WEAK SPOTS IN THE ROCKEFELLER FOUNDATION'S AGRICULTURAL PROGRAMS ... THE GREAT NEED FOR EXPANSION OF PLANT PROTEIN PRODUCTION TO

Since the establishment of the Rockefeller Foundation's Agricultural Programs first in Latin America and later in Asia and Africa, our basic aim has been to develop research and training programs, and with the results from these programs, increase the basic food crops of the host countries. Initially (and rightly so) we concerned ourselves with "filling bellies" through increasing the production of corn, wheat, sorghum, potatoes, and (cooperatively with the Ford Foundation), rice. Collectively these crops constitute the basic foods of a large segment of the peoples of the world.

In general we can all be proud of what has been accomplished in the fields of research, food production and the training of scientists and educators. Moreover, our programs have been tremendous catalyses to show what can be accomplished when a program is organized in depth, well supported financially, and staffed and led by capable, dedicated scientists. In reflecting on what has been done it startles even an old greybeard like myself.

In a number of countries we have seen crops doubled and tripled in production, and more significantly in yields per hectare within a decade. Recently, as an organization - as well as individual scientists - we have had the satisfaction of seeing the ... materials, knowledge and experience which have been developed in the country programs to which we have been assigned, extended to other countries. I feel that the biggest pay-off in this respect is yet to come. To illustrate this point I will use the case of wheat with which I am most familiar.

It took us about eleven years to double and fifteen years to triple the average per hectare yield of wheat in Mexico. I am now confident that in the West Pakistan's Cooperative Accelerated Wheat Improvement Program, which is a joint undertaking of the government of West Pakistan, the Ford Foundation and the International Center for Maize and Wheat Improvement, we will have the satisfaction of seeing yields of wheat doubled within five years and tripled within eight years, - barring war.

Despite these gratifying accomplishments in cereal crop production, I feel, with the exception of our research programs in animal industry, that we have paid entirely too little attention to overall human nutritional needs - especially those of protein. Admittedly we made several feeble and interrupted starts in bean research and production programs in Latin America. None of them, however, have blossomed into topnotch programs. Several of our country programs also have made modest research attempts in soybeans and chickpea, but nothing really significant has come from them. The sum of all this piecemeal effort has been that even after twenty-... years of research in the general field of agricultural sciences, we do not have a singletopnotch R.F. staff member specialist in legume "grain crops" such as beans, soybeans, and chickpea (gram). Not only have we been neglectful of developing this area of crop production (so vital to human nutrition), but we have also given a very low order of priority to improving the nutitional qualities in the cereal crops and in potatoes. I will again use our wheat program to illustrate this weakness, but I simultaneously wish to emphasize that in our haste to increase overall food production we have been equally neglectful of nutritional quality in all of the other crops on which we have worked intensively.

1. Grain Protein Levels (%) in Wheat.

Among the cereal grains of major importance, wheat is the crop which has the highest percentage of grain protein. Despite the deficiency of wheat grain, in certain essential amino acids, especially lysine, when consumed as whole grain products such as chapattis in combination with additions of small amounts of animal proteins it has provided the basis upon which hundreds of millions of people have lived throughout the Near and Middle East for centuries. The relatively high level of grain protein has been primarily responsible for pushing wheat to the front in the nutrition of these people, not its superiority as a grain from which leavened, baked products can be made, as is the case in Europe, the Americas, Australia and New Zealand. Paradoxically it is not the genetic makeup of wheat that makes it superior to corn or rice in level of grain protein, but rather the differential effect of the environments under which the three crops are grown commercially.

Wheat is generally grown on drier sites where in most years the principal factor limiting grainyields is moisture, not soil nitrates, thus reflecting in high grain protein levels and low grain yields per unit of area. Maize and rice are generally grown in more moist sites, where soil nitrates, not water, are the limiting factors in grain yields, and this results in higher grain yields per acre and lower grain protein content.

These are the "biological crosscurrents" we are trying to countermand in wheat when we greatly increase wheat yields per acre under irrigation. And we, to this day, have not been able in large commercial acreages, to bring into satisfactory equilibrium high grain yields (more than 100 bushels per acre) and high grain protein content (more than 13 percent).

