WHEAT IMPROVEMENT PROGRAM OF THE

OFICINA DE ESTUDIOS ESPECIALES

I - Mode of Reproduction of Crop Plants in Relation to Plant Breeding Method.

In the most general terms crop plants can be divided into two groups, based on their method of reproduction:

a) Sexual - all plants which are normally propagated by seed, i.e. corn, beans, wheat, cabbage.

b) Asexual - these crop plants normally not propagated be seed, i.e. potatoes, sugar cane, many of the fruits.

On the basis their method of pollination and fertilization the group above designated as being propagated by "Sexual" reproduction can be further subdivided three rather distinct groups. This sub-division is of importance in determining the breeding method to be employed in the improvement of these crops. The three groups are:

A - Naturally Self-Pollinated Group - which generally have less than 5% of cross pollination.
i.e. Wheat, barley, oats, tobacco, flax, rice, peas, beans, soybeans, cowpeas, tomatoes and potatoes (when potatoes reproduce sexually)

B - Often Cross-Pollinated Group - Self pollination in this group is more frequent, as a rule, than cross-pollination. However, cross-pollination may occur so frequently that some method of preventing cross-pollination between varieties and strains of different genotyp c constitution must be followed throughout the breeding and seed distribution program.
i.e. Cotton, sorghums, and some straisn of sweet clovers.

C - Naturally Cross-pollinated Group - This group is made up of crop plants which are normally cross-pollinated and includes such crops as:
corn, rye, clovers, sunflower, sugar beets, cucurbits, Brassica species and many fruits.

II - Wheat as an example of the Methods Used in Breeding Self-Pollinated Crops.

A - Intriduction - General

1 - Estimated World Wheat Acreage (annual) 1936 - 160 million hectares (or 400 million acres). Wheat acreage compreses 1/5 of the cultivated land area of the world. Acreage increased 22% from 1910-32.

2 - Estimated World Production (1925) - 140 millino tons (or 5 million bushels)

3 - Range of Cultivation

a. SPRING WHEATS:

1). - Northern Limit Solovetski Island 65 1/2° N.
Northern Limit Alaska (Yukon) 66° 20' N.

2) Wheat is grown at high elevtions near the equator.

3) In the southern hemisphere wheat is grown in Argentina, Australia.

b. WINTER WHEAT:

1) Northern Limit - is determined by "winter-kill" and varies somewhat with precipitation.

2) Southern Limit - is determined by the winter temperature - in general wheat cannot be grown farther south than where the January isoterm is -12°C. (without vernalization).

4 - Relative Importance of "Bread" Wheats and other Wheats

a) Bread Wheats (Triticum vulgare and related species) Comprise 90% of world production.

b). Durums and Related Species (i.e. T. durum, T. turgidum, T. dicoccum and T. monococcum) Comprise 10% of world production.

5. History of Wheat Production

a. Bread Wheats (Triticum vulgare, T. Spelta, T. Compactum), T. durum, T. turgidum, T. dicoccum and T. monococcum, were selected and cultivated thousands of years ago. They were being cultivated before the beginning of written history.

1) Heads of Emmer (Triticum dicoccum) have been found in the Egyptian tombs.

2) There is conclusive evidence wheat was grown by the "Lake Dwellers" of Switzerland.

b. At present wheat is grown extensively over temperate climates of the world. The countries which are the larges producers are:

United States, Russia (U.S.S.R.), Canada
Argentina, Australia, China and India.

1) Wheat was brought to the Western Hemisphere first by Columbus.

2) Cortés first introduced wheat in Mexico in 1521.

B - Most Important Methods Used in Wheat Improvement are:

1 - Selection

2 - Hybridization

a) Selection as a means of Improvement:

Most of the early improved varieties were the result of selections. Selection was used as a means of developing "improved varieties of seed" long before the laws governing inheritance were demonstrated by Mendel (1866). In the early part of the 1800's Le Coutier on the Isle of Jersey and Prof. La Gasca of the University of Madrid had selected improved wheat varieties. By 1857 Hellett was carrying on an extensive selecting program in wheat. About the same time Vilmerin in France carried on an extensive selection program. W. M. Hays in the United States began his selection program in 1888.

