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BUILDING A PROTEIN REVOLUTION ON GRAIN LEGUMES

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"Green Revolution" refers to the recent rapid rise in yields and production of wheat, rice, and maize in a number of developing countries. Those increases have resulted from the development of high-yielding crop varieties that were capable of responding spectacularly to such improved cultural practices as better land preparation, planting methods, fertilization, weed control, and pest eradication.

The high-yielding Mexican wheat varieties were the catalysts in triggering the Green Revolution. When properly grown by the new technology developed through agronomic research, those varieties often have been able to increase yields from 800 pounds to as much as 4,000 to 5,000 pounds per acre. This spectacular increase has taken place on many millions of acres. As a result, the new seeds and new technology, and the resultant high yields, have made wheat production highly profitable in such countries as India and Pakistan. Therefore, many farmers have begun to shift to wheat part of their land that formerly was grown to grain legumes – a not unnatural reaction.

Wheat production in India soared from a level of 12.4 million metric tons in 1965 to 26.5 million metric tons in 1972. The increase in per-acre yields of grain accounts for more than 85 per cent of the increase in production; the remainder, however, resulted from an increase in the area sown to wheat, part of which was diverted from winter grain legumes (pulses).

Unfortunately, the pulse yields (chick peas, grains, pigeon peas, mung beans, lentils, peas) remain at a low-yield level, and pulse production is either stagnant or dropping.

Neither new high-yielding varieties of grain legumes (pulses) nor improved technology have been developed, so gradually part of the land that once grew pulses has shifted in winter to wheat and in summer to rice or maize. Of course, the reduction in the production of grain legumes is undesirable nutritionally. Grain legumes are essential in providing the amino-acid balance needed for normal growth development and maintenance of health in those vegetarian diets that depend primarily on cereals and root crops.

What is to be done about this dilemma?

Governments could increase the price of grain legumes and so encourage or speed up the production of pulses. Such action would, however, have a twofold adverse effect. First, the price of grain legumes, which already are the most expensive part of the vegetarian diet, would increase for the consumer. Second, if the price differential were made great enough, some land would be shifted back from cereals to pulses without, at the same time, increasing per-acre pulse yields. But as these countries also need more cereal grains, such a result also would be undesirable.

My recommendation is to speed up the "slow runners" – the pulses – by introducing new high-yielding varieties and new technology that will increase pulse yields and thereby result in increased production.

As early as 1965, I anticipated the dilemma of rapid increases in wheat yields and an adverse, indirect, negative effect on grain-legume and oil-seed production. In reports to the governments of both India and Pakistan, I indicated that such a breakthrough on the cereal front would adversely affect grain-legume and oil-seed production – for example, that of safflower, cotton, peanut, and rape – with a concomitant adverse effect on diets. I urged both governments to launch aggressive research programs to increase the yield of these crops. At that time (1966), I wrote the report to The Rockefeller Foundation to which Dr. L.M. Roberts has referred, urging them to stimulate research and production of grain legumes and oil-seed legumes in the semitropics and tropics.

Grain-legume and oil-seed legume crop research and production – despite the prodding from Dr. Roberts, myself, and a few other scientists – remains even today the ugly duckling of agricultural crops. Very little research money is being allocated to the improvement of this diverse group of crops that is so important to human diets in the developing countries.

During May, 1971, the Secretary General of the United Nations named a panel of scientists to examine the world protein-deficiency problem, especially in the developing nations, and to recommend methods of alleviation. These recommendations, which I assisted in drafting, were embodied in a report entitled "Strategy Statement on Action to Avert the Protein Crisis in the Developing Countries," by the United Nations Secretary General's Panel, May, 1971.

We are meeting here today as a working group under the auspices of the Protein Advisory Group (PAG) to decide what action should be taken, if any, to implement one aspect of that report. I refer to the improvement of grain-legume and oil-seed crops from the points of view of genetic varieties, agronomy, plant protection, biochemistry, and nutrition.