2. Background on Wheat Quality (Industrial and Nutritional) Considerations in Mexico

In our wheat program in Mexico we had no laboratory facilities for initiating any aspects of quality improvement until 1958. The first few years of research in this laboratory were dedicated primarily to evaluating the commercial varieties and orienting the breeding program to produce varieties more suitable for milling and baking purposes - which unfortunately are only very indirectly related to nutritional considerations. The conventional wheat quality laboratory tests are primarily concerned with producing uniform flours which will make a uniform "pretty" loaf of bread, when baked under a given set of conditions. No important consideration is given to the nutritive value of the bread, except that fortunately high protein flours generally make larger loaves of bread - and are preferred by the bakers for this reason.

Unfortunately, when Dr. Reggie J. Laird and his Mexican colleagues were doing most of their resdarch on the use of chemical fertilizers on wheat our laboratory had not been established. During the last year that his work was being done some of the samples of grain from plots receiving different levels of nitrogen were analyzed for total protein and also evaluated for milling and baking properties. Their limited data indicate that when 40 pounds of nitrogen is applied to wheat in the Bajio region grain yields increase but grain protein drops to 8-1/2 percent from a level of 10 percent in the unfertilized plots. At the 80 pounds level of nitrogen fertilization grain yields per acre continue to increase but the grain protein level increases to about the same level - 10% - as that of the unfertilized plots. When rates of 120 to 140 pounds of nitrogen are applied per acre - and especially when part of the nitrogen is applied in the latter part of the vegetative cycle of the plant-grain protein content increases to 12 percent.

Unfortunately under irrigation when wheat is fertilized to produce maximum grainyields per hectare it may and often does result in a reduction of protein content. The total production or extraction of protein per acre is more or less constant, but at the higher levels of grain yield this same quantity of protein is distributed in more kilos of starch - or grain. This poses problems both from bread baking and from nutritional standpoints. Dr. Laird's data bore out data from other countries.

With the release and wide acceptance of farmers of the high yielding dwarf wheat varieties Pitic 62, Penjamo 62, Lerma Rojo 64, Sonora 64, etc. which utilize efficiently heavy rates of nitrogen fertilizers without lodging and by so doing produce much higher yields, the grain protein problem has become acute. The average national yield per acre increased by 12 bushels during the two year period from 1961 through 1963 with a corresponding decrease of between 1-1/2 to 2 % in grain protein. This created a furore in the milling industry and certainly had adverse effects nutritionally as well.

During the past four years we have tried rather inadequately to develop the information and materials to solve this problem. The approach has been a three-pronged attack, namely:

1) A continuation of the studies initiated by Dr. Laird. Studying in smallplots the effect of late applications of different quantities of nitrogen on grain yield, grain protein content, and its milling and baking properties. In these tests 40 pounds of nitrogen applied prior to the last irrigation (flowering has been found to generally increase grain protein by from 2 to 3 percent).

2) Application by airplane of 40 pounds of nitrogen at time of flowering (just prior to the last irrigation) on a number of commercial fields. These results in most cases have been able to bear out the results from the small plots. There are, however, inconsistencies in some cases and much more research is needed to find out what factors are involved. Such studies should be conducted by qualified soil scientists, working closely with our wheat quality laboratory. In our wheat section we do not have the scientific man power to solve this problem.

Even though late applications of 40 pounds of nitrogen generally increase grain protein content by 2-1/2 to 3 percent, the flour from this grain is somewhat different in dough handling properties and baking characteristics than the flour from grain produced by "normal" nitrogen fertilization. Good bread can be made from it by modifying the oxidation treatment of the flour. There is need for comparing the biological nutritional values of the protein in the grain produced under these two systems of fertilization. To my knowledge this has never been done.

3. Breeding to Improve the Bread-making Quality of Wheat (Gluten Quality)

During the past 3-1/2 years the milling and baking properties of the Mexican wheat breeding program has been revolutionized. The varieties now being multiplie for distribution are as good in baking quality as any in the world when observed at comparable protein levels. This great improvement in gluten strength will compensate greatly for lower protein levels in the grain, but will not do anything to improve the nutritional aspects of the grain and bread.

4. Attempts to Stimulate the Production of Higher Protein Content in Varieties of Desirable Gluten Types through the Establishment of Market Classes and Price Differentials.

