosses were made among families for recombination. The selected ears from 1978A harvest were grown on family basis at Poza Rica and Obregon during 1978B. The sibbed ears from each selected family were saved based on the performance and stability of the families. A total of 1191 ears were planted during 1979A at Poza Rica. Also, during 1978B, all tropical gene pools were backcrossed. Table 5 lists the number of ears saved from each pool. The backcrossed ears from each pool were planted next to the hard endosperm opaque-2 families of the same pool during 1979A at Poza Rica.

At Tlaltizapan, the temperate gene pools were handled in the same fashion as were the tropical gene pools. Table 6 shows the number of families grown in each pool during each season. Table 5 shows the number of backcrossed ears saved from each pool during 1978B. These were planted along-side the hard endosperm opaque-2 families of the corresponding pool at Tlaltizapan during 1979A.

c) Conversion of populations being selected for earliness, plant efficiency and adaptation.

Most of the Special Project materials that have been converted to opaque-2 show good kernel modification that is fairly stable over environments. The materials that are being converted to hard endosperm opaque-2 are listed in Table 7. Most of these materials have never been backcrossed to their corresponding parental population. Also, most of these materials (except Selección Precoz) are being handled at Tlaltizapan during the "A" season and at both Tlaltizapan and Obregon during the "B" season.

The materials have been worked continuously in homozygous opaque-2 backgrounds without involving any backcross. The handling of these materials involves growing of hard endosperm opaque-2 families at Tlaltizapan and Obregon during the "B" season, followed by recombination and regeneration of new families in the "A" season. During "B" season, within-family variation for plant and kernel characteristics also is exploited.

Table 7 shows the number of families that were handled in each population during each season. Also this table shows that one of the materials (Planta peaqueña mazorca grande H.E.$o_2$) was merged with Amarillo Bajío x varios templados H.E.$o_2$ during 1978A. During 1979A, two other materials (Mezcla Amarilla P.B. x Lin. Ill. H.E.$o_2$ and Amarillo Bajío x maíces Argentinos H.E.$o_2$) are being merged wih opaque-2 versions of Pool 34 and Amarillo Bajío x varios Templados H.E.$o_2$ respectively. Another population (Maíz tropical selección Batan H.E.$o_2$) will be merged with Amarillo Bajío x Mezcla Tropical Blanca H.E.$o_2$ during 1979A.

Because two of the Special Project populations (Amarillo Bajío and Selección precoz) have been promoted to the Advanced Unit as populations 45 and 31, the hard-endosperm opaque-2 versions of these materials will be handled in the previously described backcrossing-cum-recurrent selection program.

d) Conversion of Collaborative research materials to opaque-2

Three maize populations (Tropical late white dent, intermediate white flint, and yellow flint-dent) are being selected for resistance to downy mildew, stunt and streak. Crosses of these materials to corresponding hard endosperm opaque-2 donors were made during 1978A. The $F_1$'s were advanced to $F_2$ during 1978B. The $F_2$ families from each material will be further advanced to $F_3$ or $F_4$ to accumulate modifiers before they are tested in "hot-spots" for the above mentioned diseases.

e) Stability of hard endosperm opaque-2 families in conversions of advanced and back-up materials.

Stability of hard endosperm in quality protein maize materials is very important because this characteristic will be reflected in the final product being accepted in the market. Several breeders working on quality protein maize materials have pointed out the instability of genetic modifiers under different environmental conditions. Even materials grown at one location continue to show varying proportions of soft kernels. It seems likely that this will continue to happen in all materials that have undergone only few cycles of selection. If the material is very variable in kernel modification, it is not surprising to find that it will exhibit varying frequencies of ears that are either completely soft or segregating for soft kernels. Experience gained by CIMMYT seems to show that it is possible to stabilize modifiers by completing 6 to 7 cycles of selection. After the materials have attained a fairly high frequency of modifiers, the majority of the families over environments appear stable. Thus stability of modifiers should be a concern only after the material has gone through sufficient cycles of selection and the variation for the hard endosperm opaque-2 character within the population has been reduced to the minimum.

As has been mentioned earlier the hard-endosperm, opaque-2 families from the Advanced, Back-up and Special Project materials were planted in two locations within Mexico to screen for the hard endosperm character. There were several families within each material that looked good and seemed stable in the two environments. The mean endosperm hardness ratings of different materials is presented in Table 3. The average rating of most of the materials falls between 2.5 and 3.0. There were, however, fairly large number of families within each material that had a rating of 2 and below. Most of the families selected in each material were stable and had lower ratings. Table 9 also shows that most of the families did not differ widely in their ratings in the two locations. There were relatively few families in each material, that showed a difference of more than one point between the two locations. The same kind of trend is shown in the 1978 data.

f) Protein Content and Quality of opaque-2 versions from the Advanced, Back-up and Special Project materials.

Hard-endosperm, opaque-2 families from different materials are analyzed each season in an attempt to discard families in which the protein quality might have been affected adversely as a result of selection for vitreous endosperm. The families that do not have acceptable levels of protein quantity and quality are eliminated in the selection process. Through continuous analyses, and through elimination of families that do not possess good quality, there has been an increase in the frequency of favorable modifiers that alter the phenotype of opaques from soft to a more completely vitreous or normal endosperm, with shiny appearance.

Apart from family analyses, the bulk samples of each material also are analyzed for protein, tryptophan and lysine in the endosperm and whole kernel. Tables 10 and 11 show results of the analyses of tropical opaque-2 conversions. Tables 12 and 13 show findings from similar analyses on subtropical and temperate hard endosperm opaque-2 materials. These tables indicate that protein quality has been maintained very much like that of the soft opaques, though the kernel phenotype has been changed from a soft to a more normal appearing endosperm.

Table 14 shows findings from similar analyses of the bulk samples from 1978A harvested materials. Most of the materials have a lysine content of 3.5 and above in the whole kernel protein. Also, the protein level, in most cases, was 10 and above in the whole grain.

g) Evaluation of progress in the opaque-2 versions of Advanced and Back-up materials

To evaluate the progress in the accumulation of modifiers in different materials, three different cycles or generations were included at the end of each plot of the same material in each location. These different generations were rated for endosperm hardness and for days to 50% silking as shown in Table 15. Most of the materials have shown steady progress in the accumulation of modifiers. The maturity has not changed greatly though in some cases the opaques have become somewhat earlier than the normal population.

## 6. DEVELOPMENT OF HARD ENDOSPERM OPAQUE-2 BACK-UP GENE POOLS

Hard endosperm opaque-2 gene pools must be developed so as to accumulate modifiers from as many different sources as possible. Such gene pools can be formed by genetic mixing of several diverse hard endosperm opaque-2 varieties, variety crosses, and hybrids with similar climatic adaptation, maturity, grain color and type. Alternatively, such pools can be created by crossing several normal materials with available opaque-2 donor stocks with vitreous endosperm. $F_1$ ears can be advanced to $F_2$ either by bulk sibbing or by planting in a half-sib recombination block with one row of male alternating with every two rows of females.

From the harvested segregating $F_2$ ears, hard endosperm opaque-2 segregates can be sorted out and planted again in a half-sib recombination block for recombination. Genetic mixing can be continued over cycles, with major emphasis on accumulation of modifiers and maintenance of protein quality. A total of seven hard endosperm opaque-2 gene pools with tropical and temperate adaptation are being maintained at CIMMYT. In the handling of such gene pools the following features are important:

a) All hard endosperm opaque-2 gene pools are handled in a half-sib recombination block with 2 ♀ : 1 ♂ in an isolated block.

b) Each pool consists of 400-500 half-sib families with an effective population size of 9600 to 12000 plants each cycle.

c) One cycle of recombination can be completed in one season.

d) The first cycles of recombination can be achieved at one location. Later, once every year, the half-sib families from each pool can be planted at two locations or more within Mexico to select for broader adaptation and for stability of modifiers.

e) A sample of 10-15 kernels from each ear is analyzed for protein quality every season. The ears with poor protein quality can be rejected, either before planting or before harvesting, depending upon the availability of laboratory data.

f) Only those ears with acceptable protein quality should be included in the male composite for planting male rows.

g) Between- and within-family selection can be practiced in female rows within each pool.

h) Selection also can be done in male rows for those characters that can be detected visually before, or at, flowering.

i) Mild selection intensity is used within each pool to prevent depletion of attributes or genes necessary for further advance at some stage. Lower selection intensity also provides better chance and opportunities for recombination among linked genes, which with higher selection would probably be discarded much earlier. Between-family slection pressure of about 50 to 60% is used, and within-family selection in selected families is 6 to 18%.

j) Gene pools can be broadened continually through addition of new hard-endosperm, opaque-2 materials from different countries or from the on-going conversion program.

k) At harvest, the selected ears from each pool are grouped as males and females. In the ensuing cycle, all selected ears enter as separate female families. However, the male rows are planted with a balanced male composite made up from only the ears selected as males.

l) Improvements or changes occurring in each pool from cycle to cycle can be checked rather easily by planting two or more rows of each cycle of selection (with or without replications) at the end rows of each pool.

m) White hard-endosperm, opaque-2 gene pools can be artificially contaminated with pollen from yellow normal materials. Yellow normal kernels are used for comparing only kernel weight and are then discarded. Only those ears in which the weight of opaques is comparable to that of the normals are used in further recombination. This contamination procedure helps in accumulating modifiers for kernel weight.

The gene pools are reservoirs of genes. Within each pool there are tremendous opportunities for obtaining new gene combinations. These gene pools can be used in the following ways:

a) Good families can be extracted from a pool for more intensive improvement in a population improvement program.

b) These can serve as excellent donor stocks for modified opaque-2 endosperm.

c) Good superior families from a pool can also be fed into a population already undergoing population improvement.

The names of the back-up gene pools with tropical and temperate adaptation are listed in Tables 16 and 17, respectively. The major emphasis in all such Back-up gene pools has been to increase kernel vitreosity without sacrificing protein quality. Kernel appearance in these materials has now reached a point of acceptance. The number of half-sib families that were handled in each pool during each cycle are given in the above tables. The four tropical pools have completed eight cycles of half-sib selection. Of the three temperate pools, two have already gone through nine cycles of selection while the third temperate pool has so far completed only three cycles of selection. In one of the temperate pools (Temperate x tropical H.E.$o_2$ (Flint) ), the selected plants within each family were selfed and inoculated with Diplodia ear rot organism. At harvest disease-free selfed ears were selected from families with good performance.

The four tropical pools were planted at Poza Rica and Obregon during 1978B. Similarly, the two temperate gene pools were planted at Tlaltizapan and Obregon. The third temperate gene pool (temperate x tropical H.E.$o_2$ (Flint) ) was planted at Poza Rica, Tlaltizapan and Obregon. Good modified ears were selected from promising families at all the locations, for planting in the next season's crossing block. The number of families planted in each pool during 1979A is given in Tables 16 and 17.

Table 18 lists the mean values for protein, tryptophan and lysine in bulk samples of four tropical and three temperate gene pools. Most of these materials have satisfactory protein and lysine values. The lysine values in the whole kernel are as good as those found in the soft opaques.

During 1978B, different cycles of each pool were planted at the end of each pool to evaluate progress in the accumulation of modifiers. In some pools, these cycles were planted as observational plots while in others these were replicated to get the needed information. In temperate x tropical H.E.$o_2$, the performance of different cycles across three locations is given in Table 19. The most significant change that has occurred in this material is in the percentage of hard endosperm opaque-2 ears. There has been steady progress from cycle-to-cycle with respect to this character; the last few cycles, however, did not show wide differences. Some progress also was evident in the incidence of ear rots, though differences between cycles were not significant. The yield increment was negligible and non-significant.

The performance of the yellow opaque-2 Back-up pool and white opaque-2 Back-up pools is given in Tables 20, 21a and 21b. In both of these materials, significant progress was evident for endosperm hardness as well as the percentage of hard endosperm opaque-2 ears.

Data also was obtained on observational plots of some materials in different cycles. The trend in most of the materials was similar. The more advanced cycles had lower ratings compared to the initial cycles (Table 22).

## POPULATION IMPROVEMENT PROGRAM

There are five Advanced unit opaque-2 materials that are being tested on family basis at the international level. Four materials have a vitreous endosperm, while the fifth one has soft chalky appearance. The materials are:

Tuxpeño opaque-2 (Population 37);
PD(MS)6 H.E.$o_2$ (Population 38);
Yellow H.E.$o_2$ (Population 39);
White H.E.$o_2$ (Population 40); and
Templado Amarillo $o_2$ (Population 41).

A total of 250 full-sibs is being used from each of these populations. These are tested, along with six checks, in a 16x16 simple lattice at locations in six different countries. One of the six test sites is always in Mexico. The performance of each of the populations in the international progeny testing trial is cited below:

i) Tuxpeño opaque-2 (Population 37): This population has soft chalky endosperm and is very high yielding. During 1977B, this population was evaluated at Poza Rica and Obregon. The best performing 38 families were selected at two locations. The mean yield of selected families showed an advantage of about 7.9% over the mean of tested families.

This population is fairly susceptible to ear-rots and will be improved for this trait during the period between the two population improvement cycles.

ii) PD(MS)6 H.E.$o_2$ (Population 38): In terms of kernel hardness and appearance of the grain, this is one of the best materials in the program. It has undergone four cycles of half-sib recombination, along with simultaneous selection for modifiers. Following one year of population improvement in Mexico, this material has been promoted to the Advanced unit as population 38. In the first year of population improvement, the three test sites were within Mexico. On the basis of progeny trial data, 93 full-sib families were selected. The selected families were planted in 1977A at Poza Rica to generate a new set of 250 full sibs. These full-sibs were sent to six different sites for evaluation. The locations of the progeny trials are listed in Table 23. The summary of performance of the full-sib families is presented in Table 24. A very mild selection intensity was used. For plant height and days-to-flower, the means of the selected families were similar to those of the tested families. The mean yield of selected families, however, showed a superiority over that of tested families, by about 3.9%. In the selection of families for further work, endosperm hardness was given special attention.

In the present system of improving Advanced Unit materials, one cycle of selection is completed every two years. Since progeny trials from each population are sent to northern as well as southern hemispheres, it becomes difficult to use data from all sites in the selection of new families. To compensate for this relatively slow process, CIMMYT has developed a system through which the time available between two cycles can be utilized more efficiently and effectively for improving those traits in which a particular population may be deficient. That is, within family improvement can be made for the deficient character in the interval between two cycles.

The material PD(MS)6 H.E.$o_2$ is somewhat intermediate in maturity, with good plant type and good yield performance, with stable hard-endosperm opaque-2 kernels. This material can probably serve better and more areas if it can be made earlier. Thus, there will be family selection for earliness in the period between the two cycles.

iii) Yellow H.E.$o_2$ (Population 39): This new population was handled in the Back-up stages of the opaque-2 program as CIMMYT H.E. $o_2$. It is also a very promising material in the quality protein program. It is a broadbased material with respect to both genetic diversity of the materials and the modifiers and has undergone four cycles of recombination to improve the frequency of the modifiers, without sacrificing protein quality. This material has replaced the previous Yellow H.E.$o_2$ population.

In 1977, 250 full-sibs were generated and these were tested in three locations within Mexico. On the basis of data from three locations, 109 full-sibs were selected. The mean performance of 250 full sibs in each location and with respect to different characters is given in Table 25. The across location data show that the mean of the selected families was about 10 cm. shorter, 3 days earlier, with a yield superiority of 5.9%, as compared to the means of the tested families.

The selected families were planted in 1978A to generate 250 new full-sibs. These have been sent to 6 different countries for evaluation. The results will be included in next year's report. Since this material is somewhat tall and tends to lodge, extra selection pressure will be used to reduce plant height during the time between cycles.

iv) White H.E.$o_2$ (Population 40): This white material has a mixture of flint and dent grain texture; it represents some promising hard endosperm opaque-2 families derived from the white opaque-2 back-up pool. These families were used to develop 250 full-sibs, which in turn were tested at three locations within Mexico during 1976B. A total of 99 families were selected on the basis of across-site data. During 1977A, the selected families were used to generate 250 new full-sibs. These were sent to six different countries as listed in Table 23. The results are reported in Table 25. The across-site mean yield of the selected families was 6.9% greater than the mean of the tested families. This material will also receive special emphasis for the reduction of plant height during the period between the two cycles of selection (Table 25).

v) Templado Amarillo $o_2$ (Population 41): This is the most advanced population from the temperate-subtropical opaque-2 porgram. It has good plant type, good yielding ability, and acceptable ear and kernel characteristics. Good families from the temperate x tropical H.E.$o_2$ Composite were used to develop this population. It was used as Advanced unit population (Population 41) for the first time in 1977. The locations of the progeny trials are shown in Table 23. The results of the progeny trials from different locations are presented in Table 24. From the mean data across all locations, the selected families were shown to be shorter in plant height and a day earlier than were the tested families. The mean yield of the selected families was superior to that of the tested families by 3.5%. In general, this material has done very well in different locations and holds much promise for the future; however, ear rot incidence is high, thus this material will be improved for resistance to ear rot organisms in the between cycle period.

## 8. DEVELOPMENT OF EXPERIMENTAL VARIETIES

The experimental varieties are developed on the basis of site-specific and across-site progeny trial data. In the development of experimental varieties, a very high selection intensity of 2.5% is used. Since each progeny trial is conducted in six locations, each population has a potential of producing seven experimental varieties (6 site-specific and one across-site). Since the best fraction of each population is selected to form the experimental varieties, they would be expected to have a considerably higher genetic gain for immediate use and exploitation. In the selection of 10 best families, high yielding families with relatively uniform agronomic attributes are recombined, so that the variety will have fairly uniform appearance.

In the formation of experimental varieties, diallel matings are made among 10 families. Also at this stage, relatively uniform plants are used in recombination. From a recombination of 10 families, adequate seed is obtained to conduct at least 40 experimental variety trials. A balanced bulk of selected ears goes into a second-order seed increase to build up enough seed quantity for each experimental variety. This process facilitates use of the variety in the elite experimental variety trials (ELVT), if it performs well in the EVT trial.

During the report period, a number of experimental varieties were developed from four advanced unit opaque-2 populations: PD(MS)6 H.E.$o_2$, Templado Amarillo $o_2$, White H.E.$o_2$ and Yellow H.E.$o_2$.

The experimental varieties developed from PD(MS)6 H.E.$o_2$ and Templado Amarillo $o_2$ are listed in Table 26. Six experimental varieties were developed in population 38 and seven in population 41. With respect to the means for plant height and days-to-flower, the experimental varieties developed from these populations did not differ widely from the mean of the population. The selected families entering into the development of experimental varieties had a mean yield of about 15% above that of the population.

The experimental varieties developed from Yellow H.E.$o_2$ and White H.E.$o_2$ are listed in Table 27. In the White H.E.$o_2$, six experimental varieties were developed on the basis of 1977 IPTT data. The mean of selected families used in the formation of experimental varieties was generally shorter than the mean of the population. The selected family mean yield for each experimental variety was at least 31.7%-15.3% above the mean of the tested families.

Only one experimental variety was developed from population 39 on the basis of 1978 IPTT data. The selected families used in the formation of this variety had means for plant height at least 2 cm. shorter than the population mean, and mean yields were about 16.3% above the population mean.

The experimental varieties developed on the basis of IPTT data are being tested in appropriate experimental variety trials, to be discussed in another section of this report.