With the rediscovery of Mendel's laws of inheritance in 1900 a great deal of impetus was given to plant breeding work. However, it was not until the work of Johannsen(190301909) that the scientific basis for the selection of individual plants, together with its limitations, was firmly established (his "pure line" theory). On the basis of the pure line theory many selections which were made in farmers' fields have given rise to varieties which have been or are still of economic importance. i.e.,

1) Kanred - selected at Kansas in 1906 from a Russian wheat.

2) Turkey

3) Kota - North Dakota selection from Russian wheat.

4) IoTurk - Selected in 1926 by Iowa State College from a Turkey wheat.

5) Blackhull - Selected by Clark in Kansas field from a Turkey wheat.

6) Mindum - Selected at Minnesota in farmers' field in 1896 but not distributed until 1916.

Possibility of Improvement in Mexico by Selection

Because of the wide range of types of wheats found in Mexico, together with the fact that it is not uncommon to find fields which are made up of a mixture of a large number of types of the same or different species, selection should prove to be valuable source of varietal improvement. Approximately 8000 selections are now being grown and studied in Chapingo, Cd. Obregón, and León. Already two outstanding lines have been isolated, and both are in the preliminary stages of increase

at present. All of these selections are being studied for:

1) Tillering ability and potential yielding ability.
2) Maturity
3) Drought resistance
4) Resistance to lodging
5) Resistance to shattering
6) Resistance to diseases
7) Quality
8) Frost resistance

Hybridization as a Method of Improving Wheat.

Among the most successful of the pioneer wheat breeders were William Farrer (Australian) and A. P. Saunders and C. P. Saunders of Canada. These investigators developed a number of varieties which were grown commercially for a long time and which have also been used as breeding material for varieties which have been developed recently. An outstanding example of a variety developed by "crossing" is shown below:

i.e.

A. P. Saunders (1892) crossed Hard Red Calcutta x Red Fife.

In 1903 C. P. Saunders selected Marquis

1 - Object of Crossing: To combine in one variety the desirable characteristics found in two or more varieties.

2 - Procedure in Developing a Wheat Improvement based on Hybridization.

a).-Survey and evaluation of plant material.

1).- Collection and selection (to purify) in farmers fields.

2).- Introduction and planting (for observation) the introduced varieties from other parts of the world, locate characters (genes) in which the native material are deficient.

3).- Classification of allmaterial both native and introduced for:

(a) Yielding ability.

(b) Tillering ability.

(c) Maturity.

(d) Drought resistance.

(e) Resistance to lodging.

(f) Resistance to shattering.

(g) Winterhardiness

(h) Resistance to diseases and insects.

(i) Quality.

b).- Making artificial crosses to combine desired characteristics.

c).- Procedure used in handling hybred material:

1).- Produce sufficient F_1 seed to give F_2 population of sufficient size to sample value of cross.

2).- Select best plants in segregating populations.

3).- Test the most promising lines on a regional basis when they are in F_5 and F_6.

4).- After ample yield test data are available increase best varieties for distribution.

Methods of handling hybred material can be classified as follows:

a).- Pedigree Method.

b).- The Bulk Method.

c).- The Back-cross Method.

d).- Multiple crosses.

Of these methods the Pedigree and Back-cross methods are being used most extensively in the program of the Oficina de Estudios Especiales.

Pedigree Method as Used Here in Mexico.

The principle group of "native" varieties used has been:

1).- Mentana

2).- Aguilera

3).- Pelón Colorado

4).- Candeal

5).- Querétaro

6).- Marroqui

7).- And several very promising native selections.

These have been crossed with the following introduced varieties:

1).- Kenya RF-324 and RF-321

2).- Trigo Supreme x 41-116 RF-211

3).- Newthatch

4).- Timstein

5).- Renown

6).- Regent

The group of "native" wheats are in general deficient in one or tow characteristics but well adapted to climate and soil conditions, i.e., Mentana yields well, is early, but susceptible to diseases, and susceptible to shattering. Pelón Colorado and Candeal are high yielding wheats, but too late for most areas of Mexico and they are extremely susceptible to diseases. By crossing these wheats with varieties such as Newthatch it should be possible to isolate in segregating population lines which will be high yielding, early, resistant to shattering and diseases, and of good quality. Under Chapingo and Bajío conditions two generations of breeding material can be grown each year. Crosses can either be made in the winter or summer crop. However, when crosses are made during the summer months the disease resistant parent must be used as the female parent to assure satisfactory seed production.