During September of 1964 Drs. Narvaez, Ortega and I drew up a plan to place wheat marketing on a sounder basis both from the viewpoint of farmer, miller and baker. A series of market grain classes were proposed on the basis of their grain texture and gluten (dough baking characteristics) properties. Provisions were made for establishing price differentials between the different market classe Those market classes that were most needed by the industry would receive a higher price than other classes that were being over-produced. Within each market class a premium would be paid for each percent of grain protein above the base of 10 percent, and price reductions would be applied for correspondingly lower protein levels. Currently no country anywhere in the world has a market structure for wheat based as we have proposed, in realistic premiums for protein in desirable gluten (protein) classes.

I am convinced that this proposal of market classes has a sound basis both fr the standpoint of the miller and baker, and from a nutritional standpoint. Althoug the progressive elements in the milling industry are interested in exploring the possibility of using this proposal, it has not been implemented to date.

We urgently need much more research on the manipulation of application of nitrogenous fertilizer - both as to amount, time of application, and method of application in order to make this plan feasible economically both to the farmer and the consumer. We need to find out how we can produce 100 bushel acre yields (which we can do) and in the process economically produce grain with 11-1/2 to 13 percent protein, which we are unable to do at present.

There are deep implications in our lack of research information in this are on grain protein levels. I am convinced that - barring war - we can double the national per acre wheat yields of Pakistan in the next five years. However, I am now deeply concerned about the fact that in so doing, the grain protein content might drop from 10-1/2 to 8-1/2 percent. This would be disastrous in a country that has the nutritional protein defect that Pakistan possesses today.

5. Breeding for Higher Grain Protein Content.

Within the past six years it has become evident that there is at least one gene in the Brazilian variety Frondosa that controls grain protein level, independently of grain yield. In general under the same ecological and soil conditions, there is an inverse relationship between grain yield per acre and grain protein content. In some crosses with Frondosa and its derivatives (e.g. Atlas 66) it has become evident that some of the highest yielding lines are also the highest in grain protein content. Recent evidence from Nebraska and Purdue indicates that the Frondosa gene is capable of increasing grain protein content by from 2 to 3 percent. This is a very significant break-through from a nutritional standpoint. If one such gene exists there are likely to be others.

We are currently trying to incorporate this gene containing high grain protein content into our high yielding dwarf varieties. It will take several years, however, to accomplish this and meanwhile we must learn how to increase grain protein levels - at high grain yields per acre - by the manipulation of nitrogen fertilization.

The difficulties of maintaining grain protein content while increasing grain yields per unit of area is a problem that will also be of increasing importance in rice breeding and production. If the average grain protein content of the commercial irrigated rice crop could be increased by 2 percent it would be a tremendously significant, world-wide step forward.

6. Breeding for the Improvement in Nutritional Value (Amino Acid Balance) of Wheat Protein.

During the past 35 years nutritionists and biochemists have demonstrated how to prepare balanced diets by bringing together in the proper proportion, different foods and food supplements. In recent years an ever-increasing number of food supplements have been developed which can be used to improve the diets in many underdeveloped countries. Unfortunately, these improvements seldom reach the rural peoples, - who generally constitute from 75 to 90% of the total population in such underdeveloped countries, and where the worst nutritional problems exist.

Most of the population of underdeveloped countries live primarily on one of the cereals: wheat, rice, corn, sorghum, etc. supplemented only by small amounts of legumes, fruit and a limited amount of animal proteins. All of the cereal grains are deficient in one or more of the essential amino acids, especially lysine. Within recent years a number of investigators have shown that there are considerable differences in the levels of lysine in different varieties of corn and wheat. The difficulties of launching a frontal attack on breeding to improve the amino acid balance, have been augmented by the inadequacy of reliable analytical methods for amino acids. The methods that have been available have been both slow and unreliable. The automation of amino acid analysis which is now on the horizon offers hope of soon bypassing this bottleneck.