## 9. HIGHLAND OPAQUE-2 CONVERSION PROGRAM

The highland opaque-2 program consists of three main types of activities:

a) Conversion of non-floury highland back-up gene pools to opaque-2.

b) Development and improvement of highland opaque-2 composites.

c) Conversion of floury materials to opaque-2.

Each of these activities is discussed below:

i) <u>Conversion of non-floury highland back-up gene pools</u>

All highland pools from 1 through 14 (except pools 3 and 8) are being converted to hard endosperm opaque-2. These materials remain unsatisfactory so far as genetic modifiers are concerned. Additional generations are needed to improve the performance of these materials.

Table 28 shows the number of families handled in each pool during each year. Emphasis is being placed on the accumulation of modifiers in all of these pool conversions. During 1977, 1017 hard endosperm opaque-2 families were grown from opaque-2 versions of different pools. Some families were eliminated on the basis of laboratory data, and plant-to-plant crosses were made among different families of the remainder. Depending upon the number of good plants in each selected family, an attempt was made to cross each selected family to at least 4 to 6 other families. At harvest, good modified ears were selected for the next year's planting. From the harvest of 1977, 564 ears were saved. As usual, these were shelled individually and good vitreous kernels were selected from each ear separately.

Good modified kernels from selected ears of 1977 harvest were planted on a family basis at Batan and Toluca in 1978. The Toluca nursery was treated as observational nursery. At Batan, pollinations were made among families in different materials separately. The ears from 1978 harvest showed promise. The harvested ears showed considerable improvement in kernel modification.

In addition to highland non-floury gene pools, several other materials are being converted to hard endosperm opaque-2. The materials are listed in Table 29, which also lists the number of families handled each year. Development of vitreous endosperm with more or less normal kernel appearance is a major emphasis in the materials.

ii) <u>Development and improvement of highland opaque-2 composites</u>

The highland opaque-2 composites that have been developed are listed in Table 29. There are three opaque-2 composites that have soft chalky endosperm. These composites are being improved for plant type, yield, and reduced lodging, using a half-sib breeding procedure. Both Composite I and Puebla $o_2$ Composite have done fairly well in many countries of the Andean region. The third composite (Barraza x Puebla $o_2$) is a relatively early material and can be grown at elevations as high as 2,600 meters above sea level. The number of families grown during 1978 were 458 for Composite I, 384 for Puebla $o_2$ Composite, and 130 for Puebla opaque-2 x Barraza.

Composite I and Puebla opaque-2 were grown at Toluca as well as at Batan. Also, the half-sib ears were saved from each location for the 1979 planting. Barraza x Puebla $o_2$ Composite, however, was planted only in Toluca. This material appears to be early and has a good yield potential. Both Composite I and Puebla opaque-2 have completed six cycles of selection, whereas, Puebla $o_2$ x Barraza has gone through three generations of selection following the original $F_1$ cross.

Only one modified opaque-2 composite is being handled in the highland program; it has completed three cycles of selection for hard endosperm. During 1978, 366 H.E.$o_2$ families were grown from this composite. These were handled in the half-sib recombination crossing block. At harvest, this material seemed to have performed fairly well. The frequency of soft segregates or completely soft ears has been reduced considerably in this material. With one or more cycles of selection, this material might serve as a good donor source for converting highland maize materials to opaque-2. Also, it might be worth using on off-station trials in the highland areas.

iii) Floury-opaque-2 conversion program

Conversion of soft floury materials to opaque-2 has received considerable attention in CIMMYT's quality protein maize program. The main research thrust is in transferring opaque-2 gene into those genetic backgrounds that will have wider use in the Andean region.

The opaque-2 versions of pools 3 and pool 8 have been obtained. These conversions, however, have not been back-crossed to the recurrent parent. The number of families planted in each one of the two opaque-2 versions is shown in Table 30. During 1978, families from the conversion of Pool 3 and Pool 8 were handled in the half-sib recombination block. At the time of detasseling, considerable pressure was put on male rows to eliminate tall and undesirable plants. At harvest time the ears were saved from good plants in the selected families. Only half-sib ears were saved that were free of ear rot organisms and with large sized kernels. These two materials also were planted in Toluca in the same fashion. The selection of ears was done in the same way as in Batan.

A floury-opaque-2 composite also has been developed in the highland program. During 1978, 483 half-sib families from this composite were grown in Batan and Toluca. Undesirable plants were eliminated in the male rows at tasseling, and clean ears with large kernels from the female rows were selected at harvest time. This composite was tried in some trials in the Andean region. In general, it did fairly well, though it had a relatively higher incidence of ear rots.

## 10. SUGARY-2/OPAQUE-2 DOUBLE MUTANT

The sugary-2/opaque-2 conversion program began about three years ago. This combination was thought to have considerable potential to solving some problems associated with opaque-2 maize. To assess this potential many materials were converted to sugary-2/opaque-2 ($su_2o_2$). During this conversion program, the $su_2o_2$ segregates were observed to have: 1) considerable variation in phenotypic expression of the kernels; 2) reduced kernel size and weight, but with better kernel density; 3) kernels with vitreous endosperm; 4) an intense color and unattractive appearance; 5) kernels that occasionally exhibit mosaic appearance; 6) an absence of soft starch in the dented portion of dent materials; 7) ears with a tendency to shell easily; and 8) spaces between and within kernel rows.

Initial assessments of the $su_2o_2$ segregates, suggested that a straight sugary-2/opaque-2 conversion program would not achieve the desired goals. A strong selection pressure for kernel phenotype, size and absence of spaces between kernel rows will be necessary to develop materials that will be comparable in performance to the normal maize.

All good families resulting from the conversion of $su_2o_2$ program were pooled to form a composite. Between 500 and 800 families are being handled in this population each cycle in the half-sib selection program. During 1978B, 800 half-sib families were planted to achieve the third cycle of recombination. At harvest, 490 half-sib ears were selected to undergo the fourth cycle of recombination and selection. The comparatively little work with this composite seems to have improved phenotype, seed size, and reduced spacing between the rows on the ears. Two or more additional cycles are needed to determine the potential of this material. Both protein quantity and quality are excellent in this material.

## 11. ACCUMULATION OF DRY MATTER IN THE HARD ENDOSPERM OPAQUE-2 MATERIALS

To determine if selection of genetic modifiers alters the dry matter accumulation pattern of hard endosperm opaque-2 materials, three to four cycles or generations of some hard endosperm opaque-2 materials were studied along with the normal counterparts. Data from this study has not yet been summarized. The mean values in one material have been calculated and plotted in a graph (Fig. 1).

The data on mean 100-kernel weight shows that there has been some improvement in kernel weight by selection from $F_4$ to $F_6$. The differences in moisture percentage between the two generations and the normal were not clear-cut. It is hoped that data from other populations will throw more light on this aspect.

## 12. COMPARISON OF OPAQUES AND NORMALS IN THE SAME GENETIC BACKGROUND

During 1978, a trial was designed to compare 10 hard endosperm opaque-2 entries and their normal counterparts. The trial was conducted at Poza Rica, Tlaltizapan and Obregon. The trial had four replications and four row plots. All 4 rows of normals and the two central rows of opaques were detasseled to avoid contamination of opaques by normals. The results of the trial are presented in Tables 31, 32 and 33.

From the data of Poza Rica, Tlaltizapan and Obregon, it is clear that the performances of opaque-2 versions of Tuxpeño 1, Mix.1-Col.Gpo. 1 x Eto, Mezcla Amarilla, Ant. x Rep. Dom. and La Posta were similar to the normal counterparts. The opaques, in general, registered a higher incidence of ear rots. Some of the opaque-2 entries seemed to be somewhat earlier than their normal counterparts. The data also show that the number of hard endosperm opaque-2 ears was fairly high in all materials.

## 13. OFF STATION TRIALS

During 1978B, two off-station opaque-2 trials were conducted in farmer's fields. Five opaque-2 entries were compared with Tuxpeñito at Zapatolillo and at El Jardin in the state of Veracruz, as shown in Table 34. At Zapatolillo, Tuxpeñito gave somewhat higher yield than did the opaque-2 entries in the trial. The difference, however, was not significant statistically. In the second location (El Jardin), the three opaque-2 entries (Mezcla Tropical Blanca, Tuxpeño Caribe, and La Posta) performed as well or better than did Tuxpeñito. The differences, however, were not significant.

## 14. INTERNATIONAL TESTING - 1977 AND 1978

CIMMYT's International Testing Program consisted of four major aspects: International progeny testing trials; OMPT-11; EVT-15 and ELVT-19.

i) International progeny testing trials: During 1977, three opaque-2 populations namely PD(MS)6 H.E.$o_2$ (Pop. 38), White H.E.$o_2$ (Pop. 40), and Templado Amarillo $o_2$(Pop.41) were sent out to different countries for evaluation. Table 35 shows the test locations for each population.

During 1978, only Yellow H.E.$o_2$ (Pop. 39) has been sent to Bolivia, Ivory Coast, Thailand and Ecuador. The other two sets were planted in Mexico.

ii) OMPT-11: On the basis of performance of hard endosperm opaque-2 families in different locations within Mexico, a number of good, stable, hard-endosperm, opaque-2 families were identified in several materials. Using remnant seed, the families from each material were recombined during 1978A at Poza Rica. The materials were harvested separately as bulks to provide entries for opaque-2 maize population trial (OMPT-11). This trial has been sent to 44 different countries. The distribution of the trials is shown in Table 36; the results are shown in Table 37. In some locations, the opaques were comparable in performance to the best normal entry included in the trial. There were several $o_2$ entries in most of the locations that had yield levels of 90% or above of the best normal. This trial provides a good indication of the performance of some of the new opaques in different locations.

iii) Experimental variety trial 15: During 1977, thirty-eight sets of this trial were sent to different countries as shown in Table 38.

The results of this trial are presented in Table 39. The experimental varieties derived from Population 37 were top performers in many locations. The experimental varieties derived from population 39 did fairly well. The performance of three varieties in the trial was about the same. Hard Endosperm opaque-2 version of Population 24 (Ant. x Ver. H.E.$o_2$) also did fairly well.

Table 40 shows the performance of the best opaque as compared with the best normal in each country the best opaque-2 entry was comparable to the best normal.

During 1978, experimental variety trial No. 15 was sent to 36 locations. The test locations are given in Table 36. The trial data from different locations will be reported in next year's report.

In 1979, EVT 15 may be split into 15 and OMPT-11B, EVT-15 and OMPT-11B will be reserved for tropical and temperate materials respectively.

iv) ELVT-19: During 1977, this trial consisted of 10 entries. The trial was distributed to 55 locations around the world as shown in Table 38.

The results of ELVT-19 are presented in Table 41. A number of opaque-2 entries in the trial were comparable to both normal and opaque-2 check entries included in the trial. The performance of best opaque as compared with the best normal in each location is shown in Table 42. The data shows that in some locations the best opaque was fairly comparable to the best normal in the same location.

Table 36 shows the distribution of ELVT-19 during the year 1978. The trial has been sent to 52 locations in different countries. The results will be reported in next year's report.

## 15. CONSIDERATIONS FOR FUTURE RESEARCH

This report has emphasized that the future of quality protein maize materials depends to a great extent on solving the problems of acceptance of these materials at the production level. A breakthrough in the use of opaque-2 varieties will come only if they can compete with existing normal varieties in yied and other agronomic characters with protein quality as a bonus.

Though attempts to solve the problems in opaques began several years ago, successful results have been achieved only recently. A set of complex and interrelated problems with opaques have been remedied through the exploitation of genetic modifiers of the opaque-2 locus. Recent developments at CIMMYT have developed quality protein maize materials with good yield potential, reduced susceptibility to ear rots and with a kernel phenotype that is indistinguishable from the normals. Visiting scientists coming to CIMMYT have made favorable comments about the opaque-2 materials that have been developed at CIMMYT. They have shown satisfaction with the progress achieved and they have expressed their interest in making use of them in their own national programs.

CIMMYT has developed hard endosperm opaque-2 versions of genetically diverse materials that have climatic adaptation to lowland tropics, highlands and subtropical areas. Some of these materials may be of direct use in some areas. In other areas, some of these populations may serve as source populations for further selection. The available materials can also serve as good donors to convert promising locally developed materials to hard endosperm opaques. Since most of the donor stocks are in good genetic backgrounds, the usual backcrossing program may not be necessary.

Opaque-2 materials are being sent to different national programs to demonstrate their performance. Trial 11 should convince scientists in the national programs of the potential of these materials and should encourage extensive testing of the most promising materials in the farmers' fields.

The future of the floury-1 opaque-2 conversion program is also bright. The use of the Ninhydrin test has accelerated the development of such materials.

The encouraging results obtained in recent years underline opaque-2 maize prospects in developing countries. They show that it is possible to break the yield and grain quality barriers, which have been the main obstacles to its commercial use. It is hoped that these new developments will encourage breeders in national programs to accelerate and intensify their work in this area so that quality protein maize will soon be of direct use to the people.

## 16. SUMMARY

CIMMYT's research efforts in quality protein maize improvement are reported for the period up to December, 1973. The development in

quality protein maize are reviewed for the past fourteen years. Various breeding approaches have been described including search for new mutants, recurrent selection for high lysine in normal maize materials, double mutant combinations, increasing germ size and the exploitation of genetic modifiers of opaque-2 locus. The advantages and disadvantages of each of the above approaches are mentioned, along with the possibility of using these approaches in breeding high quality protein maize.

The complex and interrelated problems confronting opaque-2 maize are pointed out and the underlying causes of some of the problems described. Some methods are given for dealing with problems of yield, kernel opacity, ear-rots, and greater moisture content at harvest.

CIMMYT's rationale for research in developing quality protein maize is cited, the major thrust in the breeding program is development of quality protein maize genotypes competitive with the normals in terms of yield, kernel acceptability, and other agronomic traits. The major research emphasis is being placed on obtaining opaque-2 versions of normal materials with tropical, temperate and highland adaptation, on development of broadbased hard endosperm opaque-2 back-up gene pools, on improving of existing populations, and on the evaluation of quality protein maize materials internationally in the form of progeny and experimental variety trials. Accumulation of genetic modifiers, maintenance of protein quality and screening for stability of hard endosperm opaque-2 character is being continued as the principal strategy to develop hard endosperm opaque-2 materials at CIMMYT. Several direct and indirect field criteria are being used including selecting against spacing between kernel rows, elimination of dull modifiers, discarding popped kernels and early harvesting to screen for faster drying genotypes.

Conversion of normal maize materials into opaque-2 continued in the maize improvement program. A backcrossing-cum-recurrent selection procedure was used across the entire conversion program. Hard endosperm opaque-2 ears saved from the conversions of Advanced, Back-up and Special Project materials during 1977A harvest were planted at two of three locations namely Poza Rica, Tlaltizapan and Obregon. Pollinations were made at Tlaltizapan or Poza Rica to capitalize on within-family variation. The within-family sibs from stable families were saved, based on two location data. These were planted for recombination in Tlaltizapan or Poza Rica during 1978A. The hard endosperm opaque-2 bulks from some materials were used to make backcrosses with corresponding Advanced unit populations. The selected ears were again evaluated for stability during 1978B. Also, the backcrosses were advanced by sibbing within the family. During 1978B, the hard endosperm opaque-2 bulks from some pool conversions also were backcrossed with corresponding pools. The sibbed ears from stable hard endosperm opaque-2 families, based on two location data, plus the backcrossed generations, were planted during 1979A.

The analyses of bulk samples for protein lysine and tryptophan showed that most of the hard endosperm opaque-2 versions had good levels of protein quantity and quality. Also different cycles or generations within each material were evaluated for the progress. The results indicate that most of the materials have shown steady progress in the accumulation of modifiers.

A half-sib procedure was used in four tropical and three temperate gene pools. Three additional cycles of recombination were achieved during 1977B, 1978A and 1978B. In temperate x tropical H.E.$o_2$ gene pool, selfs were made during 1978B. The pollinated ears were artificially inoculated with ear rot organisms. Two tropical and one additional temperate pools also were inoculated with ear rot organisms.

Population improvement program with five advanced unit opaque-2 populations was continued; these populations are Tuxpeño opaque-2 (Pop. 37), PD(MS)6 H.E.$o_2$ (Pop. 38), Yellow H.E.$o_2$ (Pop. 39), White H.E.$o_2$ (Pop. 40) and Templado Amarillo $o_2$ (Pop. 41). During 1977, three advanced unit populations (38, 40 and 41) were each tested internationally at six different sites in different countries. The mean of the selected families showed a yield superiority of 3.9%, 3.5%, and 6.9% over the mean of the tested population in PD(MS)6 H.E.$o_2$, Templado Amarillo $o_2$, and White H.E.$o_2$ respectively. Two other populations (Yellow H.E.$o_2$ and Tuxpeño opaque-2) were tested at three locations within Mexico. The mean of the selected families showed a yield superiority of 5.9% and 7.9% over the mean of the tested population in Yellow H.E.$o_2$ and Tuxpeño $o_2$, respectively.

Experimental varieties were developed from Advanced unit populations on the basis of IPTT data. Six experimental varieties from PD(MS)6 H.E.$o_2$, seven from Templado Amarillo $o_2$ and six from White H.E.$o_2$ were developed on the basis of IPTT data. The mean of the selected families entering into the development of experimental varieties had a mean yield superiority of about 15% and above. Only one experimental variety was developed from Yellow H.E.$o_2$. The selected family mean for the experimental variety showed a yield difference of 16.3% above that of the population mean.

In the highland program, three main types of research activities were continued. These were conversion of non-floury highland back-up gene pools to opaque-2, development and improvement of highland $o_2$ composites, and conversion of floury materials to opaque-2. Effort to accumulate genetic modifiers in all gene pools 1 through 14 (except pools 3 and 8) was underway in 1977 and 1978. The selected ears will be planted on family basis in 1979. Two additional cycles of recombination and selection were achieved in three soft opaque-2 composites (Composite I, Puebla $o_2$ Comp., and Puebla x Barraza $o_2$) and one highland modified opaque -2 composite. Also two additional cycles of recombination were achieved in $fl_1o_2$ composite, and Pool 3($o_2fl_1$). Emphasis in this conversion program was placed on selection of ears with big kernels and that were free of ear rots.

Improvement of sugary-2/opaque-2 population was continued using half-sib procedure in each of the three seasons 1977B, 1978A and 1978B. Between 500-800 half-sib families were handled in each cycle. Both protein content and quality are excellent in this material and there seem to be improvements in phenotype, seed size and reduced spacing between kernel rows on the ears.

Dry matter accumulation pattern was studied in different cycles of some hard endosperm $o_2$ materials. The summarized data from one population seems encouraging.

Ten hard endosperm opaque-2 materials and their normal counterparts were compared at three locations within Mexico. Performance of opaque-2 versions of Tuxpeño-1, Mix.1-Col. Gpo. 1 x Eto, Mezcla Amarilla, Ant. x Rep. Dom., and La Posta was similar to that of the normal counterparts. Some of the opaque-2 entries also turned out to be earlier.

Some promising $o_2$ materials were evaluated in off-station trials at two locations. Three opaque-2 entries (Mezcla Tropical Blanca, Tuxpeño Caribe, and La Posta) performed as well, or better than the Tuxpeñito normal. The differences, however, were non-significant.