Steps in carrying out Pedigree Program.

1).- Crosses are nearly all made at Chapingo.

2).- F_1 seeds are space planted at Chapingo and rougued for non-crosses. F_2 seed is harvested in bulk.

3).- F_2 seed is divided in 4 parts and planted as follows:

a).- One part is planted in Chapingo

b).- One part is planted in Ciudad Obregón, Son.

c).- One part is planted in León, Gto.

d).- One part is planted in Torreón or Saltillo, Coah.

4).- F_3 plants with desired combination of characteristics are selected from F_2 rows in each region.

5).- F_4 seed is space planted.

6).- Seed from Uniform F_4 or F_5 rows are bulked and included in regional yield tests.

Back-cross - Method as used in Oficina de Estudios Especiales.

Wheat Improvement Program

1 - F_1 seed from single cross (i.e. Mentana x Newthatch) is space planted.

2 - F_1 plants are backcrossed to Mentana.

3 - F_1 seed of first backcross is space planted in F_1 rows.

4 - F_2 plants with desired combination of characters are selected.

5 - F_3 seeds are space planted and second backcross is made on selected F_3 plants.

6 - This procedure repeated with second backcross material and selected F_3 plants are backcrossed the third time.*

7 - Best lines are selected from segregating generations of third backcross, and when they are homozygous they are placed in regional yield tests.

* In a few cases three consecutive backcrosses have been made in F_1 plants with considerable success. i.e. (Mentana x Kenya) x $Mentana_3$

There are indications that selecting stable improved lines from single crosses, and further improving these lines by use of the backcross method, may be one of the best methods of developing good varieties for Mexico.

The following characteristics are receiving special attention in making selections in the hybred material at present.

1).- Yielding ability.

2).- Tillering.

3).- Maturity classes for each region.

4).- Resistance to lodging.

5).- Resistance to shattering

6).- Resistance to diseases.

a).- Puccinia graminis tritici

b).- Puccinia triticina

c).- Puccinia glumarum.

d).- Tilettia levis and tritici

7).- Quality of grain.

Within recent years in many countries such as Canada, United States, Australia and Argentina a great deal of emphasis has been placed on breeding for good milling and baking properties. "High Quality" flour is positively correlated with high protein content. However, flours from two different wheats which possess identical percentages and proportions of gliodin and glutenin, the two amino acids which are responsible for making wheat the "king of leaven breads", may have very different baking properties. These differences in some cases can be atributed to differences in the colloidal properties of the flours. Climate and soil factors in addition to varietal characteristics, also greatly influence the quality of wheat. Additional research is needed to classify many points relating to the factors influencing the milling and baking properties of wheat.

III - Possibilities of Utilizing Characteristics of Various species of Triticium, Aegilops, Hynaldia, Agropyron and Secalis in the improvement of Bread (T. vulgare) and Durum (T. Durum) Wheats.

A - Successful Transfer of Stem and Leaf Rust Resistance from Triticum dicoccum to T. vulgare by McFadden (1918) Established Value of this work. i.e.

MARQUIS (Triticum vulgare) n = 21 X JAROSLAV (Triticum dicoccum) n = 14

Hope (and a sister selection H-44)

Hope or H-44 have been used as disease resistant parents in most of the varieties which have been developed recently, i.e. Newthatch, Renown, Regent, Pilot, Rival and Henry.

B - Use of Triticum timopheevi as source of leaf rust resistance.

Steinwedel X timopheevi

Timstein

C - Russian Attempts to Transfer Perennial Habit from Species of Agropyron and Secalis to Bread Wheats

Varieties of wheats which have perennial habit have been isolated from these crosses. Although all of the varieties which have been developed from these crosses to date have definite shortcomings, there are possibilities that these shortcomings may be corrected by further breeding.

Additional work on intraspecific and intergeneric crosses may be logically important in introducing additional genes for disease and insect resistance, earliness, and drought and frost resistance. The following photos show the relation of the genus Triticum to other genera (table #1), and indicate also the relation of species within the genus Triticum (table #2).