The breakthrough at Purdue University two years ago on the discovery of high lysine content in maize associated with the Opaque 2 gene has generated a great deal of enthusiasm in the fields of nutrition and plant breeding. Obviously if the defects of the proteins of cereal grains from a nutritional standpoint can be improved upon by genetic manipulation in the process of developing high yielding varieties it will be of great significance to the people of the underdeveloped countries. Through the distribution of high-yielding new varieties of the cereals carrying the improved amino acid balance this nutritional improvement will be distributed at a minimum cost to rural peoples everywhere. It also will result in automatically establishing a higher nutritional plateau upon which to subsequently superimpose other nutritional improvements, such as food supplements.

I am convinced that the action that the trustees of the Rockefeller Foundation have taken in authorizing Dlls 700,000 to establish and equip "biochemical genetic laboratories" in close collaboration with our various cereal breeding programs will pay big dividends.

I am certain that our staff that is working in corn has a great lead over those of us who are working in wheat, rice or sorghums. The linkage of floury-high lysine content simplifies the identification and analysis aspects of the breeding problem. Moreover, the fact that maize is a diploid makes it much more ammenable to work with in breeding programs where desirable recessive genes (such as the Opaque 2 high lysine gene) are involved.

Nevertheless we feel that there are real opportunities for improvement of the amino acid balance of wheat. We have already indirectly initiated research in this direction by having Miss Evangelina Villegas, who is now at North Dakota State University, assigned a thesis problem on lysine content in wheat. This research is currently a follow-up on a study done in 1957 at Washington State University by Dr. J. A. Lawrence et al, who obtained promising but inconsistent results on the variability of lysine content in a study of about 200 different wheats. As soon as the laboratory is equipped and ready for operation in Chapingo we will transfer this work there.

During the past several years it has become increasingly evident that there are a number of genes that are important in wheat improvement that are inherited as multiple recessives. Among these are the Norin genes for short, strong straw, the genes controlling gluten strength in varieties such as Thatcher and Chris, and branching in tetraploid species. In all probability the genes controlling lysine level in wheat will also turn out to be recessives.

It is very difficult to handle recessives genes in polyploid species-such as Triticum vulgare. These difficulties, combined with the very great progress that we have made in improving agronomic type, yield and disease resistance in tetraploid species of Triticum within the past five years (which would be much easier to handle in breedingprograms) - leads me to question the validity of the theory always advanced by botanists, cytologists, geneticists and plant breeders, that the hexaploids are definitely a tremendous practical step forward in evolution of the wheat plant over that of the tetraploid species. We are now seriously considering the feasibility of trying to find out what chromosome or chromosomes in the D genome (the "other" genome in hexaploid wheats) are responsible for dough extensibility. If this can be determined it should be possible to substitute this chromosome into a tetraploid wheat i.e. *T. durum* - and thus convert *T. durum* into a "bread wheat". By so doing one would have a far simpler species to work with in further improvements in yield, disease resistance, and quality, and greatly reduce the buffering or masking effect now experienced while working with multiple recessives in hexaploid bread wheat. These are currently ideas, but I feel that theymerit certain experimentation to check on the feasibility of this modification in approach. These considerations are also involved in attempting to breed an improved wheat variety with a higher lysine content.

7. The Rockefeller Foundation's Position in the Improvement of Legume Crops to Help Solve the Protein Production in a Crowded World.

I am certain that most of us agree that with the world population increasing at its present cataclysmic rate, it will become increasingly difficult to justify converting grain to animal proteins in order to meet dietary needs. In the first few paragraphs of this report I alluded to the great weakness of the Rockefeller Foundation Agricultural Programs in this respect. I will now point out some of the challenges that are open to it in this field.

7A.- Soybean Research

The cooperative research program of the U.S.D.A. and collaborating state experiments have revolutionized soybean production in the U.S.A. within the past thirty years. Soybeans constitute the principal source of edible oils in the U.S. and constitute 50% of the protein supplement (9,000,000 tons) of the feed industry. The development of the latter has revolutionized the production of poulty, eggs, and pork within the past two decades. The following table briefly summarizes the tremendous increase of soybeans in the U.S.A. within the past few decades.

U.S.A. Soybean Production

Year	Bushels
1923	No record
1924	5,000,000
1930	14,000,000
1940	78,000,000
1950	299,000,000
1960	533,000,000
1962	725,000,000

The establishment of the Cooperative United States Regional Soybean Laboratory at Urbana, Illinois, in 1935, was the key to this fantastic development. The improved high yielding varieties developed in this cooperative program has been the catalyst for the rapid extension and expansion of cultivation.