Several trials (OMPT-11, EVT-15 and ELVT-19) were each sent to several locations in different countries. The data from OMPT-11 provides data on the performance of new opaque-2 materials that have been developed in CIMMYT's quality protein maize program. EVT-15 and ELVT-19 conducted during the year 1977, indicated that one or more entries in each location were either equal to or better than the best normal check entries included in the trial.

TABLE 1. Conversion of advanced unit populations to opaque-2.

| Population No. | Pedigree | No. of families grown each cycle | | | | |
|---|---|---|---|---|---|---|
| | | 1977A | 1977B | 1978A | 1978B | 1979A |
| 21 | Tuxpeño-1 | 211 | 401 | 384 | 300 | 158 |
| 22 | Mezcla Tropical Blanca H.E.$o_2$ | 126 | 154 | 192 | 252 | 144 |
| 23 | Blanco Cristalino-1 | 361 | 266 | 230 | 318 | 144 |
| 24 | Ant. x Ver.181 | 225 | 233 | 178 | 208 | 175 |
| 25 | Mix.1-Col.Gpo.x Eto | 79 | 189 | 260 | 383 | 199 |
| 26 | Mezcla Amarilla | 191 | 162 | 202 | 276 | 120 |
| 27 | Amarillo Cristalino | 212 | 148 | 66 | 222 | 152 |
| 28 | Amarillo Dentado | 144 | 228 | 293 | 413 | 244 |
| 29 | Tuxpeño Caribe | 175 | 233 | 228 | 381 | 215 |
| 32 | Eto Blanco | 293 | 234 | 211 | 244 | 135 |
| 33 | Amarillo Subtropical | 226 | 243 | 138 | 261 | 135 |
| 34 | Blanco Subtropical | 56 | 165 | 102 | 158 | 39 |
| 35 | Ant. x Rep. Dom. | 312 | 209 | 201 | 408 | 240 |
| 36 | Cogollero | - | 36 | 23 | 90 | 27 |
| 42 | Eto x Illinois | 90 | 74 | 34 | 56 | 81 |
| 43 | La Posta | 114 | 288 | 147 | 280 | 187 |
| 48 | Hungarian Composite | 42 | 62 | 58 | 76 | 113 |
| | Total | 2857 | 3325 | 2947 | 4326 | 2508 |

TABLE 2.- Evaluation of hard endosperm opaque-2 families of the advanced unit populations for stability of hard endosperm character.

| Population No. | Pedigree | 1977B No. evaluated | 1977B No. stable | 1978B No. evaluated | 1978B No. stable |
|---|---|---|---|---|---|
| 21 | Tuxpeño-1 H.E.$o_2$ | 401 | 220 | 300 | 158 |
| 22 | Mezcla Tropical Blanca H.E.$o_2$ | 154 | 94 | 252 | 107 |
| 23 | Blanco Cristalino H.E.$o_2$ | 266 | - | 318 | 111 |
| 24 | Ant. x Ver.181 H.E.$o_2$ | 233 | 126 | 208 | 120 |
| 25 | Mix.1-Col.Gpo.1 x Eto H.E.$o_2$ | 189 | 147 | 383 | 199 |
| 26 | Mezcla Amarilla H.E.$o_2$ | 162 | 104 | 276 | 120 |
| 27 | Amarillo Cristalino H.E.$o_2$ | 148 | 66 | 222 | 114 |
| 28 | Amarillo Dentado H.E.$o_2$ | 228 | 144 | 413 | 244 |
| 29 | Tuxpeño Caribe H.E.$o_2$ | 233 | 107 | 381 | 215 |
| 32 | Eto Blanco H.E.$o_2$ | 234 | 211 | 244 | 75 |
| 33 | Amarillo Subtropical H.E.$o_2$ | 243 | 134 | 261 | 79 |
| 34 | Blanco Subtropical H.E.$o_2$ | 165 | 32 | 158 | 39 |
| 35 | Ant. x Rep. Dom. H.E.$o_2$ | 209 | 118 | 408 | 210 |
| 36 | Cogollero | 36 | 4 | 90 | 27 |
| 42 | Eto x Illinois H.E.$o_2$ | 74 | 32 | 56 | 19 |
| 43 | La Posta H.E.$o_2$ | 288 | 147 | 280 | 187 |
| 48 | Hungarian Composite | 62 | 39 | 76 | 32 |
| | T o t a l | 3325 | 1725 | 4326 | 2056 |

TABLE 3. - Number of families saved from advanced generation of backcrosses.

| Population No. | Pedigree | No. of backcrossed ears saved 1978A | No. of ears saved from advanced generation of backcrosses 1978B |
|---|---|---|---|
| 22 | Mezcla Tropical Blanca | 50 | 37 |
| 23 | Blanco Cristalino | 50 | 33 |
| 24 | Ant. x Ver. 181 | 55 | 55 |
| 27 | Amarillo Cristalino | 50 | 38 |
| 32 | Eto Blanco | 60 | 60 |
| 34 | Amarillo Subtropical | 60 | 56 |
| 35 | Ant. x Rep. Dom. | 60 | 30 |
| 42 | Eto x Illinois | 60 | 62 |
| 43 | La Posta | 60 | 47 |
| 45 | Amarillo Bajío | 50 | 60 |
| | Total | 555 | 478 |

TABLE 4.- Conversion of tropical gene pools to opaque-2

| Pool No. | Name | No. of families handled | | | | |
|---|---|---|---|---|---|---|
| | | 1977A | 1977B | 1978A | 1978B | 1979A |
| 15 | Tropical early white flint | - | 15 | 29 | 47 | 33 |
| 16 | Tropical early white dent | - | 31 | 70 | 143 | 141 |
| 17 | Tropical early yellow flint | - | 9 | 17 | 35 | 33 |
| 18 | Tropical early yellow dent | - | 15 | 34 | 60 | 54 |
| 19 | Tropical intermediate white flint | 87 | 99 | 90 | 226 | 91 |
| 20 | Tropical intermediate white dent | 92 | 86 | 110 | 254 | 87 |
| 21 | Tropical intermediate yellow flint | 97 | 97 | 76 | 164 | 72 |
| 22 | Tropical intermediate yellow dent | 178 | 145 | 129 | 207 | 96 |
| 23 | Tropical late white flint | 268 | 264 | 248 | 391 | 172 |
| 24 | Tropical late white dent | 154 | 163 | 157 | 254 | 87 |
| 25 | Tropical late yellow flint | 71 | 86 | 106 | 214 | 131 |
| 26 | Tropical late yellow dent | 262 | 204 | 200 | 353 | 194 |
| | | 1209 | 1214 | 1266 | 2348 | 1191 |

TABLE 5.- No. of backcrossed ears saved from different pools during 1978B.

| Pool No. | No.of $BC_2$ ears saved |
|---|---|
| 15 | 49* |
| 16 | 52* |
| 17 | 42* |
| 18 | 60* |
| 19 | 47* |
| 20 | 42 |
| 21 | 26 |
| 22 | 62 |
| 23 | 44* |
| 24 | 44 |
| 25 | 35 |
| 26 | 31 |
| 27 | 43 |
| 28 | 58* |
| 29 | 69* |
| 30 | 92* |
| 31 | 52* |
| 32 | 43* |
| 33 | 53 |
| 34 | 50* |
| | 994 |

* $BC_1$ ears.

TABLE 6.- Conversion of temperate gene pools to opaque-2.

| Pool No. | Name | Number of families handled | | | | |
|---|---|---|---|---|---|---|
| | | 1977A | 1977B | 1978A | 1978B | 1979A |
| 27 | Temperate early white flint | 43 | 109 | 39 | 75 | 28 |
| 28 | Temperate early white dent | - | 14 | 24 | 68 | 24 |
| 29 | Temperate early yellow flint | 19 | 61 | 65 | 97 | 37 |
| 30 | Temperate early yellow dent | 30 | 47 | 81 | 92 | 30 |
| 31 | Temperate intermediate white flint | 39 | 101 | 109 | 96 | 18 |
| 32 | Temperate intermediate white dent | 60 | 165 | 49 | 40 | 9 |
| 33 | Temperate intermediate yellow flint | 24 | 86 | 110 | 98 | 34 |
| 34 | Temperate intermediate yellow dent | 65 | 126 | 173 | 120 | 97 |
| | | 280 | 709 | 650 | 686 | 277 |

TABLE 7.- Conversion of populations that are being selected for earliness, plant efficiency and adaptation.

| Material | No. of families handled each cycle | | | | |
|---|---|---|---|---|---|
| | 1977A | 1977B | 1978A | 1978B | 1979 |
| Amarillo Bajío | 190 | 280 | 114 | 193 | 53 |
| ✓Amarillo Bajío x varios templados H.E.$o_2$ | 79 | 131 | 152 | 214 | 72 |
| Amarillo Bajío x Mezcla Tropical H.E.$o_2$ | 88 | 144 | 77 | 127 | 38 |
| Mezcla Amarilla P.B.x Lin.Ill.H.E.$o_2$ | 97 | 131 | 56 | 128 | 28 2/ |
| ✓Planta Pequeña mazorca grande H.E.$o_2$ | 22 | 30 | 62 1/ | - | - |
| Amarillo Bajío x Maíces Argentinos H.E.$o_2$ | 55 | 92 | 59 | 80 | 18 3/ |
| Selección precoz H.E.$o_2$ | 41 | 28 | 44 | 394 | 201 |
| Maiz Tropical selección Batan | 48 | 80 | 86 | 52 | 40 4/ |
| | 620 | 916 | 650 | 1188 | 510 |

1/ Merged with Amarillo Bajío x varios templados H.E.$o_2$.
2/ This material will be merged with opaque-2 version of Pool 34.
3/ This population will be merged with Amarillo Bajío x varios templados H.E.$o_2$ during 1979A.
4/ This population will be merged with Amarillo Bajío x Mezcla Tropical H.E.$o_2$ during 1979A.

TABLE 8.- Mean endosperm hardness ratings of different opaque-2 populations grown at two locations during the year 1977.

| Population | No. of families evaluated | Mean endosperm hardness rating | | |
|---|---|---|---|---|
| | | Poza Rica | Tlaltizapan | Mean |
| Mezcla Tropical Blanca H.E.$o_2$ | 154 | 2.7 | 3.2 | 2.9 |
| Blanco Cristalino H.E.$o_2$ | 264 | 2.6 | 3.2 | 2.9 |
| Ant. x Ver. 181 H.E.$o_2$ | 232 | 2.9 | 2.9 | 2.9 |
| Mix. 1-Col. Gpo. 1 x Eto H.E.$o_2$ | 121 | 2.7 | 2.9 | 2.8 |
| Mezcla Amarilla H.E.$o_2$ | 127 | 2.6 | 2.9 | 2.7 |
| Amarillo Cristalino H.E.$o_2$ | 148 | 2.8 | 2.7 | 2.7 |
| Amarillo Dentado H.E.$o_2$ | 166 | 2.6 | 3.0 | 2.8 |
| Tuxpeño Caribe H.E.$o_2$ | 161 | 2.8 | 2.9 | 2.9 |
| Ant. x Rep. Dom. H.E.$o_2$ | 209 | 3.2 | 3.3 | 3.3 |
| La Posta H.E.$o_2$ | 287 | 2.8 | 3.0 | 2.9 |
| Yellow flint H.E.$o_2$ | 237 | 2.4 | 2.8 | 2.6 |
| Yellow $o_2$ B.U. Pool | 79 | 2.8 | 3.2 | 3.0 |
| Late White Dent H.E.$o_2$ | 146 | 2.7 | 3.0 | 2.8 |
| Amarillo Bajío H.E.$o_2$ | 214 | 2.6 | 3.1 | 2.9 |
| Amarillo Bajío x Mezcla Tropical H.E.$o_2$ | 120 | 2.6 | 3.1 | 2.9 |
| Amarillo Bajío x Varios templados H.E.$o_2$ | 116 | 2.6 | 3.1 | 2.9 |
| Amarillo Bajío x maíces Argentinos H.E.$o_2$ | 76 | 2.6 | 3.1 | 2.8 |
| Mezcla Amarilla P.B. x Lin. Ill. H.E.$o_2$ | 85 | 2.6 | 3.3 | 3.0 |
| Pool 19 H.E.$o_2$ | 99 | 3.1 | 3.0 | 3.1 |
| Pool 20 H.E.$o_2$ | 85 | 2.9 | 3.0 | 2.9 |
| Pool 21 H.E.$o_2$ | 97 | 2.6 | 2.6 | 2.6 |
| Pool 22 H.E.$o_2$ | 145 | 3.0 | 3.2 | 3.1 |
| Pool 23 H.E.$o_2$ | 86 | 2.6 | 3.3 | 2.9 |
| Pool 24 H.E.$o_2$ | 163 | 2.9 | 3.2 | 3.1 |
| Pool 25 H.E.$o_2$ | 86 | 2.7 | 2.7 | 2.7 |
| Pool 26 H.E.$o_2$ | 204 | 2.8 | 3.0 | 2.9 |

TABLE 9.- Frequency of difference in endosperm hardness ratings of opaque-2 families from different populations grown at two locations during the year 1977B.

| Entry No. | Population | Frequency of difference in endosperm hardness ratings of families | | | | | Total No. of families |
|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | |
| 1 | Mezcla Tropical Blanca H.E.$o_2$ | 62 | 81 | 11 | 3 | - | 154 |
| 2 | Blanco Cristalino H.E.$o_2$ | 97 | 128 | 37 | 2 | - | 264 |
| 3 | Ant. x Ver.181 H.E.$o_2$ | 121 | 99 | 12 | - | - | 232 |
| 4 | Mix.1-Col.Gpo.1 x Eto H.E.$o_2$ | 61 | 54 | 6 | - | - | 121 |
| 5 | Mezcla Amarilla H.E.$o_2$ | 55 | 64 | 8 | - | - | 127 |
| 6 | Amarillo Cristalino H.E.$o_2$ | 76 | 64 | 8 | - | - | 148 |
| 7 | Amarillo Dentado H.E.$o_2$ | 75 | 76 | 14 | 1 | - | 166 |
| 8 | Tuxpeño Caribe H.E.$o_2$ | 70 | 82 | 9 | - | - | 161 |
| 9 | Ant. x Rep. Dom. H.E.$o_2$ | 99 | 95 | 15 | - | - | 209 |
| 10 | La Posta H.E.$o_2$ | 126 | 149 | 12 | - | - | 287 |
| 11 | Yellow flint H.E.$o_2$ | 112 | 112 | 13 | - | - | 237 |
| 12 | Yellow $o_2$ B.U. Pool | 30 | 41 | 7 | 1 | - | 79 |
| 13 | Late White Dent H.E.$o_2$ | 55 | 78 | 13 | - | - | 146 |
| 14 | Amarillo Bajío H.E.$o_2$ | 78 | 108 | 26 | 2 | - | 214 |
| 15 | Amarillo Bajío x Mez.Trop.Am. H.E.$o_2$ | 56 | 52 | 12 | - | - | 120 |
| 16 | Am. Bajío x varios temp. H.E.$o_2$ | 43 | 59 | 14 | - | - | 116 |
| 17 | Am. Bajío x maíces Argentinos H.E.$o_2$ | 29 | 39 | 8 | - | - | 76 |
| 18 | Mezcla Amarilla P.B. x Lin. Ill.H.E.$o_2$ | 20 | 54 | 11 | - | - | 85 |
| 19 | Pool 19 H.E.$o_2$ | 48 | 46 | 5 | - | - | 99 |
| 20 | Pool 20 H.E.$o_2$ | 39 | 41 | 4 | 1 | - | 85 |
| 21 | Pool 21 H.E.$o_2$ | 46 | 47 | 4 | - | - | 97 |
| 22 | Pool 22 H.E.$o_2$ | 70 | 68 | 7 | - | - | 145 |
| 23 | Pool 23 H.E.$o_2$ | 30 | 42 | 14 | - | - | 86 |
| 24 | Pool 24 H.E.$o_2$ | 70 | 69 | 23 | 1 | - | 163 |
| 25 | Pool 25 H.E.$o_2$ | 39 | 42 | 5 | - | - | 86 |
| 26 | Pool 26 H.E.$o_2$ | 93 | 103 | 7 | 1 | - | 204 |

TABLE 10.- VALUES FOR PROTEIN, TRYPTOPHAN AND LYSINE IN BULK SAMPLES OF SOME TROPICAL HARD ENDOSPERM OPAQUE-2 MATERIALS (ENDOSPERM ANALYSIS)

| Pedigree | Origin | Mean Values | | |
|---|---|---|---|---|
| | | Protein (%) | Tryptophan in protein (%) | Lysine in protein (%) |
| Tuxpeño-1 H.E.$o_2$ | PR77A Lote 93 | 7.5 | 0.72 | 3.05 |
| Mezcla Tropical blanca H.E.$o_2$ | PR77A-310 | 7.5 | 0.84 | 3.12 |
| Blanco Cristalino H.E.$o_2$ | PR77A-316 | 8.2 | 0.78 | 2.90 |
| Ant. x Ver. 181 H.E.$o_2$ | PR77A-312 | 8.5 | 0.82 | 2.95 |
| Mix. 1 - Col. Gpo. 1 x ETO H.E.$o_2$ | PR77A-309 | 8.9 | 0.72 | 2.67 |
| Mezcla Amarilla H.E.$o_2$ | PR77A-311 | 8.4 | 0.77 | 2.86 |
| Amarillo Cristalino H.E.$o_2$ | PR77A-336 | 8.5 | 0.73 | 2.56 |
| Amarillo Dentado H.E.$o_2$ | PR77A-308 | 8.5 | 0.78 | 2.64 |
| Tuxpeño Caribe H.E.$o_2$ | PR77A Lote 94 | 7.7 | 0.83 | 2.84 |
| ETO Blanco H.E.$o_2$ | PR77A Lote 95 | 7.2 | 0.89 | 3.06 |
| Ant. x Rep. Dom. H.E.$o_2$ | PR77A-307 | 8.9 | 0.82 | 2.81 |
| La Posta H.E.$o_2$ | PR77A Lote 96 | 8.9 | 0.79 | 2.63 |
| Pool 19 H.E.$o_2$ | PR77A-317 | 8.6 | 0.86 | 2.76 |
| Pool 20 H.E.$o_2$ | PR77A-318 | 9.9 | 0.67 | 2.70 |
| Pool 21 H.E.$o_2$ | PR77A-319 | 8.5 | 0.73 | 2.84 |
| Pool 22 H.E.$o_2$ | PR77A-320 | 9.1 | 0.69 | 2.64 |
| Pool 23 H.E.$o_2$ | PR77A-321 | 9.1 | 0.66 | 2.62 |
| Pool 24 H.E.$o_2$ | PR77A-322 | 8.4 | 0.74 | 2.71 |
| Pool 25 H.E.$o_2$ | PR77A-323 | 7.8 | 0.79 | 2.92 |
| Pool 26 H.E.$o_2$ | PR77A-324 | 8.2 | 0.71 | 2.84 |
| Late White Dent H.E.$o_2$ | PR77A-313 | 8.3 | 0.77 | 2.89 |
| Yellow Flint H.E.$o_2$ | PR77A-315 | 8.5 | 0.75 | 2.86 |
| Tuxpeño $C_{11}$ x La Posta ($C_2$) H.E.$o_2$ | PR77A-328 | 7.9 | 0.81 | 2.73 |
| PD(MS)6 H.E.$o_2$ | PR77A-301 | 8.9 | 0.63 | 2.68 |
| Yellow H.E.$o_2$ | PR77A-305 | 8.1 | 0.74 | 2.91 |
| White H.E.$o_2$ | PR77A-306 | 7.9 | 0.86 | 3.16 |