Table 1 - McFadden - Sears Theory of Evolution of Hexaploid Wheats. Am. Jour. Agron. 39: 1011 - 1026. 1947.

Primary Form (Diploid)	Divergent Forms (Diploids)		Convergent Forms (Poluploids)	
	Agropyron	Genome "B"	Triticum Tetraploids	
Unknown i.e. (Acylops Speltoides type ??)	Triticum	Genome "A"		
	Aegilops	Genome "C"		Triticum Hexaploids

Table 2 - Relationship as Species of Genus Triticum

	DIPLOID SERIES n = 7, 2n = 14 Genome A	TETRAPLOID SERIES n = 14, 2n = 28 Genomes A+B	HEXAPLOID SERIES n = 21, 2n = 42 Genomes A+B+C
	Species		
INVESTED KERNEL	T. aegilopoides (Link) Bol. T. thaoudar. Reut.	T. dicoccoides Körn T. armeniacum (Jakuf) Mol.	None
FREE KERNEL	None	None	None
INVESTED KERNEL	T. monococcum L. highly resistant to most diseases	T. dicoccum schrank T. timopheevi Zhuk - Is highly resistant to most diseases.	T. Spelta L. Grows well on poor soils T. Spltiforme Aschers. T. Rigidum schrad. T. Macha Dekap. T. Vvilov (Tuman) Jak.
FREE KERNEL	None	T. turgidum L. drought, and disease resistant T. persicum (Boiss) Aitch. "Low heat unit" requirement, res. to Mildew T. polonicum L. T. durum Desf. diseases, drought and insect resistance T. pyramidale (Dol) Pere.	T. Vulgare Vill. T. Compactum Host T. Sphaerococcum Pere. Early non-shattering, stiff straw.

* Probably Contains Genomes A + G

General References Relating to Wheat Improvement

1) - Armstrong, J. M. Investigations in Triticum-Agropyron Hybridization. Emp. Jour. Exp. Agr. 13: 41-53. 1945.

2) - Goulden, C. H. Breeding Rust Resistant Wheat-Fundamental Aspects of Problem. Scie. Agr. 10: 258-267. 1929.

3) - McFadden, E. S. A successful Transfer of Emmers Characters to Vulgare Wheat. Jour. Amer. Soc. Agron. 22: 1020-1034. 1930.

4) - McFadden, E. S., and Sears, E. R. The Origin of Triticum Spelta and Its Free-Threshing Hexaploid Relatives. Jour. Hereidty 37: 81-89; 107-116. 1946.

5) - Peterson, R. F. and Love, R. M. A Study of the Transference of Immunity to Stem Rust from Triticum durum Var. I to T. Vulgare by Hybridization. Sci. Agri. 20: 608-623. 1940.

6) - Pridham, J. T. A successful Cross Between Triticum vulgare and Triticum timopheevi. Jour. Austr. Inst. Agr. Sci. 5: 160-162. 1939

7) - Shahds, R. G. Disease Resistance of Triticum timopheevi Transferred to Common Wheat. Jour. Amer. Soc. Agr. 33: 709-712. 1941.

8) - Smith, D. C. Intergeneric Hybridization of Cereals and Other Grasses. Jour. Agr. Res. 64: 33-47. 1942.

9) - Hayes, H. K. and Immer, F. R. Methods in Plant Breeding. McGraw-Hill Book Co. 1942. 432 pages.

10) - Hector, J. M. An Introduction to the Botany of Field Crops. Vol. #1 479 pages Central News Agency Inc., Johannesburg, S. A., 1936.

11) - De Hevesy, Paul World Wheat Planning and Economic Planning in General. Oxford Univ. Press. London 1940. 911 pages

12) - Jacobs, M. B. et al. The Chemistry and Technology of Food and Food Products. Volumes 1 and 2. Interscience Publishers, Inc. N. Y.

13) - Jasny, N. Competition Among Small Grains. Food Res. Inst., Stanford Univ. Inc., Calif. 1940. 606 pp.

14) - Vavilov, N. I. The Scientific Bases of Wheat Breeding (Transl. to English by K. Starr Chester).

15) - United States Department of Agriculture Yearbook 1936 pp. 207-301.

16) - " " " " " " 1941 pp. 321-342.

17) - " " " " " " 1943-47 pp. 379-384 and 648-649.