Soybeans, originally of oriental origin, were introduced into the United States in 1804 but made very little progress until the establishment of the aforementioned cooperative program in 1936. Soybeans (Glycine max) originally a native of the orient is now much more important as a crop in the U.S.A. than in its native home, in North China.

The soybean is very sensitive to changes in length of day (or more correctly stated it is a dark length sensitive plant). It is only through breeding varieties well adapted to different latitudes, soils and climates, that it has been possible to adapt soybean cultivation to the different areas of the U.S.A. Today there are well adapted soybean varieties available for growing between 32 degrees and 48 degrees latitude in the U.S.A.

The amazing fact remains that there are no high yielding well adapted varieties of soybeans available for cultivation in zones between 30 degrees N° Latitude and 30° S Latitude. This fact automatically excludes soybeans as an important crop from all Latin America, all Africa and virtually all of Asia, except North China, which lies outside of this belt.

Many half-hearted attempts have been made by our programs and by other organizations, to introduce soybeans into this belt by importing U.S. varieties. These results have been failures. In western Mexico at between 26 to 28° Latitude the small beginning of a commercial soybean crop has been established on the basis of the introduction of several of the southern U.S. varieties. Nevertheless, despite good agronomic practices these varieties only yield about 60 percent of what they would conceivably yield if well adapted varieties were bred and developed for the region. INIA has not developed a dynamic breeding program on soybeans even at this date.

Colombia, Peru, Chile, Argentina, Brazil, Uruguay, Pakistan, India, many Near and Middle East countries, and African countries, have attempted to establish soybeans as a crop by the introduction of varieties from other parts of the world-always with the same result -failure.

What is needed is to establish a vigorous breeding program at some perhaps tropical or subtropical location close to the equator. Genes for adaptation to low latitudes must be present in some of the primitive unimproved varieties that have been grown under primitive agricultural systems in Indonesia and southeast Asia for centuries.

If a large number of U.S. varieties were crossed widely with Asiatic "low latitude types" to form a considerable number of large variable gene pools, which would be grown and selected at many locations, I am confident that promising results would be forthcoming promptly. Such work could be done effectively perhaps at some such latitude as:

IBADAN, Nigeria + 8° latitude S.
PALMIRA Colombia, 4° Latitude N
SANTO DOMINGO or PICHILINGUE, Ecuador- 3° Latitude S.

If large quantities of seed of early generation lines of these gene pools were distributed in a number of places in Latin America, Africa and Asia, between the equator and 25°N and 25°S, I have no doubt as to what would happen. Within ten years we would have an international soybean program of tremendous magnitude and impact which would provide breeding materials and commercial varieties for many parts of the world, which are now extremely deficient in high quality proteins to meet human nutritional needs.

Soybeans have found their greatest outlet as protein supplements for feeds in the U.S.A. and for the production of edible oils. Nevertheless, there are many modern industrial processes presently coming into use which are diverting increasing quantities of the soybean proteins into foods. It does not appear that the Rockefeller Foundation should confine all of its efforts to improving the protein nutritional values of cereal grains (as commendable a research undertaking as this is, and over which I am very enthusiastic), but at the same time ignore the remendous opportunities of doing something spectacular in soybean production.

There is no doubt of the productivity of soybeans as a commercial crop over a wide range of soil and climatic conditions, when adapted, high yielding, improved varieties are available. Of course it always is necessary to combine the use of the improved varieties with good agronomic practices to realize the yield potential.

Moreover, the large indirect benefit that would come from the successful introduction of soybeans - a legume - into the cropping rotations with cereals in many countries of the world should not be underestimated.

Currently, to my knowledge, there is no vigorous, dynamic, visionary breeding program on soybeans, gram (chickpea), peanuts, etc. anywhere in the tropics or subtropics. I have seen the rather academic, feeble attempts of chickpea (gram) improvement under a PL 480 contract in India, but I am not convinced that this type of program will contribute much to plant protein production.

A single young, dynamic, well-motivated and broadly trained R.F. staff member assigned to a soybean project could produce a revolution in protein production in the tropics within a decade.