TABLE 11.- VALUES FOR PROTEIN, TRYPTOPHAN AND LYSINE IN BULK SAMPLES OF SOME TROPICAL QUALITY PROTEIN HARD ENDOSPERM OPAQUE-2 MATERIALS. (WHOLE GRAIN ANALYSIS)

| Pedigree | Origin | Protein (%) | Mean Values: Tryptophan in protein (%) | Mean Values: Lysine in protein (%) |
|---|---|---|---|---|
| Tuxpeño-1 H.E.$o_2$ | PR77A-Lote 93 | 10.6 | 0.81 | 3.79 |
| Mezcla Tropical blanca H.E.$o_2$ | PR77A-310 | 11.2 | 0.80 | 3.81 |
| Blanco Cristalino H.E.$o_2$ | PR77A-316 | 10.7 | 0.80 | 3.72 |
| Ant.x Ver.181 H.E.$o_2$ | PR77A-312 | 11.0 | 0.87 | 3.89 |
| Mix.1 - Col.Gpo.1 x ETO H.E.$o_2$ | PR77A-309 | 10.9 | 0.84 | 4.09 |
| Mezcla Amarilla H.E.$o_2$ | PR77A-311 | 11.1 | 0.81 | 3.87 |
| Amarillo Cristalino H.E.$o_2$ | PR77A-336 | 11.1 | 0.81 | 3.80 |
| Amarillo Dentado H.E.$o_2$ | PR77A-308 | 10.5 | 0.84 | 4.15 |
| Tuxpeño Caribe H.E.$o_2$ | PR77A-Lote 94 | 10.6 | 0.82 | 3.74 |
| ETO Blanco H.E.$o_2$ | PR77A-Lote 95 | 10.2 | 0.88 | 4.12 |
| Ant. x Rep. Dom. H.E.$o_2$ | PR77A-307 | 11.4 | 0.85 | 3.77 |
| La Posta H.E.$o_2$ | PR77A-Lote 96 | 11.9 | 0.87 | 3.78 |
| Pool 19 H.E.$o_2$ | PR77A-317 | 11.1 | 0.86 | 3.68 |
| Pool 20 H.E.$o_2$ | PR77A-318 | 11.0 | 0.89 | 3.54 |
| Pool 21 H.E.$o_2$ | PR77A-319 | 10.5 | 0.93 | 3.76 |
| Pool 22 H.E.$o_2$ | PR77A-320 | 11.0 | 0.89 | 3.66 |
| Pool 23 H.E.$o_2$ | PR77A-321 | 11.2 | 0.89 | 3.89 |
| Pool 24 H.E.$o_2$ | PR77A-322 | 9.5 | 0.97 | 4.15 |
| Pool 25 H.E.$o_2$ | PR77A-323 | 10.5 | 0.93 | 4.00 |
| Pool 26 H.E.$o_2$ | PR77A-324 | 9.8 | 1.04 | 4.18 |
| Late White dent H.E.$o_2$ | PR77A-313 | 10.8 | 0.96 | 3.94 |
| Yellow flint H.E.$o_2$ | PR77A-315 | 11.2 | 0.87 | 3.72 |
| Tuxpeño $C_{11}$ x La Posta ($C_2$) H.E.$o_2$ | PR77A-328 | 10.6 | 0.91 | 3.85 |
| PD(MS)6 H.E.$o_2$ | PR77A-301 | 11.6 | 0.72 | 3.87 |
| Yellow H.E.$o_2$ | PR77A-305 | 10.8 | 0.64 | 3.85 |
| White H.E.$o_2$ | PR77A-306 | 11.0 | 0.72 | 3.84 |

TABLE 12.- VALUES FOR PROTEIN, TRYPTOPHAN AND LYSINE IN BULK SAMPLES OF SOME TEMPERATE-SUBTROPICAL HARD ENDOSPERM OPAQUE-2 MATERIALS. (ENDOSPERM ANALYSIS).

| Pedigree | Origin | Protein (%) | Mean Values: Tryptophan in protein (%) | Mean Values: Lysine in protein (%) |
|---|---|---|---|---|
| Amarillo subtropical H.E.$o_2$ | TL77A-1311 | 8.9 | 0.75 | 3.03 |
| Blanco subtropical H.E.$o_2$ | TL77A-1312 | 9.4 | 0.78 | 3.04 |
| ETO x Illinois H.E.$o_2$ | TL77A-1313 | 9.1 | 0.77 | 2.79 |
| Amarillo Pakistan H.E.$o_2$ | TL77A-1314 | 9.2 | 0.75 | 2.72 |
| Blanco Pakistan H.E.$o_2$ | TL77A-1315 | 8.1 | 0.79 | 2.85 |
| Hungarian Composite H.E.$o_2$ | TL77A-1316 | 9.4 | 0.60 | 2.31 |
| Pool 27 H.E.$o_2$ | TL77A-1304 | 8.6 | 0.72 | 2.79 |
| Pool 29 H.E.$o_2$ | TL77A-1319 | 9.6 | 0.67 | 2.50 |
| Pool 30 H.E.$o_2$ | TL77A-1317 | 8.9 | 0.85 | 3.12 |
| Pool 31 H.E.$o_2$ | TL77A-1320 | 9.4 | 0.77 | 2.88 |
| Pool 33 H.E.$o_2$ | TL77A-1318 | 9.4 | 0.70 | 3.06 |
| Pool 34 H.E.$o_2$ | TL77A-1305 | 8.5 | 0.82 | 3.13 |
| Amarillo Bajio H.E.$o_2$ | TL77A-1302 | 9.2 | 0.82 | 3.02 |
| Mezcla Amarilla P. B. x Lin. Illinois H.E.$o_2$ | TL77A-1303 | 9.3 | 0.80 | 2.84 |
| Amarillo Bajio x Maíces Argentinos H.E.$o_2$ | TL77A-1306 | 9.6 | 0.73 | 2.88 |
| Amarillo Bajio x Varios Templados H.E.$o_2$ | TL77A-1307 | 8.9 | 0.81 | 3.28 |
| Amarillo Bajio x Mezcla Tropical blanca H.E.$o_2$ | TL77A-1308 | 9.8 | 0.76 | 2.94 |
| Amarillo Bajío x P.P.M.G. H.E.$o_2$ | TL77A-1309 | 9.8 | 0.73 | 2.98 |
| Maíz tropical selección Batán H.E.$o_2$ | TL77A-1310 | 8.9 | 0.78 | 3.17 |
| Templado Amarillo $o_2$ | TL77A-1301 | 8.7 | 0.74 | 3.03 |

TABLE 13.-VALUES FOR PROTEIN, TRYPTOPHAN AND LYSINE IN BULK SAMPLES OF SOME TEMPERATE-SUBTROPICAL HARD ENDOSPERM OPAQUE-2 MATERIALS. (WHOLE GRAIN ANALYSIS).

| Pedigree | Origin | Protein (%) | Mean Values: Tryptophan in protein (%) | Mean Values: Lysine in protein (%) |
|---|---|---|---|---|
| Amarillo subtropical H.E.$o_2$ | TL77A-1311 | 10.9 | 0.93 | 4.06 |
| Blanco subtropical H.E.$o_2$ | TL77A-1312 | 11.5 | 0.90 | 3.81 |
| ETO x Illinois H.E.$o_2$ | TL77A-1313 | 11.0 | 0.91 | 3.97 |
| Amarillo Pakistan H.E.$o_2$ | TL77A-1314 | 10.6 | 0.92 | 4.09 |
| Blanco Pakistan H.E.$o_2$ | TL77A-1315 | 11.0 | 0.96 | 4.22 |
| Hungarian Composite H.E.$o_2$ | TL77A-1316 | 11.4 | 0.81 | 3.90 |
| Pool 27 H.E.$o_2$ | TL77A-1304 | 10.5 | 0.87 | 4.04 |
| Pool 29 H.E.$o_2$ | TL77A-1319 | 11.0 | 0.78 | 3.67 |
| Pool 30 H.E.$o_2$ | TL77A-1317 | 12.2 | 0.92 | 4.10 |
| Pool 31 H.E.$o_2$ | TL77A-1320 | 11.4 | 0.82 | 4.00 |
| Pool 33 H.E.$o_2$ | TL77A-1318 | 11.9 | 0.84 | 3.97 |
| Pool 34 H.E.$o_2$ | TL77A-1305 | 10.1 | 0.89 | 3.76 |
| Amarillo Bajio H.E.$o_2$ | TL77A-1302 | 10.6 | 0.90 | 4.00 |
| Mezcla Amarilla P. B. x Lin. Ill. H.E.$o_2$ | TL77A-1303 | 12.2 | 0.84 | 3.53 |
| Amarillo Bajio x Maíces Arg. H.E.$o_2$ | TL77A-1306 | 11.6 | 0.83 | 3.67 |
| Amarillo Bajio x Varios Templados H.E.$o_2$ | TL77A-1307 | 11.6 | 0.79 | 3.57 |
| Amarillo Bajio x Mezcla Tropical blanca H.E.$o_2$ | TL77A-1308 | 11.5 | 0.86 | 3.91 |
| Amarillo bajio x P.P.M.G. H.E.$o_2$ | TL77A-1309 | 11.6 | 0.93 | 3.88 |
| Maíz tropical selección Batán H.E.$o_2$ | TL77A-1310 | 11.0 | 0.91 | 3.72 |
| Templado Amarillo $o_2$ | TL77A-1301 | 10.6 | 0.89 | 4.04 |

TABLE 14.- Mean values for protein, tryptophan and lysine in bulk samples of hard endosperm opaque-2 materials (Whole grain analysis).

| Pedigree | Origin | Whole grain defatted | | |
|---|---|---|---|---|
| | | Protein | Tryptophan in protein % | Lysine in protein % |
| Tuxpeño 1 H.E.$o_2$ | PR78A-Lote 96 | 10.5 | 0.85 | 3.5 |
| Mezcla Tropical Blanca H.E.$o_2$ | PR78A-Lote 97 | 10.1 | 0.91 | 3.7 |
| Blanco Cristalino H.E.$o_2$ | PR78A-302# PaP | 11.2 | 0.82 | 3.6 |
| Ant. x Ver. 181 H.E.$o_2$ | PR78A-301# PaP | 10.9 | 0.92 | 3.9 |
| Mix. 1-Col. Gpo. 1 x Eto H.E.$o_2$ | PR78A-303# PaP | 10.4 | 0.90 | 3.9 |
| Mezcla Amarilla H.E.$o_2$ | PR78A-304# PaP | 11.2 | 0.86 | 3.9 |
| Amarillo Cristalino H.E.$o_2$ | PR78A-305# PaP | 11.6 | 0.83 | 3.6 |
| Amarillo Dentado H.E.$o_2$ | PR78A-306# PaP | 11.2 | 0.78 | 3.5 |
| Tuxpeño Caribe H.E.$o_2$ | PR78A-307# PaP | 10.8 | 0.84 | 3.7 |
| Cogollero H.E.$o_2$ | PR78A-308# PaP | 11.5 | 0.80 | 3.7 |
| La Posta H.E.$o_2$ | PR78A-309# PaP | 10.3 | 0.86 | 3.8 |
| Ant. x Rep. Dom. H.E.$o_2$ | PR78A-Lote 95 | 10.4 | 0.89 | 3.7 |
| Yellow $o_2$ B.U. Pool | PR 8A-311# PaP | 10.6 | 0.85 | 3.9 |
| Late White dent H.E.$o_2$ | PR78A-310# PaP | 11.1 | 0.85 | 3.6 |
| Yellow flint H.E.$o_2$ | PR78A-312# PaP | 10.9 | 0.83 | 3.8 |
| White flint H.E.$o_2$ | PR78A-325,328 PaP | 10.8 | 0.83 | 3.7 |
| Recombination of yellow dent fam. | PR78A-330# PaP | 11.0 | 0.85 | 3.6 |
| Selección precoz H.E.$o_2$ | PR78A-326# PaP | 10.0 | 0.87 | 3.8 |
| Pool 15 H.E.$o_2$ | PR78A-313# PaP | 10.4 | 0.90 | 3.8 |
| Pool 16 H.E.$o_2$ | PR78A-314# PaP | 10.8 | 0.83 | 3.9 |
| Pool 17 H.E.$o_2$ | PR78A-315# PaP | 9.7 | 0.84 | 4.0 |
| Pool 18 H.E.$o_2$ | PR78A-316# PaP | 10.2 | 0.75 | 3.3 |
| Pool 19 H.E.$o_2$ | PR78A-317# PaP | 10.0 | 0.78 | 3.5 |
| Pool 20 H.E.$o_2$ | PR78A-318# PaP | 10.5 | 0.82 | 3.6 |
| Pool 21 H.E.$o_2$ | PR78A-319# PaP | 9.5 | 0.88 | 3.6 |
| Pool 22 H.E.$o_2$ | PR78A-320# PaP | 10.4 | 0.81 | 3.5 |
| Pool 23 H.E.$o_2$ | PR78A-321# PaP | 9.2 | 0.85 | 3.7 |
| Pool 24 H.E.$o_2$ | PR78A-322A PaP | 10.2 | 0.82 | 3.8 |
| Pool 25 H.E.$o_2$ | PR78A-323A PaP | 10.5 | 0.80 | 3.9 |
| Pool 26 H.E.$o_2$ | PR78A-3[illegible]4A PaP | 10.8 | 0.81 | 3.6 |
| Amarillo Subtropical H.E.$o_2$ | TL78A-1301# PaP | 10.8 | 1.05 | 3.4 |
| Blanco subtropical H.E.$o_2$ | TL78A-1302# PaP | 10.5 | 1.08 | 3.9 |
| Eto x Ill. H.E.$o_2$ | TL78A-1303# PaP | 10.9 | 0.90 | 3.4 |
| Hungarian Composite H.E.$o_2$ | TL78A-1304# PaP | 9.5 | 0.93 | 4.0 |
| Pool 27 H.E.$o_2$ | TL78A-1305# PaP | 10.6 | 0.90 | 3.5 |
| Pool 28 H.E.$o_2$ | TL78A-1306# PaP | 10.4 | 1.09 | 3.5 |
| Pool 29 H.E.$o_2$ | TL78A-1307# PaP | 10.2 | 1.02 | 3.7 |
| Pool 30 H.E.$o_2$ | TL78A-1308# PaP | 10.0 | 0.92 | 3.8 |
| Pool 31 H.E.$o_2$ | TL78A-1309# PaP | 9.2 | 1.09 | 4.1 |
| Pool 32 H.E.$o_2$ | TL78A-1310# PaP | 9.1 | 1.08 | 4.1 |
| Pool 33 H.E.$o_2$ | TL78A-1311# PaP | 9.5 | 1.08 | 3.9 |
| Pool 34 H.E.$o_2$ | TL78A-1312# PaP | 10.7 | 1.06 | 3.3 |
| Amarillo Bajío H.E.$o_2$ | TL78A-1313# PaP | 9.5 | 1.09 | 4.0 |
| Am. Bajío x Maíces Argentinos H.E.$o_2$ | TL78A-1315# PaP | 8.6 | 1.05 | 3.8 |
| Am. Bajío x Varios templados H.E.$o_2$ | TL78A-1315B# PaP | 8.1 | 1.01 | 4.1 |
| Am. Bajío x Mezcla tropical bl. H.E.$o_2$ | TL78A-1316# PaP | 10.0 | 1.07 | 4.0 |
| Maiz tropical selección Batan H.E.$o_2$ | TL78A-1317# PaP | 10.7 | 0.95 | 3.3 |
| Mezcla Am. P.B. x Lin. Ill. H.E.$o_2$ | TL78A-1314 | 8.6 | 1.19 | 3.8 |

TABLE 15.- Evaluation of different generations for endosperm hardness.

| Material | Stage of development | Endosperm hardness rating |
|---|---|---|
| Eto x Illinois H.E.$o_2$ | $F_6$ | 2.8 |
| | $F_4$ | 3.0 |
| | $F_2$ | 3.5 |
| (Normal) | | 1.8 |
| Amarillo del Bajío H.E.$o_2$ | $F_7$ | 2.5 |
| | $F_5$ | 3.0 |
| | $F_3$ | 3.8 |
| (Normal) | | 1.8 |
| Amarillo Bajío x varios templados H.E.$o_2$ | $F_7$ | 2.8 |
| | $F_5$ | 3.0 |
| | $F_3$ | 3.5 |
| (Normal) | | 1.8 |
| Amarillo Bajío x Mezcla Trop. Amarilla H.E.$o_2$ | $F_7$ | 2.3 |
| | $F_5$ | 2.8 |
| | $F_3$ | 3.2 |
| (Normal) | | 1.5 |

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

| Material | Breeding scheme | Cycle of selection during 1978B | No. of families planted 1977A | 1977B | 1978A | 1978B | 1979A |
|---|---|---|---|---|---|---|---|
| White opaque-2 back-up pool (Flint) | half-sib | $C_8$ | 644 | 624 1/ | 480 | 351 | 288 |
| White opaque-2 back-up pool (Dent) | half-sib | $C_8$ | - | - | 243 | 196 | 266 |
| Yellow opaque-2 back-up pool (Flint) | half-sib | $C_8$ | 704 | 667 1/ | 606 | 374 | 458 |
| Yellow opaque-2 back-up pool (Dent) | half-sib | $C_8$ | - | - | 245 | 248 | 333 |
| Full-sibs from Yellow opaque-2 back-up pool ($C_3$)-#-#-⊠-#-# | full-sib | - | 108 | 82 | 33 | 106 | 28 |

1/ Flint and dent separation was done following 1977B harvest.

TABLE 17.- Subtropical-temperate opaque-2 materials in the back-up stages of the program.

| Material | Breeding scheme | Cycle of selection during 1978B | No. of families planted | | | | |
|---|---|---|---|---|---|---|---|
| | | | 1977A | 1977B | 1978A | 1978B | 1979A |
| Temperate x tropical H.E.$o_2$ (Flint) | half-sib | $C_9$ | 771[1/] | 215 | 308 | 475 | 592 |
| Temperate x tropical H.E.$o_2$ (Dent) | half-sib | $C_9$ | - | 396 | 310 | 487 | 343 |
| Temperate white H.E.$o_2$ | half-sib | $C_3$ | - | 30 | 274 | 293 | 363 |

1/ Divided into flint and dent following 1977A harvest.

TABLE 18.- Mean values for protein, tryptophan and lysine in bulk samples of hard endosperm opaque-2 materials (Whole grain analysis).

| Pedigree | Origin | Whole grain, defatted | | | |
|---|---|---|---|---|---|
| | | Protein | Q.I. | Tryptophan in protein % | Lysine in protein % |
| White $o_2$ B.U. Pool (Flint) | PR78A-Lote 91 | 8.9 | 5.3 | 1.03 | 4.0 |
| White $o_2$ B.U. Pool (Dent) | PR78A-Lote 92 | 9.1 | 5.5 | 1.01 | 4.1 |
| Yellow $o_2$ B.U. Pool (Flint) | PR78A-Lote 93 | 9.1 | 5.2 | 1.01 | 4.2 |
| Yellow $o_2$ B.U. Pool (Dent) | PR78A-Lote 94 | 9.8 | 4.9 | 0.91 | 4.0 |
| Temperate x tropical H.E.$o_2$(Flint) | TL78A-Lote 191 | 9.6 | 5.5 | 1.12 | - |
| Temperate x tropical H.E.$o_2$(Dent) | TL78A-Lote 192 | 9.4 | 5.5 | 1.19 | - |
| Temperate x White H.E.$o_2$ | TL78A-Lote 193 | 10.0 | 5.0 | 1.00 | - |

TABLE 19.- Cycles of selection trial with temperate x tropical H.E.$o_2$ grown at three locations in Mexico during the year 1978B.

| Cycle | Mean across three locations | | | | |
|---|---|---|---|---|---|
| | Grain yield (kg/ha) | Days to silk | Ear rots (%) | Moisture (%) | Hard endosperm ears (%) |
| $C_0$ | 4245 | 57.0 | 11.8 | 4.7 | 54.2 |
| $C_1$ | 4727 | 56.9 | 6.9 | 21.9 | 68.4 |
| $C_2$ | 4607 | 56.9 | 9.6 | 21.9 | 75.6 |
| $C_3$ | 4288 | 57.1 | 7.2 | 21.9 | 79.9 |
| $C_4$ | 4347 | 57.1 | 12.5 | 22.6 | 83.3 |
| $C_5$ | 4420 | 56.3 | 8.2 | 21.6 | 85.9 |
| $C_6$ | 4564 | 56.1 | 7.8 | 21.2 | 85.9 |
| $C_7$ | 4416 | 56.2 | 6.7 | 22.1 | 89.7 |
| $C_8$ | 4484 | 55.9 | 7.0 | 21.9 | 90.8 |
| LSD(5%) | 475 | 0.9 | 5.3 | 2.0 | 7.5 |

TABLE 20.- Evaluation of different cycles in yellow opaque-2 back-up pool (Flint) grown at Poza Rica during the year 1978B.

| Cycle | Yield (kg/ha) | Days to flower | Endosperm hardness (1 - 5) | Hard endosperm ears (%) |
|---|---|---|---|---|
| $C_0$ | 3774 | 56 | 3.9 | 59.6 |
| $C_1$ | 3822 | 57 | 4.0 | 58.1 |
| $C_2$ | 4050 | 57 | 3.4 | 76.0 |
| $C_3$ | 3895 | 56 | 2.9 | 84.3 |
| $C_4$ | 4180 | 57 | 3.0 | 85.0 |
| $C_5$ | 4722 | 56 | 2.5 | 89.7 |
| $C_6$ | 5021 | 55 | 2.4 | 92.9 |
| $C_7$ | 4328 | 56 | 2.1 | 92.7 |
| LSD(5%) | 703 | 0.0 | 0.36 | 6.1 |

TABLE 21a.- Evaluation of different cycles of selection in white opaque-2 back-up pool grown at Poza Rica during 1978B.

| Cycle | Yield (kg/ha) | Days to flower | Endosperm hardness (1 - 5) | Hard endosperm ears (%) |
|---|---|---|---|---|
| $C_0$ | 3537 | 57 | 2.8 | 54.1 |
| $C_1$ | 2487 | 58 | 2.0 | 82.4 |
| $C_2$ | 2864 | 58 | 2.4 | 91.0 |
| $C_3$ | 2969 | 58 | 1.9 | 86.5 |
| $C_4$ | 2646 | 58 | 2.0 | 88.4 |
| $C_5$ | 3160 | 57 | 2.0 | 95.0 |
| $C_6$ | 3655 | 56 | 2.1 | 90.1 |
| $C_7$ | 3477 | 56 | 1.6 | 94.3 |
| LSD(5%) | 1104 | 0.0 | 0.62 | 13.4 |

TABLE 21b.- Evaluation of different cycles of selection in white opaque-2 back-up pool grown at Obregon during 1978B.

| Cycle | Yield (kg/ha) | Days to flower | Endosperm hardness ( 1 - 5) | Hard endosperm ears (%) |
|---|---|---|---|---|
| $C_0$ | 2448 | 63 | 4.0 | 63.3 |
| $C_1$ | 2538 | 61 | 3.3 | 77.9 |
| $C_2$ | 2668 | 63 | 3.1 | 82.3 |
| $C_3$ | 3148 | 61 | 3.1 | 82.2 |
| $C_4$ | 2839 | 58 | 2.9 | 82.5 |
| $C_5$ | 3238 | 59 | 2.2 | 94.4 |
| $C_6$ | 3106 | 56 | 2.6 | 89.8 |
| $C_7$ | 3033 | 58 | 2.0 | 95.7 |
| LSD(5%) | 944 | 0.0 | 0.4 | 7.3 |

TABLE 22.- Mean across two locations for days to 50% silking and endosperm hardness in different generations of different materials.

| Material | generation | Days to 50% silking | Endosperm hardness |
|---|---|---|---|
| Tuxpeño 1 H.E.$o_2$ | $F_6$ | 58.0 | 2.5 |
| | $F_4$ | 60.5 | 2.8 |
| | $F_2$ | 59.5 | 3.0 |
| | N | 61.0 | 1.5 |
| Blanco Cristalino H.E.$o_2$ | $F_7$ | 58.5 | 2.8 |
| | $F_5$ | 62.0 | 3.0 |
| | $F_3$ | 59.5 | 3.8 |
| | N | 58.5 | 1.5 |
| Mezcla Amarilla H.E.$o_2$ | $F_8$ | 56.0 | 2.5 |
| | $F_6$ | 57.0 | 3.0 |
| | $F_4$ | 60.0 | 3.5 |
| | N | 58.5 | 1.5 |
| Amarillo Cristalino H.E.$o_2$ | $F_9$ | 63.0 | 2.5 |
| | $F_7$ | 63.0 | 3.0 |
| | $F_5$ | 63.5 | 4.0 |
| | N | 63.0 | 2.0 |
| Pool 19 H.E.$o_2$ | $F_9$ | 60.0 | 2.2 |
| | $F_7$ | 62.0 | 3.0 |
| | $F_6$ | 56.0 | 3.5 |
| | N | 63.0 | 1.5 |

TABLE 23.- 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 24.- Summary of performance of full-sib families from two populations grown during the year 1977B.

| Population | Test sites | No. of families | | Mean yield in kg/ha. | | | % superiority of sel. fam. mean over | | C.V. | L.S.D. | Plant height | | Days to flowe[r] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Tested | Selected | Tested | Selected | Check $\bar{X}$ | Pop. $\bar{X}$ | Check $\bar{X}$ | | | Tested | Selected | Tested | Selecte[d] |
| PD(MS)6 H.E.$o_2$ | Guatemala | 250 | 121 | 4228 | 4344 | 5548 | 2.7 | -21.7 | 15.5 | 1323 | 204 | 202 | 61 | 61 |
| | Panama | 250 | 121 | 1553 | 1699 | 1545 | 9.4 | 10.0 | 34.7 | 1079 | 177 | 177 | 50 | 50 |
| | Poza Rica | 250 | 121 | 3731 | 3865 | 4079 | 3.6 | - 5.3 | 15.0 | 1123 | 209 | 207 | 58 | 58 |
| | Obregon | 250 | 121 | 2755 | 2915 | 2760 | 5.8 | 5.6 | 21.3 | 1175 | 193 | 192 | 57 | 57 |
| | Thailand | 250 | 121 | 4362 | 4455 | 3893 | 2.1 | 14.4 | 12.9 | 1118 | 218 | 216 | 50 | 50 |
| | Across | 250 | 121 | 3326 | 3456 | 3565 | 3.9 | - 3.1 | | 1164 | 200 | 199 | 55 | 55 |
| Templado Amarillo $o_2$ | Tlaltizapan | 250 | 87 | 6467 | 6621 | 6460 | 2.4 | 2.5 | 13.0 | 1677 | 202 | 200 | 62 | 62 |
| | Pantnagar | 250 | 87 | 5370 | 5501 | 8179 | 2.4 | -32.7 | 18.4 | 2003 | 259 | 252 | 52 | 51 |
| | Khumultar | 250 | 87 | 5000 | 5143 | 5323 | 2.9 | - 3.4 | 24.4 | 2441 | 214 | 212 | 59 | 59 |
| | Geiza | 250 | 87 | 3845 | 4142 | 5396 | 7.7 | -23.2 | 27.7 | 2147 | 232 | 228 | 65 | 64 |
| | Across | 250 | 87 | 5171 | 5352 | 6340 | 3.5 | -15.6 | 20.9 | 2067 | 227 | 223 | 60 | 59 |

TABLE 25.- Summary of performance of full-sib families from three opaque-2 populations grown during the year 1977B.

| Population | | No. of families | | Mean yield in kg/ha. | | | % superiority of sel. fam. mean over | | C.V. | L.S.D. | Plant height | | Days to flower | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Tested | Selected | Tested | Selected | Check $\bar{x}$ | Pop. $\bar{x}$ | Check $\bar{x}$ | | | Tested | Selected | Tested | Selected |
| CIMMYT H.E.$o_2$ | Poza Rica | 250 | 109 | 4092 | 4264 | 3797 | 4.2 | 12.3 | 14.5 | 1186 | 200 | 183 | 64 | 60 |
| | Obregon | 250 | 109 | 2349 | 2534 | 2340 | 7.9 | 8.3 | 26.9 | 1262 | 193 | 193 | 70 | 66 |
| | Tlaltizapan | 250 | 109 | 5719 | 6080 | 4888 | 6.3 | 24.4 | 15.9 | 1817 | 240 | 228 | 65 | 64 |
| | Across | 250 | 109 | 4053 | 4293 | 3675 | 5.9 | 16.8 | 19.1 | 1422 | 211 | 201 | 66 | 63 |
| White H.E.$o_2$ | Poza Rica | 250 | 98 | 4366 | 4599 | 4510 | 5.3 | 2.0 | 14.9 | 1300 | 209 | 207 | 60 | 60 |
| | Obregon | 250 | 98 | 3021 | 3303 | 3239 | 9.3 | 2.0 | 21.0 | 1270 | 197 | 196 | 61 | 60 |
| | Tlaltizapan | 250 | 98 | 6323 | 6750 | 5153 | 6.8 | 31.0 | 13.9 | 1751 | 233 | 231 | 66 | 65 |
| | Across | 250 | 98 | 4570 | 4884 | 4301 | 6.9 | 13.6 | 16.6 | 1440 | 213 | 212 | 62 | 62 |
| Tuxpeño opaque-2 | Poza Rica | 250 | 88 | 3671 | 3928 | 2949 | 7.0 | 33.2 | 20.9 | 1525 | 195 | 195 | 62 | 62 |
| | Obregon | 250 | 88 | 2857 | 3118 | 2723 | 9.1 | 14.5 | 20.8 | 1186 | 178 | 177 | 63 | 63 |
| | Across | 250 | 88 | 3264 | 3523 | 2836 | 7.9 | 24.2 | 20.9 | 1356 | 187 | 186 | 63 | 63 |

TABLE 26.- Mean grain yield and other agronomic traits of families for the development of experimental varieties from advanced unit opaque-2 populations on the basis of IPTT data 1977.

| Population No. | Population | Experimental Variety | Grain yield kg/ha. Pop. $\bar{x}$ | Sel. fam. $\bar{x}$ | Checks $\bar{x}$ | % superiority of sel. fam. $\bar{x}$ over Pop. $\bar{x}$ | Check $\bar{x}$ | Days to flower Pop. $\bar{x}$ | Sel. fam. $\bar{x}$ | Pl. Ht. in cms. Pop. $\bar{x}$ | Sel. fam. $\bar{x}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 38 | PD(MS)6 H.E.$o_2$ | San Jerónimo 7738 | 4228 | 5140 | 5548 | 21.6 | -7.4 | 61 | 62 | 204 | 204 |
| | | Tocumen 7738 | 1553 | 2371 | 1545 | 52.7 | 53.5 | 50 | 49 | 177 | 179 |
| | | Poza Rica 7738 | 3731 | 4424 | 4079 | 18.6 | 8.5 | 58 | 59 | 209 | 210 |
| | | Obregon 7738 | 2755 | 3447 | 2760 | 25.1 | 24.9 | 57 | 55 | 193 | 192 |
| | | Suwan 7738 | 4362 | 5342 | 3893 | 22.5 | 37.2 | 50 | 48 | 218 | 216 |
| | | Across 7738 | 3326 | 3841 | 3565 | 15.5 | 7.7 | 55 | 54 | 200 | 204 |
| 41 | Templado Amarillo $o_2$ | Tlaltizapan 7741 | 6467 | 7808 | 6460 | 20.7 | 20.9 | 62 | 61 | 202 | 203 |
| | | Tlaltizapan 7741(E) | 6467 | 6853 | 6460 | 4.1 | 6.1 | 62 | 63 | 202 | 204 |
| | | Pantnagar 7741 | 5370 | 6604 | 8179 | 23.0 | -19.3 | 52 | 51 | 259 | 249 |
| | | Khumultar 7741 | 5000 | 6619 | 5323 | 32.4 | 24.4 | 59 | 57 | 214 | 209 |
| | | Gemeiza 7741(1) | 3845 | 6378 | 5396 | 65.9 | 18.2 | 65 | 64 | 232 | 247 |
| | | Gemeiza 7741 | 3845 | 5400 | 5396 | 40.4 | 0.1 | 65 | 64 | 232 | 233 |
| | | Across 7741 | 5171 | 6385 | 6340 | 23.5 | 0.7 | 60 | 60 | 227 | 232 |

TABLE 27.- Mean grain yield and other agronomic traits of families for the development of experimental varieties from advanced unit opaque-2 populations on the basis of IPTT data 1977.

| Population No. | Population | Experimental Variety | Grain yield kg/ha. Pop. $\bar{x}$ | Sel. fam. $\bar{x}$ | Checks $\bar{x}$ | % superiority of sel. fam. $\bar{x}$ over Pop. $\bar{x}$ | Check $\bar{x}$ | Days to flower Pop. $\bar{x}$ | Sel. fam. $\bar{x}$ | Pl. Ht. in cms. Pop. $\bar{x}$ | Sel. Fam. $\bar{x}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | White H.E.$o_2$ | Poza Rica 7740 | 4366 | 5264 | 4510 | 20.6 | 16.7 | 60 | 60 | 209 | 204 |
| | | Obregon 7740 | 3021 | 3977 | 3239 | 31.7 | 22.8 | 61 | 58 | 197 | 196 |
| | | Tlaltizapan 7740 | 6323 | 7603 | 5153 | 20.2 | 47.6 | 66 | 66 | 233 | 231 |
| | | Ilonga 7740 | 2543 | 3188 | 2260 | 25.4 | 41.1 | 55 | 54 | 239 | 229 |
| | | Laguna 7740 | 4427 | 5321 | 3593 | 20.2 | 48.1 | 61 | 61 | 202 | 193 |
| | | Across 7740 | 4570 | 5268 | 4301 | 15.3 | 22.5 | 62 | 63 | 213 | 209 |
| 39 | Yellow H.E.$o_2$ | Poza Rica 7839 | 5219 | 6070 | 4133 | 16.3 | 46.9 | 57 | 57 | 205 | 207 |

TABLE 28.- Conversion of highland gene pools to opaque-2

| Pool No. | Name | No. of fam. handled during each cycle 1976 | 1977 | 1978 |
|---|---|---|---|---|
| 1 | Highland early white flint | 39 | 68 | 30 |
| 2 | Highland early white dent | 45 | 91 | 43 |
| 4 | Highland early yellow flint | 35 | 226 | 81 |
| 5 | Highland early yellow dent | 45 | 129 | 53 |
| 7 | Highland intermediate white dent | 17 | 63 | 51 |
| 9 | Highland intermediate yellow flint | 55 | 158 | 105 |
| 10 | Highland intermediate yellow dent | 26 | 132 | 69 |
| 11 | Highland late white flint | 24 | 9 | 5 |
| 12 | Highland late white dent | 32 | 40 | 36 |
| 13 | Highland late yellow flint | 30 | 47 | 42 |
| 14 | Highland late yellow dent | 13 | 54 | 49 |
| | | 361 | 1017 | 564 |

TABLE 29.- Highland opaque-2 materials in the back-up stages of the program.

| Population | Method of recombination | Generation/ cycle of selection | No. of families handled each cycle 1977 | 1978 |
|---|---|---|---|---|
| a) Soft endosperm $o_2$ materials | | | | |
| Composite I | H.S. | $C_6$ | 416 | 458 |
| Puebla opaque-2 composite | H.S. | $C_6$ | 384 | 384 |
| Puebla opaque-2 x Barraza | H.S. | $F_4$ | 157 | 130 |
| b) Hard endosperm $o_2$ materials | | | | |
| Highland modified opaque-2 comp. | H.S. | $C_3$ | 288 | 366 |
| Mezcla amarilla P.B. x Lin. Ill. H.E.$o_2$ | F.S. | $F_4$ | 79 | 65 |
| Mezcla amarilla P.B. x Lin. Ill. x precoces H.E.$o_2$ | F.S. | $F_4$ | 53 | 49 |
| Planta pequeña mazorca grande H.E.$o_2$ | F.S. | $F_4$ | 46 | 38 |
| Composite I H.E.$o_2$ | F.S. | $F_6$ | 122 | 80 |
| Intercrosses among H.E. $o_2$ families | F.S. | $F_3$ | 77 | 30 |
| Highland white H.E.$o_2$ families | F.S. | $F_2$ | 57 | 33 |

TABLE 30.- Development of floury-1 opaque-2 materials

| Material | Breeding scheme | Generation/ cycle | No. of fam. handled each cycle | |
|---|---|---|---|---|
| | | | 1977 | 1978 |
| Pool 3 opaque-2 | H.S. | $F_4$ | 393 | 513 |
| Pool 8 opaque-2 | H.S. | $F_4$ | 185 | 190 |
| Floury-1 opaque-2 composite | H.S. | $C_5$ | 479 | 483 |

TABLE 31.- Comparison of opaques versus normals for yield and other agronomic characteristics (Poza Rica 1978B)

| Entry No. | Material | Yield (kg/ha) N | Yield (kg/ha) $o_2$ | Days to flower N | Days to flower $o_2$ | Plant height N | Plant height $o_2$ | % Ear rots N | % Ear rots $o_2$ | Hard ears (%) N | Hard ears (%) $o_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Tuxpeño 1 | 3920 | 3866 | 59 | 57 | 181 | 185 | 3.7 | 6.2 | 100 | 78 |
| 2 | Mezcla Tropical Blanca | 3678 | 2868 | 58 | 56 | 182 | 174 | 6.1 | 11.3 | 100 | 92 |
| 3 | Blanco Cristalino | 3578 | 3134 | 55 | 55 | 191 | 190 | 3.8 | 8.8 | 100 | 88 |
| 4 | Mix.1-Col.Gpo.1 x Eto | 3398 | 3862 | 57 | 54 | 193 | 190 | 5.6 | 8.1 | 100 | 83 |
| 5 | Mezcla Amarilla | 3004 | 3042 | 56 | 56 | 181 | 186 | 7.3 | 10.9 | 100 | 84 |
| 6 | Amarillo Dentado | 2902 | 3643 | 60 | 54 | 206 | 198 | 3.4 | 4.6 | 100 | 86 |
| 7 | Tuxpeño Caribe | 3822 | 3682 | 57 | 54 | 196 | 193 | 2.8 | 9.1 | 100 | 83 |
| 8 | Ant. x Rep. Dom. | 2964 | 2962 | 54 | 54 | 167 | 176 | 5.9 | 8.1 | 100 | 82 |
| 9 | La Posta | 2627 | 3075 | 61 | 58 | 202 | 195 | 7.2 | 7.8 | 100 | 93 |
| 10 | Pool 23 | 3918 | 3470 | 57 | 55 | 191 | 185 | 7.0 | 7.6 | 100 | 90 |
| | LSD(5%) N versus $o_2$ | 549 | | | | 12.6 | | 4.5 | | 7.0 | |

**TABLE 32.- Comparison of opaques versus normals for yield and other agronomic characteristics. (Tlaltizapan 1978B).**

| Entry No. | Material | Yield kg/ha. N | Yield kg/ha. $o_2$ | Days to flower N | Days to flower $o_2$ | Ear height N | Ear height $o_2$ | Ear rots (%) N | Ear rots (%) $o_2$ | Hard ears (%) N | Hard ears (%) $o_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Tuxpeño 1 | 10122 | 10075 | 64 | 63 | 110 | 110 | 0.5 | 1.1 | 100 | 91 |
| 2 | Mezcla Tropical Blanca | 11488 | 9740 | 63 | 62 | 125 | 113 | 0.5 | 0.0 | 100 | 94 |
| 3 | Blanco Cristalino | 10504 | 9024 | 62 | 62 | 110 | 115 | 0.0 | 1.0 | 100 | 95 |
| 4 | Mix.1-Col.Gpo.1x Eto | 9862 | 9263 | 63 | 62 | 108 | 108 | 0.9 | 0.5 | 100 | 93 |
| 5 | Mezcla Amarilla | 8773 | 8358 | 62 | 62 | 104 | 114 | 0.0 | 1.5 | 100 | 92 |
| 6 | Amarillo dentado | 8295 | 8426 | 64 | 61 | 130 | 113 | 0.6 | 0.5 | 100 | 91 |
| 7 | Tuxpeño Caribe | 10271 | 9161 | 65 | 61 | 125 | 120 | 1.0 | 0.0 | 100 | 93 |
| 8 | Ant.x Rep. Dom. | 8774 | 8411 | 58 | 60 | 97 | 112 | 0.0 | 0.0 | 100 | 85 |
| 9 | La Posta | 10376 | 9857 | 65 | 62 | 150 | 123 | 0.0 | 0.5 | 100 | 96 |
| 10 | Pool 23 | 10218 | 9191 | 62 | 61 | 117 | 119 | 1.0 | 0.5 | 100 | 96 |
| | LSD(5%) N versus $o_2$ | 1134 | | | | 8.5 | | 1.7 | | 4.8 | |

TABLE 33.- Comparison of opaques versus normals for yield and other agronomic characteristics (Obregon 1978B)

| Entry No. | Material | Yield kg/ha N | Yield kg/ha $o_2$ | Days to flower N | Days to flower $o_2$ | Plant height N | Plant height $o_2$ | Ear rots (%) N | Ear rots (%) $o_2$ | Hard ears (%) N | Hard ears (%) $o_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Tuxpeño 1 | 3229 | 3151 | 63 | 61 | 187 | 195 | 0.6 | 1.6 | 100 | 82 |
| 2 | Mezcla Tropical Blanca | 3996 | 3108 | 61 | 59 | 201 | 194 | 1.2 | 3.7 | 100 | 93 |
| 3 | Blanco Cristalino | 3600 | 3106 | 59 | 58 | 200 | 201 | 0.8 | 0.0 | 100 | 85 |
| 4 | Mix.1-Col.Gpo.1 x Eto | 3448 | 3207 | 62 | 59 | 190 | 202 | 0.7 | 3.5 | 100 | 89 |
| 5 | Mezcla Amarilla | 2527 | 3131 | 60 | 61 | 188 | 197 | 0.0 | 2.4 | 100 | 89 |
| 6 | Amarillo Dentado | 2318 | 3039 | 62 | 59 | 205 | 201 | 0.0 | 2.4 | 100 | 88 |
| 7 | Tuxpeño Caribe | 4172 | 3820 | 62 | 59 | 206 | 210 | 1.9 | 2.0 | 100 | 86 |
| 8 | Ant. x Rep. Dom. | 3336 | 3360 | 57 | 58 | 182 | 207 | 0.6 | 0.0 | 100 | 88 |
| 9 | La Posta | 3825 | 4131 | 64 | 60 | 214 | 209 | 0.5 | 3.9 | 100 | 89 |
| 10 | Pool 23 | 3575 | 3120 | 60 | 56 | 209 | 204 | 1.4 | 0.6 | 100 | 95 |
| | LSD(5%) N versus $o_2$ | 658 | | | | 10.4 | | 2.5 | | 6.9 | |

TABLE 34.- Average yields (ton/ha) of opaque entries in 1978B.

| Entry | El Jardin | Zapotalillo | Average |
|---|---|---|---|
| Mezcla Tropical Blanca | 5.96 | 4.28 | 5.12 |
| Mix. - Col. x Eto | 4.17 | 4.22 | 4.20 |
| Tuxpeño Caribe | 5.18 | 4.21 | 4.70 |
| La Posta | 5.14 | 4.25 | 4.70 |
| Yellow (IPTT-39) | 4.66 | 4.37 | 4.52 |
| Tuxpeñito | 5.28 | 4.93 | 5.11 |

TABLE 35 .- 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 |
| | T O T A L | | | | | | | | | | | | | | | 23 |

TABLE 36.- Distribution of progeny and experimental variety trials during the year 1978.

| | No. of sets distributed | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | S. America | C. America | Caribbean | Mexico | Africa | Asia | Others | |
| Yellow H.E.$o_2$(IPTT-39) | 2 | - | - | 1 | 2 | 1 | - | 6 |
| OMPT-11 | 5 | 14 | 7 | 5 | 6 | 6 | 1 | 44 |
| EVT-15 | 9 | 4 | 3 | 5 | 9 | 6 | - | 36 |
| ELVT-19 | 9 | 8 | 5 | 7 | 11 | 12 | - | 52 |

TABLE 37.- Results of OMPT 11 during the year 1978 (Yield in kg/ha).

| Entry No. | Material | San Andres El Salvador | Santa Cruz El Salvador | Cuyuta Guatemala | La Maquina Guatemala | Tocumen Panama | Poza Rica Mexico | Sids Egypt | Alajuela Costa Rica |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Tuxpeño 1 H.E.$o_2$ | 3071 | 4235 | 4866 | 4346 | 4516 | 5622 | 4031 | 5742 |
| 2 | Mezcla Tropical Blanca | 3104 | 3891 | 4775 | 3876 | 3945 | 4600 | 4012 | 5189 |
| 3 | Blanco Cristalino H.E.$o_2$ | 3458 | 4077 | 4927 | 3576 | 4031 | 4860 | 4476 | 5920 |
| 4 | Antigua x Ver.181 H.E.$o_2$ | 2789 | 3555 | 4132 | 4306 | 3028 | 4782 | 4095 | 4429 |
| 5 | Mix.1-Col.Gpo.1 x Etò H.E.$o_2$ | 2658 | 3723 | 3895 | 3824 | 3880 | 5300 | 4242 | 5130 |
| 6 | Mezcla Amarilla H.E.$o_2$ | 3185 | 3384 | 4189 | 3791 | 3465 | 4328 | 3635 | 4962 |
| 7 | Amarillo Cristalino H.E.$o_2$ | 2983 | 3440 | 4614 | 4400 | 3743 | 5061 | 4150 | 5121 |
| 8 | Amarillo Dentado H.E.$o_2$ | 2697 | 3576 | 4154 | 3927 | 3764 | 4884 | 4182 | 5331 |
| 9 | Tuxpeño Caribe H.E.$o_2$ | 3835 | 4269 | 4855 | 4327 | 4155 | 4969 | 4233 | 5454 |
| 10 | Eto Blanco H.E.$o_2$ | 3184 | 4145 | 4509 | 3706 | 3380 | 4336 | 4296 | 5180 |
| 11 | Antigua x Rep. Dom. H.E.$o_2$ | 2986 | 3980 | 4473 | 3724 | 3685 | 3872 | 4339 | 4619 |
| 12 | La Posta H.E.$o_2$ | 3264 | 4221 | 4828 | 4173 | 4041 | 4930 | 4093 | 5447 |
| 13 | Yellow Flint H.E.$o_2$ | 3225 | 3774 | 4971 | 4100 | 4493 | 4495 | 4514 | 5359 |
| 14 | White Flint H.E.$o_2$ | 3226 | 4073 | 4788 | 4142 | 3724 | 4723 | 3974 | 5932 |
| 15 | Late White Dent H.E.$o_2$ | 3513 | 4190 | 4939 | 4779 | 4415 | 4814 | 5156 | 5949 |
| 16 | CIMMYT H.E.$o_2$ | 2946 | 4105 | 4453 | 3655 | 4162 | 4256 | 4693 | 4906 |
| 17 | White H.E.$o_2$ | 3181 | 4655 | 4862 | 4733 | 4379 | 4756 | 5094 | 5283 |
| 18 | PD(MS)6 H.E.$o_2$ | 3367 | 3865 | 4787 | 3970 | 3716 | 4258 | 4195 | 4873 |
| 19 | White B.U. Pool H.E.$o_2$ | 3198 | 3973 | 4670 | 3733 | 3495 | 4344 | 4692 | 5599 |
| 20 | Yellow B.U. Pool H.E.$o_2$ | 3050 | 3971 | 4155 | 3924 | 3829 | 4774 | 4779 | 5574 |
| 21 | Temp. x Trop. H.E.$o_2$ | 2715 | 3399 | 3568 | 3755 | 3353 | 3892 | 2943 | 3778 |
| 22 | Check (1)* | 2373 | 3964 | 5284 | 5527 | 4825 | 6816 | 4380 | 5073 |
| 23 | Check (2)* | 3272 | 4349 | 4742 | 3806 | 4780 | 6545 | 3915 | 5416 |
| 24 | Check (3)* | 3276 | 5202 | 5195 | 4415 | 4292 | 6067 | 4454 | 6352 |
| 25 | Check (4)* | 2603 | 4532 | 4097 | 4227 | 4208 | 3688 | 5612 | 5542 |
| | LSD (.05) | 655 | 751 | 588 | 1131 | 640 | 625 | 1009 | 503 |
| | C.V. | 15.0 | 13.2 | 9.1 | 19.5 | 11.4 | 9.1 | 16.5 | 6.7 |

* The checks can be different according to locations.

TABLE 38.- 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 39. - Results of EVT No. 15 during the year 1977

| Entry No. | Pedigree | San Jerónimo | La Calera Nicaragua | Tocumen Panama | Poza Rica Mexico | Obregon Mexico | Tlaltizapan México | Guanacaste Costa Rica | San Andres El Salvador | Cotaxtla México | Jamaica | Ludhiana India | Pirsabak Pakistan | Suwan Thailand | Across Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Ferke 7537 | 4914 | 3946 | 2903 | 5461 | 2297 | 6830 | 3479 | 3394 | 4315 | 2406 | 5458 | 4394 | 5611 | 4005 |
| 2 | Cotaxtla 7537 | 5030 | 3539 | 2752 | 5497 | 1948 | 6779 | 2900 | 3146 | 4400 | 2661 | 5473 | 4021 | 5253 | 3837 |
| 3 | CIMMYT H.E.$o_2$ | 4141 | 3106 | 2652 | 4561 | 1578 | 4804 | 2900 | 3149 | 3858 | 2491 | 5282 | 4200 | 4821 | 3537 |
| 4 | Ferke 7539 | 4217 | 3479 | 2600 | 4321 | 1869 | 5394 | 3370 | 2964 | 4039 | 2730 | 5624 | 4176 | 4785 | 3659 |
| 5 | Suwan 7539 | 4025 | 3776 | 2755 | 5382 | 1766 | 5324 | 2849 | 2958 | 4288 | 2864 | 5767 | 3982 | 4800 | 3690 |
| 6 | Poza Rica 7539 | 3351 | 2897 | 2824 | 4612 | 1539 | 5412 | 3052 | 2955 | 3900 | 2646 | 5515 | 4176 | 4861 | 3510 |
| 7 | Ant.x Ver.181 H.E.$o_2$ | 4379 | 3818 | 2721 | 4861 | 1867 | 5397 | 3333 | 3252 | 3855 | 2821 | 5797 | 4297 | 4562 | 3728 |
| 8 | Poza Rica 7540 | 4303 | 3033 | 1761 | 4727 | 1824 | 4706 | 2652 | 2524 | 3470 | 2133 | 5146 | 3382 | 4499 | 3232 |
| 9 | Across 7437 | 3394 | 3930 | 2621 | 5415 | 2093 | 6015 | 2509 | 2906 | 4152 | 2403 | 6036 | 3252 | 4673 | 3551 |
| 10 | Check (opaque-2) | 4134 | 4409* | 1736 | 4867 | 1649 | 5100 | 2903* | 2867* | 2991 | 3452* | 5549* | 2524* | 4141 | - |
| 11 | Check (normal) | 3644 | 3079 | 2649 | 2103 | 1491 | 2791 | 1055 | 3958* | 3855 | 3761* | 5449 | 2742** | 6692 | - |
| | Means | 4194 | 3502 | 2621 | 4981 | 1864 | 5639 | 3004 | 3027 | 4030 | 2572 | 5566 | 3986 | 4873 | |
| | L.S.D. | 1234 | 897 | 599 | 617 | 445 | 1053 | 979 | 665 | 695 | 575 | 800 | 796 | 596 | |
| | E.V. | 20.9 | 17.7 | 16.5 | 9.2 | 17.2 | 13.8 | 24.3 | 15.0 | 12.4 | 14.6 | 10.1 | 14.9 | 8.4 | |

* Normal
** Opaque-2

TABLE 40.- Performance of best opaque against normal check. EVT-15 - Year 1977

| Location | Best opaque | Normal check |
|---|---|---|
| San Jeronimo (Guatemala) | 5030 | 3644 |
| Panama | 2903 | 2649 |
| Poza Rica (Mexico) | 5461 | 2103 |
| Obregon (Mexico) | 2297 | 1491 |
| Tlaltizapan (Mexico) | 6830 | 2791 |
| Costa Rica | 3479 | 2903 |
| Cotaxtla (Mexico) | 4400 | 3855 |
| Ludhiana (India) | 6036 | 5549 |
| Pirsabak (Pakistan) | 4394 | 2742 |
| Nicaragua | 3946 | 4409 |
| El Salvador | 3394 | 3958 |
| Jamaica | 2864 | 3761 |
| Suwan (Thailand) | 5611 | 6692 |

TABLE 41.-Results of ELVT No. 19 during the year 1977 (Grain yield in kg/ha at 15% moisture).

| Entry No. | Pedigree | La Máquina Guatemala | Cuyuta Guatemala | La Celba Honduras | La Calera Nicaragua | Tocumen Panama | Bodles Jamaica | Poza Rica México | Obregón México | Tlaltizapan México | San Andres El Salvador | Río Hato Panama | Cotaxtla México | Jamaica | Gemiza Egypt | Sids Egypt | Ibadan Nigeria | Pirsabak Pakistan | Yousafwala Pakistan | Kisolon Philippines | Suwan Thailand | Across Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Cotaxtla 7437 | 4018 | 3882 | 4179 | 4597 | 3639 | 4119 | 5636 | 1539 | 7606 | 2955 | 2755 | 3058 | 2727 | 5631 | 4392 | 2600 | 3936 | 5536 | 2146 | 4832 | 3982 |
| 2 | Poza Rica 7537 | 4126 | 3412 | 3664 | 4042 | 3561 | 3789 | 5070 | 1941 | 6349 | 3161 | 2742 | 3352 | 2539 | 4588 | 3293 | 2597 | 2997 | 5127 | 1918 | 4559 | 3634 |
| 3 | Across 7537 | 4657 | 3909 | 3258 | 3700 | 3330 | 3861 | 5891 | 1935 | 7058 | 3236 | 2946 | 3239 | 2224 | 5168 | 2500 | 3421 | 3703 | 6276 | 1982 | 5164 | 3874 |
| 4 | La Máquina 7539 | 4157 | 3558 | 4024 | 3991 | 3427 | 3625 | 4730 | 1531 | 6039 | 3018 | 3024 | 3488 | 2661 | 5014 | 4097 | 2921 | 3203 | 5212 | 3200 | 4842 | 3797 |
| 5 | Across 7539 | 3909 | 3873 | 4109 | 4206 | 3603 | 3883 | 4861 | 1935 | 6203 | 2627 | 3118 | 3424 | 2430 | 7009 | 4827 | 3012 | 3191 | 4103 | 2339 | 4838 | 3875 |
| 6 | Across 7440 | 3823 | 3021 | 3179 | 3694 | 3391 | 3175 | 4046 | 1467 | 5791 | 2879 | 2676 | 2942 | 2285 | 5261 | 3563 | 3079 | 3664 | 4573 | 2124 | 4456 | 3469 |
| 7 | Poza Rica 7437 | 4669 | 3621 | 4100 | 4394 | 3897 | 4028 | 5591 | 1820 | 6442 | 3294 | 3309 | 3239 | 2264 | 5196 | 3713 | 2394 | 3455 | 6076 | 2870 | 4864 | 3958 |
| 8 | Across 7441 | 4510 | 3203 | 3961 | 3736 | 4073 | 3797 | 4670 | 1554 | 6218 | 2797 | 2888 | 3100 | 2930 | 6364 | 4901 | 3400 | 3624 | 6012 | 2873 | 5086 | 3995 |
| 9 | Check ($o_2$) | 5124 | 3439 | 3388 | 4391* | 2076 | 3869 | 4482 | 1792 | 5882 | 3697 | 909 | 4085 | 3649 | 6261 | 5347 | 3261 | 2430 | 3385 | 3658 | 4673 | - |
| 10 | Check (N) | 4861 | 3778 | 4570 | 4794 | 3218 | 4603 | 6042 | 1865 | 6352 | 3649 | 1430 | 1942 | 3491 | 7815 | 6599 | 3464 | 1812 | 5733 | 3997 | 5976 | - |
| | Means | 4233 | 3559 | 3809 | 4045 | 3615 | 3784 | 5061 | 1715 | 6463 | 2965 | 2932 | 3230 | 2507 | 5528 | 3910 | 2928 | 3471 | 5364 | 2431 | 4830 | |
| | LSD (.05) | 565 | 764 | 978 | 989 | 744 | 744 | 702 | 387 | 886 | 605 | 655 | 674 | 704 | 1666 | 844 | 853 | 1075 | 1630 | 581 | 559 | |
| | C.V. | 9.0 | 15.0 | 17.8 | 16.7 | 15.2 | 13.4 | 9.6 | 15.6 | 9.7 | 13.5 | 17.8 | 14.8 | 18.1 | 20.0 | 13.7 | 19.8 | 23.5 | 21.9 | 15.0 | 7.9 | |

* Normal

TABLE 42.- Performance of the best opaque-2 experimental variety against best normal check. ELVT-19 - Year 1977.

| Location | Best opaque | Normal Check |
|---|---|---|
| La Maquina (Guatemala) | 4669 | 4861 |
| Cuyuta (Guatemala) | 3909 | 3776 |
| La Celba (Honduras) | 4179 | 4570 |
| La Calera (Nicaragua) | 4597 | 4794 |
| Tocumen (Panama) | 4073 | 3218 |
| Bodles (Jamaica) | 4119 | 4603 |
| Poza Rica (Mexico) | 5891 | 6042 |
| Obregon (Mexico) | 1941 | 1865 |
| Tlaltizapan (Mexico) | 7606 | 6352 |
| San Andres (El Salvador) | 3294 | 3649 |
| Rio Hato (Panama) | 3309 | 1430 |
| Cotaxtla (Mexico) | 3488 | 1942 |
| Grove Place (Jamaica) | 2930 | 3649 |
| Gemeiza (Egypt) | 7009 | 7815 |
| Sids (Egypt) | 4901 | 6599 |
| Ibadan (Nigeria) | 3421 | 3464 |
| Pirsabak (Pakistan) | 3936 | 1812 |
| Yousafwala (Pakistan) | 6276 | 5733 |
| Kisolon (Philippines) | 3200 | 3997 |
| Suwan (Thailand) | 5164 | 5976 |

FIG. 1.- Dry matter accumulation in Amarillo Bajío.

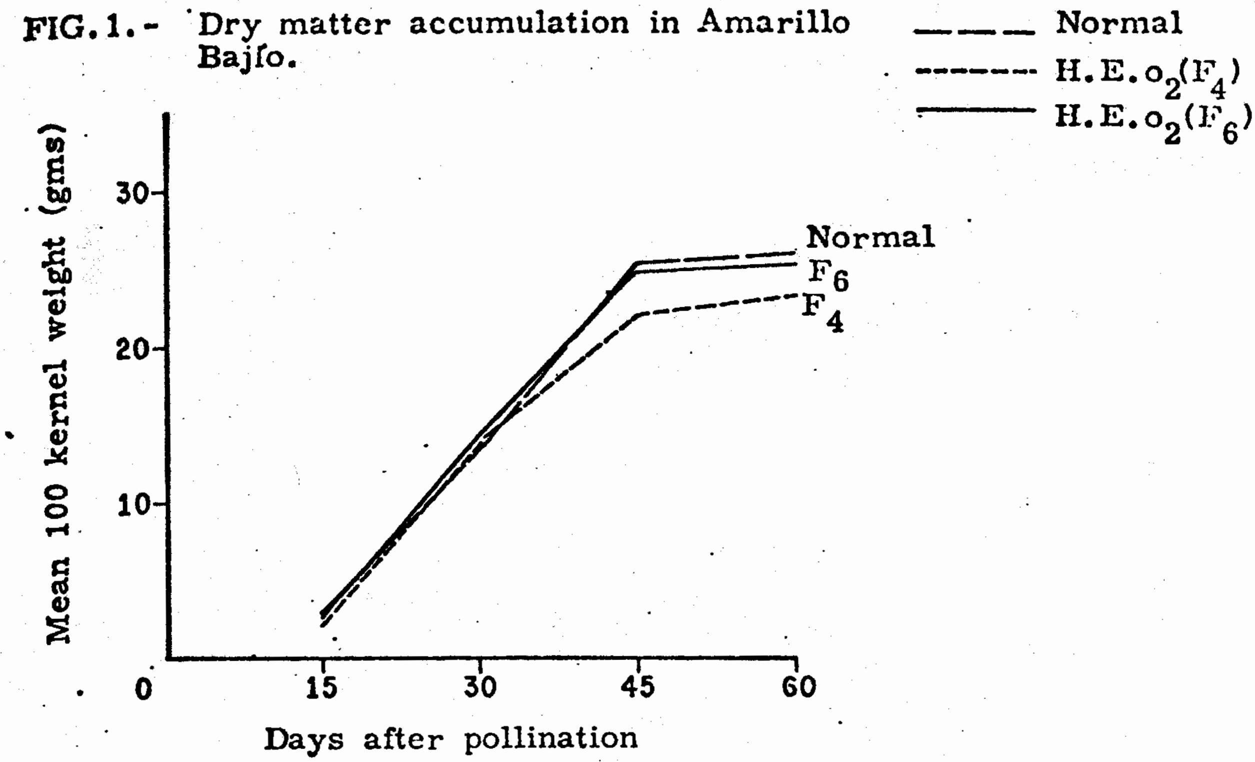
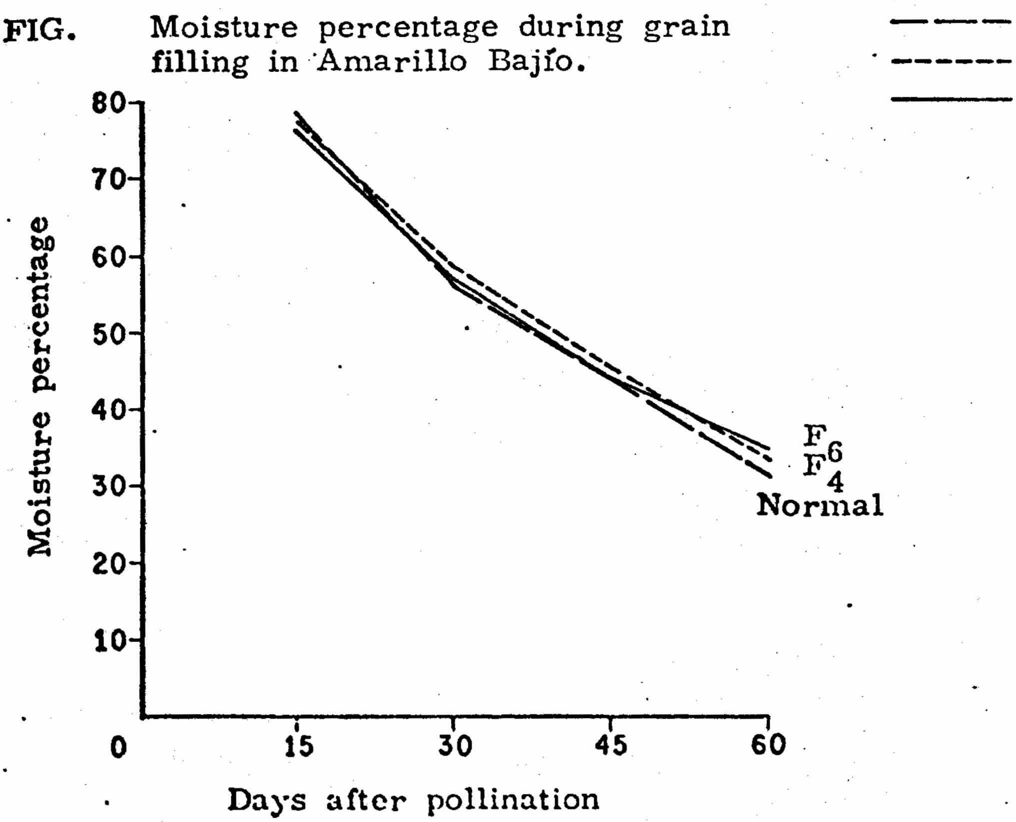



FIG. Moisture percentage during grain filling in Amarillo Bajío.



U N D P - C I M M Y T

G L O B A L R E S E A R C H P R O J E C T

P H A S E III

# CHEMICAL RESEARCH AND ANALYTICAL SERVICE

## PROTEIN QUALITY LABORATORY

## CONTENTS

# CHEMICAL RESEARCH AND ANALYTICAL SERVICE

# IN CIMMYT'S PROTEIN QUALITY LABORATORY

## I. INTRODUCTION

Development of improved, simple, rapid and reliable methods for protein quality evaluation continues to be a primary role of the protein quality laboratory at CIMMYT.

The laboratory has provided a continuous chemical analysis service for the high quality protein maize breeding program, and for the genetic improvement of hard endosperm opaque-2 and floury-1-opaque-2 maize materials. In the preliminary screening of thousands of small maize samples, approximately 16 to 17,000 samples per year are analyzed using simple direct or indirect methods to estimate the content of the two amino acids, tryptophan and/or lysine that are limiting maize protein.

## II. ANALYTICAL PROCEDURES

The chemical evaluation is based on genetic family or single kernel analysis.

### Protein Determination

The nitrogen content is estimated by the conventional micro-Kjeldahl procedure or by the automated technicon method (Hofstader, R. A. 1966) on endosperm or whole kernel samples. All samples are analyzed for total protein content.

### Tryptophan

Defatted maize endosperm samples are analyzed to determine tryptophan content, using the CIMMYT-modified Opienska and Blauth colorimetric method, after papain hydrolysis (Hernandez and Bates, 1968). This method is very simple, reliable, cheap and reproducible, thus very convenient when large number of samples must be analyzed. The tryptophan is estimated in the evaluation of high-quality maize materials, because of the high correlation between the content of this amino acid and the content of lysine in the protein of the maize endosperm. In opaque-2 maize composites grown under different environmental conditions, the laboratory has obtained a correlation coefficient of 0.85 between lysine and tryptophan in endosperm protein; this correlation is highly significant. The tryptophan parameter for screening protein quality in normal maize materials is not used when there is known to be a very poor correlation between the two amino acids. Therefore, the selection of samples with high tryptophan value in the opaque-2 materials also indirectly identifies the samples with high lysine content (The lysine content largely determines the nutritive value of maize protein).

In determining the availability of lysine, the most promising materials are evaluated in animal feeding trials, at advanced stage of development.

## Lysine

The CIMMYT-modified colorimetric method of Tsai is used to determine lysine content of defatted endosperm or whole kernel samples (Villegas and Mertz, 1971), in the screening for high quality materials on maize samples that do not have high pigmentation, or yellow endosperm.

The double mutant opaque-2-sugary-2 samples present problems in the use of the colorimetric methods for tryptophan and lysine determinations, due to the interference of the sugars; in these cases, the dye binding capacity procedure (see below) is used to verify the quality of selected materials by determining lysine content. In most promising materials, the complete amino acid analysis is performed (Moore, et al. 1958, Spackman, D. H. 1962, and Liu and Chang 1971).

## Dye Binding Capacity (DBC)

In the DBC method, an azosulphonic dye solution is mixed with the protein containing sample. The dye binds to the basic amino groups from the basic amino acids and to the terminal amino groups in the proteins. Udy (1954, 1956) introduced this method for estimation of protein in several crops where good standardization curves are obtained with the protein determinations using conventional Kjeldahl procedure. In wheat, barley, maize, and other grain crops, a very high correlation may be obtained between Udy or DBC protein estimation and Kjeldahl protein measure, when evaluating the protein content of normal materials. However, in mutant materials (such as opaque-2 maize, or the high lysine mutants in barley and sorghum materials) there is only weak correlation between DBC and KP. For this reason, as was suggested by Mossberg and Munck (1969, 1972) the ratio of DBC/KP can be used as an estimation of basic amino acids in the protein, and therefore may be used in screening for lysine. The laboratory has obtained a correlation coefficient of 0.85 between Q.I. and lysine in protein in opaque-2 maize whole kernel samples, and this measure has proved to be very efficient as a mass screening test.

## Zein

The procedure for determining zein as used in protein quality evaluation is based on an inverse correlation of the zein content with percentage of lysine in the protein. The zein is determined turbidimetrically, after being precipitated from solution in 70% ethanol-0.5% sodium acetate extracts of either whole grain or endosperm samples (Paulis, Wall and Kwoleck, 1974). This procedure is used primarily in whole kernel analysis. It is recommended for use by national service laboratories, where there is no equipment available for the DBC method.

## Ninhydrin Test

This test measures the quantity of water soluble free amino acids; opaque-2 maize has greater amounts than does its normal counterpart. The test is used in CIMMYT's laboratory only in the preliminary screening for quality of floury-1-opaque-2 materials (Mertz, Misra, and Jambunathan, 1974). As a qualitative test it indicates high or low levels of free amino acids, and thus the presence or absence of the opaque-2 gene. It is performed on a small portion of the endosperm that is cut from each kernel without damage to the embryo. The kernels identified as having the opaque-2 gene are selected and returned to the breeders for their propagation. In the following generation, a quantitative evaluation is performed for tryptophan and/or lysine in the endosperm sample.

## Protein Fractionation

Some of the most promising hard endosperm opaque-2 materials, as well as some sugary-2-opaque-2 lines, have been subjected to fractionation of their endosperm proteins using the procedures of Mertz and Bressani, 1957, and the method of Landry and Moureaux, 1970. In all of the high quality samples fractionated, the decrease in the prolamine fraction was observed along with a concomitant increase in the other protein fractions--with the attendant increase in the lysine content of the total endosperm protein.

# III. STANDARDIZATION OF PROCEDURES

The service laboratories of national programs and CIMMYT's laboratories have been seeking to standardize procedures for protein evaluation over the past three years. Check samples have been prepared at CIMMYT and distributed to laboratories where CIMMYT has been involved in the training of personnel and in the establishment of the national laboratories using equipment provided through UNDP funds.

In most cases, the results obtained on check samples distributed for analysis, have been satisfactory, where the methods tested were the same. However, in visits to some laboratories, some difficulties have been encountered in providing the best service to the breeding programs, because proper consideration has not been given to critical details in sample preparation, or to criterion for selection of the appropriate method to be used, depending of the material to be evaluated. Standardization of procedures and assessment of the needs and difficulties of these laboratories, continues on a crucial part of CIMMYT's work, so far capacity permits. Thus, the aim is to make the laboratories functional and effective for the national breeding programs, as quickly as possible.

## IV. ESTABLISHMENT OF SERVICE LABORATORIES

Equipment has been provided with the funds from the UNDP-CIMMYT Global Research Project to the following national maize breeding programs:

| Latin America | Africa | Asia | Europe |
|---|---|---|---|
| Brazil | Egypt | India (2) | Rumania |
| Peru | | Philippines | |
| Colombia | | Thailand | |
| Ecuador | | | |
| El Salvador | | | |
| Mexico | | | |

Argentina and Nepal also have analytical laboratories, but CIMMYT has not provided equipment for these countries.

## V. TRAINING

The following countries have trained young cereal chemists at CIMMYT's laboratory for periods of 2 to 4 months:

| | | | | | |
|---|---|---|---|---|---|
| Argentina | (1) | Guatemala | (1) | Egypt | (2) |
| Brazil | (1) | Mexico | (3) | Kenya | (1) |
| Peru | (4) | India | (3) | Yugoslavia | (1) |
| Colombia | (2) | Pakistan | (2) | Rumania | (1) |

| | | | | | |
|---|---|---|---|---|---|
| Ecuador | (2) | Philippines | (3) | U. S. A. | (1) |
| El Salvador | (1) | Thailand | (3) | Venezuela | (1) |

Laboratories that are now giving good support to their national breeding programs, include:

Peru, El Salvador, Guatemala, Mexico, India, Philippines, Thailand, Egypt and Yugoslavia.

## VI. BIOLOGICAL EVALUATION

Promising new maize genotypes that are shown to be high in lysine and tryptophan are selected for biological evaluation at different nutrition laboratories.

Maize samples of three opaque-2 hard endosperm types and two opaque-2 soft endosperm types were evaluated at INCAP (Instituto de Nutricion de Centro America y Panama) through use of animal (rat) experiments. The results are reported in Table 1. These findings show similar PER values for the Veracruz 181 opaque hard endosperm and Tuxpeño x La Posta opaque-2 soft endosperm, even though the lysine of the soft endosperm sample was higher than that of the hard endosperm maize.

The National Institute of Animal Science at Denmark evaluated seven maize samples (1 normal maize, 1 opaque-2 soft endosperm and 5 opaque-2 hard endosperm samples). The samples evaluated were (Table 3):

A- Tuxpeño $O_2$ (Soft E.) PR-76A # (IPTT-37) ;

B- CIMMYT HE $O_2$ PR-76B, Bh-101 ;

C- PD $(MS)_6$ HE $O_2$ IPTT-38 ;

D- Yellow HE $O_2$ IPTT-39 ;

E- Amarillo Dentado HE $O_2$ PR-76-13, 801 ;

F- Ant. x Ver 181 HE $O_2$ 806 # ; and

G- White Maize Cr Tl-77A (Normal)

Groups of five Wistar, 75 g, male rats were used in this experiment (following a preliminary period of four days preparation, feeding was continued for five days). Each animal received 150 mg N in 10 g dry matter daily throughout the preliminary (4 day) and balance (5 day) periods. Feeding occured once each day. The N was adjusted by using N-free mixture (Eggum, B. O. 1973).

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

TD is the percentage of nitrogen intake which is absorbed by the organism. In cereal grain protein it is known to be between 80 and 90%. The maize samples show higher values (95.3 to 96.6%). Less than 5% of the dietary nitrogen was not absorbed by the rats (Table 3).

Because the BV is the part of absorbed nitrogen which is retained in the organism, it serves as an indicator of 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 (Table 2), being higher in the samples with higher lysine content (more than 4.0%).

In the group of the three best samples (A, E, F.) there is one soft endosperm type (A); the others are hard endosperm types. These other hard endosperm samples also performed well. The nutritional quality of the hard endosperm types is as good as the quality of the soft endosperm type. In addition, hard endosperm has more desirable kernel characteristics and consequently good acceptability, and is by far superior in nutritional quality to normal maize.

Several promising opaque-2 hard endosperm materials now also are being evaluated for their protein efficiency ratio, using the rat as test animal at the INIP (National Institute of Animal Research, in Mexico).

The outstanding populations that are identified in performance tests at experimentation stations in national programs, will later be evaluated in farmer's fields in competition with commercial conventional varieties grown under prevailing agronomic practices.

## VII. CONCLUDING REMARKS

Progress in quality protein maize during the last five years can be summarized as follows:

- Considerable progress has been made in developing quality protein materials that are closer to the normal materials in kernel appearance and performance, including yield performance.

- Biological value of hard endosperm materials is comparable to that of soft-endosperm opaque-2, and much superior to normal maize.

- New laboratory techniques have been devised to assess quality characteristics. Laboratory activities employing simple and rapid screening techniques are supporting breeding work in several countries of the world. Standardization of procedures among the different laboratories has been developed.

- Equipment has been provided to establish service laboratories for chemical evaluation in Latin America (6 countries), Africa (1), Asia (4), and Europe (1).

- Thirty three scientists from eighteen countries have received training at the CIMMYT protein laboratory, and numerous trainees from the maize breeding program have spent short periods of approximately one week in the laboratory to study the techniques used in the chemical evaluation. Several visiting scientist (chemists) have spent three to four weeks in the laboratories, combining this experience with field work in the high quality maize breeding program. This breadth of experience shows the chemists the real needs of the breeding programs for the accurate analysis of large number of properly chosen samples. It convinces them of the need to develop effective methods for accurately screening large numbers of samples in support of the breeding programs that are struggling to produce commercially acceptable varieties with improved nutritive properties.

TABLE 1 .- BIOLOGICAL EVALUATION OF FIVE MAIZE OPAQUE-2 SAMPLES *

| INCAP No. | CIMMYT Lab. No. | PEDIGREE | PROTEIN % | LYSINE % | PER |
|---|---|---|---|---|---|
| 14593 | 14358 | Composite White (HE) | 9.7 | 3.9 | 2.22 |
| 14594 | 14360 | Composite Yellow (HE) | 9.6 | 3.8 | 2.14 |
| 14595 | 14359 | Composite K $O_2$ (Soft E) | 10.4 | 3.1 | 2.25 |
| 14596 | 14361 | Veracruz 181 $O_2$ (HE) | 9.4 | 4.0 | 2.41 |
| 14597 | 14357 | Tuxpeño x La Posta $O_2$ (Soft E) | 8.7 | 4.6 | 2.41 |
| | | Casein 8% | | | 2.86 |
| | | Casein 10% | | | 2.01 |

* This evaluation was done at INCAP by Dr. Bressani.

** Diets prepared at 8% protein level, four male and four female rats per trial.

TABLE 2 .- AMINO ACID COMPOSITION OF MAIZE SAMPLES USED IN NUTRITIO[N] STUDIES

| | SAMPLE | | | | | | |
|---|---|---|---|---|---|---|---|
| | A (S) | B (HE) | C (HE) | D (HE) | E (HE) | F (HE) | G (N) |
| AMINO ACIDS (g / 16 g NITROGEN) | | | | | | | |
| Valine | 5.22 | 5.08 | 5.15 | 5.26 | 5.39 | 5.33 | 4.74 |
| Isoleucine | 3.29 | 3.08 | 3.25 | 3.23 | 3.29 | 3.25 | 3.59 |
| Leucine | 8.63 | 8.45 | 9.58 | 8.84 | 9.02 | 8.74 | 13.17 |
| Tyrosine | 3.55 | 3.40 | 3.56 | 3.54 | 3.62 | 3.47 | 4.31 |
| Phenylalanine | 3.99 | 3.80 | 4.01 | 4.02 | 4.11 | 3.99 | 4.78 |
| Lysine | 4.18 | 3.79 | 3.54 | 3.98 | 4.09 | 4.04 | 2.63 |
| Methionine | 1.88 | 1.65 | 1.78 | 1.79 | 1.82 | 1.76 | 2.16 |
| Cystine | 2.56 | 2.54 | 2.73 | 2.65 | 2.75 | 2.67 | 2.03 |
| Tryptophan | 0.96 | 0.91 | 0.95 | 1.35 | 1.16 | 1.03 | 0.64 |

TABLE 3.- TRUE DIGESTIBILITY (TD), BIOLOGICAL VALUE (BV) AND NET PROTEIN UTILIZATION (NPU) FOR SEVEN MAIZE TYPES.

| Sample | Identification | RESPONSE CRITERIA TD % | TD (s) | BV % | BV (s) | NPU % | NPU (s) |
|---|---|---|---|---|---|---|---|
| A | Tuxpeño $O_2$ (Soft E.) PR-76A # (IPTT-37) | 96.0 | 1.8 | 77.6 | 2.1 | 74.5 | 1.3 |
| B | CIMMYT $HEO_2$ PR-76B, Bh-101 | 95.6 | 0.4 | 73.5 | .8 | 70.2 | .9 |
| C | PD $(MS)_6$ $HEO_2$ IPTT-38 | 95.7 | 0.5 | 71.8 | 1.4 | 68.7 | 1.3 |
| D | Yellow $HEO_2$ IPTT-39 | 95.3 | 1.0 | 74.0 | 1.4 | 70.5 | 1.9 |
| E | Amarillo Dentado $HEO_2$ PR-76-13, 801 | 95.8 | 1.4 | 74.5 | 0.8 | 71.4 | 1.4 |
| F | Ant. x Ver 181 $HEO_2$ 806 # | 96.6 | 1.1 | 76.2 | 1.5 | 73.6 | 1.2 |
| G | White Maize Cr Tl-77A (Normal) | 98.1 | 1.2 | 62.7 | 1.0 | 61.5 | 0.8 |

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# TRAINING PROGRAM

## MAIZE IMPROVEMENT AND PRODUCTION

During the period covered in this report 90 trainees received training in maize production and improvement at CIMMYT. These were received in three batches. Batch 1 started in December 1977 with 29 trainees and batch 2 started in June 1978 with 34 trainees. Batch 3 started in December 1978 with 27 trainees. These trainees are still continuing and will finish in May 1979. The names of the in-service trainees, country of origin and the field of specialization are listed in the attached tables. Of these, 36 trainees were funded by UNDP.

CIMMYT scientists consider Training Program 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.

Emphasis in our Training Program is on "Farm Research". Put into practice in the fields the trainee's scientific abstractions take root in reality. On return to their countries these trainees play leading roles in research and extension in their national programs and exert beneficial influence on national crop programs creating a receptive climate for production oriented research.

# MAIZE IMPROVEMENT TRAINEES

| Country | Name |
|---|---|
| Bangladesh | Md. Abdul Majid |
| Ecuador | Fausto Brito Brito<br>Marco Burbano Sánchez |
| Egypt | Fathy Ahmed Aly El-Zir |
| Indonesia | Ponidi Soepangat |
| Philippines | Tomas Lugod Ruiz |
| Rwanda | Apollinaire Mpabanzi |
| Tanzania | Zubeda Omari Mduruma<br>Bethania J. Lontu<br>Alfred Joseph Moshi |
| Thailand | Sansern Jampatong<br>Thip Lekagul |
| Turkey | Necati Polat<br>Mehmet Ali Tusuz<br>Mehmet Altay Gumus |
| Venezuela | Henry Jesús Gatica<br>Heli O. Moreno Márquez |
| Zaire | Kiatoko Soli Ntukatandi |
| **Total** | **18** |

## MAIZE PRODUCTION TRAINEES (cont.)

| Country | Name | Country | Name |
|---|---|---|---|
| Peru | Luis A. Becerra Díaz | | |
| | Hugo Casas Salazar | | |
| | Luis Fabián Rodríguez | | |
| | Jorge A. Tang Chung | | |
| | Roque González Montesinos | | |
| | José Millones Vidaurre | | |
| Syria | Mounzer El-Naimi | | |
| Tanzania | Jeremiah Rugambisa | | |
| | Sixta S. Kinombo | | |
| | Peter R. Matowo | | |
| | Muslih Haji Jecha | | |
| | Yusuf Ali Said | | |
| Thailand | Boon-Guer Poo-Sri | | |
| Zaire | Musubao Mathe Londya | | |
| | Ditona Panzu Poba | | |
| | Mudimbiyi A Mulomboyi | | |
| | Ngoy Mwan'a Nzeng | | |
| | Tubajika Kayimbi-Mend'Ha | | |
| Zambia | Christopher Lubasi | | |
| | Lingstone Singogo | | |
| Total | 72 | | |

# MAIZE PRODUCTION TRAINEES

| Country | Name |
| --- | --- |
| Afghanistan | Shamsuddin Elmi<br>Abdul Khalil Gardezi<br>Gul Ahmad Khalidi<br>Abdul Qadere Khaleqi<br>Shah Sayed Aalimi<br>Hesa Mulhaq Fazili |
| Bangladesh | Ali Ahmed<br>Noor Hossain<br>Md. Abu Hena Talukder |
| Bolivia | Víctor Mérida Corrales |
| Botswana | Joseph Motlhatlhedi |
| Costa Rica | Gilberto Araya Soto<br>Luis Javier Alvaro Varela<br>J. Fernando Araya Sánchez<br>Kenneth Jiménez Miranda |
| Colombia | Alvaro Astudillo Fernández |
| Ecuador | Rómulo Carrillo Alvarado |
| Egypt | Rohim Faesal Ebrahim<br>Fathy Hassan Said Soliman |
| Ghana | Kwasi Bruce |
| Guatemala | José Miguel León See |
| Haiti | Pierlus Rénold<br>Joseph Mitilien<br>Fritz Noel |
| Honduras | Adan Antonio Benavides |
| India | Satish Chandra Saxena<br>Sitar Singh Verma<br>Dilip Kumar Ganguli<br>Alahary Ramamurthy |
| Indonesia | Anwar Ispandi<br>Suradi |
| Korea | Hyeon-Gui Moon |
| Malaysia | Nordin bin Mamat |
| Mexico | Jesús Alcázar Andrade<br>Juan Molina Moreno<br>Hugo Vázquez Elizalde |
| Nepal | Indu B. Chaudhary<br>Keshava P. Koirala<br>Bhuban Chandra Pandit<br>Sharma Radha Raman<br>Shova Kumar Shrestha |
| Nicaragua | José Cuevas Cabrera<br>William Núñez Núñez<br>Francisco Tercero Vallecillo<br>Roberto Wong Jerez |
| Pakistan | Abdus Samad<br>Mohammad Anwar Zafar |
| Panama | José Román Araúz Beitia<br>Fidel Sánchez Andujar<br>Ernesto Vergara Vergara<br>José Luis García Bernaschina<br>Néstor Sandoval Canto |

## MAIZE IN-SERVICE TRAINEES 1978

| Region & Country | 1978 |
|---|---|
| **Latin America** | 34 |
| Bolivia | 1 |
| Costa Rica | 4 |
| Colombia | 1 |
| Ecuador | 3 |
| Guatemala | 1 |
| Haiti | 3 |
| Honduras | 1 |
| Mexico | 3 |
| Nicaragua | 4 |
| Panama | 5 |
| Peru | 6 |
| Venezuela | 2 |
| **South and East Asia** | 30 |
| Afghanistan | 6 |
| Bangladesh | 4 |
| India | 4 |
| Indonesia | 3 |
| Korea | 1 |
| Malaysia | 1 |
| Nepal | 5 |
| Pakistan | 2 |
| Philippines | 1 |
| Thailand | 3 |

| Region & Country | 1978 |
|---|---|
| **North Africa & Mideast** | 7 |
| Egypt | 3 |
| Syria | 1 |
| Turkey | 3 |
| **South Africa** | 19 |
| Botswana | 1 |
| Ghana | 1 |
| Rwanda | 1 |
| Tanzania | 8 |
| Zaire | 6 |
| Zambia | 2 |
| Total | 90 |

# WORK PLAN

# PHASE IV OF UNDP/CIMMYT

# GLOBAL RESEARCH PROJECT

Research, Training and Production for Nutritional Quality

Maize, supported by farm level surveys

## WORK PLAN

In Phase IV this Global Project will have two major streams of operations: a) Research, Training and Production for Nutritional Quality Maize, b) Agricultural Economics program with farm level surveys.

These two activities would be mutually supportive but separately managed within CIMMYT.

### Work Plan of Nutrition Quality Maize Program

Work plan for nutritional quality maize during Phase IV would incorporate the following major changes:

A) Objectives would go beyond protein improvement to include other nutritional qualities. Therefore the name of the project has been changed to "Research, Training and Production for Nutritional Quality Maize Program."

B) The program would be influenced by the current status of nutritional research and the status of nutritional thought and would have access to expertise in nutrition representing the various schools of thought current in the world today.

C) Expanded bioassay and animal feeding trials would be used to verify nutritive quality.

D) Training and on-farm research would be strengthened.

### Research Activities

1) Breeding, Agronomy, Physiology, Plant Protection and Collaborative Research

The international breeding programme will continue to focus on the production of varieties rather than hybrids. During the past years there has been ample evidence from a number of countries that the varieties are equal or superior to currently produced hybrids and they have the added advantage that the farmers can maintain their own seed.

If national programmes want to produce hybrids, the breeding system used lends itself to the direct recombination of base materials in the progeny and families distributed in the international breeding programme for the production of hybrids.

Multilocation testing of superior hard andosperm quality protein populations will be accelerated as part of the maize populations and variety improvement process. Greater emphasis will be placed on evaluation of materials internationally. Multilocation progeny evaluation trials, varietal development of site specific and across site varieties from advanced populations and their evaluation in appropriate experimental variety trials will be strengthened to identify superior germplasm for use by the national programs. Dissemination of source germplasm to different national programs will continue.

Apart from improving important agronomic traits and yield, major emphasis will be placed on stability of modifiers, maintenance of protein quality, reduced ear rot incidence, and ability to lose moisture quickly after physiological maturity. The possibility of selection for faster drying kernels following physiological maturity will be explored. Attempts will be made to select families with more dry matter accumulation and less moisture percentage at harvest. As underlying causes of problems in opaques become more apparent and better understood, efforts will be made to find the most simple, efficient and effective way(s) of remedying the original defects of the opaque-2 system.

The presence of variation for oil content in various materials will be studied. Recurrent selection for increased oil content along with yield will be practiced in some materials that are undergoing population improvement program. If it proves to be possible to increase oil content without reducing yield or creating other undesirable characteristics, the techniques will be applied more generally to other parts of the improvement program.

The other areas of research, namely agronomy, physiology and plant protection will continue to be integrated with the breeding programme. A number of national programmes will cooperate with CIMMYT to select for resistance to diseases that are more prevalent in their countries than they are in Mexico, for example Downy Mildew in the Philippines and Thailand.

On-farm testing will be strengthened. This will encourage farmers to use new technology and seed of promising varieties and multiply the seed for his own and his neighbors use in subsequent years. In this way distribution of improved quality protein varieties may be achieved even where a seed industry is lacking.

There is considerable difference of opinion among nutritionists on the relative importance of protein quality and quantity vis-a-vis energy requirements on the nutritional status of malnourished sector of population in different countries. CIMMYT will ensure that our research program has the benefit of expert advise on current status of nutritional research and problems of malnutrition. During first year of Phase IV CIMMYT plans to convene a meeting of leading nutritionists from developed as well as developing countries to arrive at a consensus of opinion on the nutritional parameters that should guide the research on high quality maize. If other parameters, in addition to protein quality, such as oil content are considered desirable, CIMMYT will explore the possibility of improving maize population for oil content without sacrificing yield and other agronomic characters.

The consultancy services of one or more prominent nutritionists will be obtained either individually or as a group, to maintain a continued dialogue with CIMMYT scientists on the nutritional aspects of the program. This technique will provide the wide spectrum of information needed by CIMMYT's administrative and scientific staff. Sufficient money has been budgeted to provide 1-2 man-years of resident or periodic consultancies in the nutrition field.

Asian Regional Program

The Asian Regional Maize Program, providing services to 11 (eleven) countries from Afghanistan to Indonesia, became operative in Phase III in collaborative arrangements with ICRISAT and with approval of the Government of India. ICRISAT provides office space and logistic support and six hectares of land on their experiment station at Hyderabad, for multiplication and testing of regional nurseries and initial seed increases for distribution in the region. The On-farm Research Program has made a good start in the region. During Phase IV heavy emphasis will be placed on the selection of nutritional quality maize for the region, wider testing in farmers' fields, on farm research to identify suitable technology for production of nutritive quality maize. A CIMMYT team of two maize scientists will devote full-time to services which will strengthen national maize programmes of the Asian region. Their activities will include:

i) Consulting with Governments regarding their production problems and their research and extension programmes for the maize crop, and assist the national scientists to design their programmes and activities.

ii) Helping plan and carry out training programmes for the staffs of national maize programmes and accelerate "On-farm Research". Assist in the selection of trainees from the region for training at CIMMYT or a University. Encourage the development of national training programmes for extension agronomists and assist with their establishment.

iii) Circulating uniform nursery trials and analysing data. Assist in the evaluation of maize materials coming from CIMMYT, the region and the national programmes.

iv) Promoting periodic workshops among workers of the region.

v) Promoting the participation of Asian scientists in the above arrangements, including arrangements for scientists from one Asian country to serve as consultants to neighboring countries.

Other headquarters staff of CIMMYT will be called upon to supplement the work of personnel assigned to the Asian region.

Research Support

1. International Nurseries.

The distribution and testing of maize populations, families and varieties is a major link between the central research programme at CIMMYT and the cooperating countries around the world. As CIMMYT's maize programme has expanded, so has the range and number of nurseries. CIMMYT proposes to continue this vital service and to further develop the concept of genetic interchange with and between cooperating nations.

Maize Quality Laboratory

Chemical evaluation will continue to be an integral part of research on nutrition quality maize. The work plan for CIMMYT laboratory will stress:

a) Continued search for better methods, and evaluation of new techniques for protein quality evaluation as well as analytical methods suitable for quick screening for other quality characters such as high oil content.

b) Tryptophan analysis will be used for preliminary screening of large numbers of maize progenies. Actual lysine values and amino acid pattern of the more promising materials will be determined as has been done in the past.

c) The nutritive value of most outstanding materials will be determined by energy and protein quality evaluation by feeding trials with laboratory animals in collaboration with INIP-Mexico (Instituto Nacional de Investigaciones Pecuarias) and NIAS-Denmark (National Institute of Animal Sciences). Cooperative studies will be arranged for nutritional evaluation of superior maize materials with young children, in collaboration with institutions having facilities and expertise in nutrition located in developing countries where maize is a basic food.

d) The CIMMYT laboratory will continue to serve as a central training center for young scientists from national maize quality laboratories, and as a central point for standardization of analytical techniques for laboratories in the developing countries. The CIMMYT biochemist will continue to monitor the service laboratories in national programs, strengthening them with necessary equipment and continue training of technicians to make these laboratories more effective.

Service to National Programmes.

CIMMYT proposes to continue to offer the following services to national agricultural research and production organisations:

a) Consulting visits by CIMMYT maize staff to assist with planning of (i) national nutrition quality maize programmes, (ii) the staff structure necessary for its initiation and operation, (iii) training schedule and (iv) operational aspects of the national programme.

b) Training fellowships. Approximately 100 fellowships will be available for training with CIMMYT scientists in Mexico during Phase IV. The subject areas are maize improvement, maize production, and training in the Quality Laboratory.

c) Provision of quality protein maize and normal maize germ plasm from CIMMYT headquarters and the international breeding programme.

d) Opportunities for national staff to participate in regional and international symposia and conferences related to high quality maize research and production.

e) Assistance to set up small national quality maize service laboratories and train chemists to operate them. These laboratories would be designed to assist the national maize breeders in their selection of quality maize varieties for local use.

f) Assistance with the establishement of national training programmes for production agronomists to ensure maximum spread of the improved materials and technology as national programmes progress.

Agricultural economics research at farm level.

1) During 1979-83 (ending about October 1983) the eastern Africa economics program will concentrate on three sets of activities:

a) To extend the previous survey activities in Kenya and Tanzania to other countries of the region, including Zambia, Malawi, Uganda, Ethiopia, and others, when and as government concurrence permits.

b) To move the findings of farmer surveys into the experiment station and into on-farm trials. This will enable the problems of representative farmers to influence the guidelines for crop research and for policy making.

c) Train more economists and cooperate in the training of more biological and other scientists for participation in farmer surveys and on-farm trials.

2) During Phase IV the Asian regional agricultural economics program will expand:

a) To participate in farmer surveys in Asian countries.

b) To continue and expand surveys on problems of improved food grain introduction, started in India in 1978 and to be extended, as feasible, to other Asian countries.

c) To extend the findings of the Asian surveys into the research station and into additional on-farm trials, in order to make available the information to researchers and policy makers.

d). To continue training of participants for the functions outlined in this program.

3) During 1979-80 a manual on farm level survey methods involving collaboration between economists, and biological scientists will be completed and published by CIMMYT.

4) In the initial stages of Phase IV (1979-80) CIMMYT will prepare

a series of case studies to be used in workshops and seminars for officials and administrators of agricultural programs in countries where maize is now, or is potentially, an important food crop. These case studies will draw heavily on CIMMYT's experience gained during the execution of Phase III of the UNDP sponsored project plus other activities of CIMMYT. These case training materials will be shared with other international developmental agencies and national governments and institutions in developing countries. They will focus on technological, socio-economic, supply and marketing and bureaucratic constraints to the wider, more equitable and more effective adoption of output increasing innovations. Contributions of other donors will be sought to sponsor individual participants and hold trial conferences. Given the experimental nature of this endeavor, CIMMYT intends to handle the workshops and seminars as an extra core activity so as to monitor, evaluate and report on them carefully. If they prove successful, CIMMYT may approach the UNDP Governing Council for a special supplementary project of approximately $350,000 to continue this endeavor during 1981-82.