Research Priorities

A large number of grain-legume and oil-seed legume crops can be helpful in alleviating the protein crisis of the developing nations. Among the grain legumes are: gram or chick pea *(Cicer arietinum);* pigeon pea *(Cajanus cajan);* lentil *(Lens esculenta);* mung bean *(Phaseolus mungo* and *P. aureus);* dry beans *(Phaseolus vulgaris);* lima beans *(Phaseolus lunatus);* dry pea *(Pisum sativum);* lathyrus pea *(Lathyrus sativus);* broad bean *(Vicia faba);* cow pea *(Vigna sinensis);* and hyacinth bean *(Lablab niger).* The most important oil-seed legumes also used for food, either directly or indirectly, are: groundnut or peanut *(Arachis hypogaea)* and soybean *(Glycine max).*

The number of species shows the complexity of this problem. Some of them are grown during the cooler winter season or at high elevation in the subtropics or tropics. Others are grown in the rainy season in only the hot, tropical areas. To embark simultaneously on the improvement of all of these species will certainly insure failure. One of the most important responsibilities of this meeting is to provide a guide or priority list of the species on which major research should be undertaken. To establish such a list, we must consider the genetic potential of grain yield for the species, its cultural and climatic requirements, disease and insect problems, nutritional value, and toxic properties, if any.

I believe that the research effort should, for the present, be concentrated on a few species, as follows:

1. Two species for the winter (dry) season in the subtropics.
2. Two species in the heavy rainfall areas of high elevation in subtropical areas or cool, winter, rainfall areas.
3. Two species for the summer seasons of the subtropics.
4. Two or three species for the wet, hot tropics.

Indirect Benefits of Grain Legumes and Oil-Seed Legumes

Although today we are concerned primarily with increasing the production and nutritional value of grain legumes and oil-seed legumes to alleviate the protein deficiency of the developing nations, these crops have several other, indirect, beneficial effects on agriculture. Legumes are symbionts of bacteria that form root nodules. These bacteria can take free nitrogen from the air and fix it in plant-root tissue. Consequently, they increase indirectly the level of soil nitrogen and this, in turn, increases the yields of cereals that may follow legumes in plant rotation. Rotation of grain legumes with cereals also reduces the weed, disease, and insect problems. Grain legumes generally sell at a much higher price per pound than cereals. Therefore, if the yield of grain legumes can be increased, they also will increase farm income.

Need for Interdisciplinary Research

Increased yields and rapidly expanded production can be attained only by an interdisciplinary research approach. Each specie or crop must be improved by:

1. Development of high-yielding varieties responsive to such improved cultural practices as better (or more) fertilizers, weed control, and moisture control. The improved varieties must, insofar as possible, be resistant genetically to the major diseases and insect pests.
2. Development of improved agronomic practices that will permit approaching the maximum genetic yield-potential of the improved varieties.
3. Development of effective measures against disease and insect depredations.
4. Development of biochemical and biological data pertaining to nutritional value and to toxic substances present in the different varieties and segregating lines now being used to develop new crop varieties.

The excellent cooperation between CIMMYT biochemist Dr. Evangelina Villegas and her group (with financial assistance from a UNDP grant) and maize-breeder Dr. Surinder Vasal in the development of "hard-endosperm, high-lysine" maize populations has been monumental in demonstrating the great value of close interdisciplinary research. They have set the pattern for what must be done to improve the genetic yield potential of grain-legume varieties and, at the same time, to improve agronomic type, disease and pest resistance, and nutritional value.

Once new, high-yielding, improved, grain-legume varieties are available, and as soon as good cultural practices and disease and insect protection are developed, they must be hitched to a vigorous, national, crop-production campaign in order to increase production rapidly. Before the production campaign is launched, a realistic policy of grain pricing must be established and guaranteed by government to stimulate the farmer and to assure him a fair return for his investment.

Leads – from CIMMYT's International Wheat Program

I. Varietal Improvement

A. Use a wide genetic base. Collect, study, and use progenitors from throughout the range of species being improved.

B. Make a large number of crosses to build a diverse gene pool. To achieve this rapidly, single crosses, double crosses (between different F_1 generations), and back crosses all should be used.

C. Grow two generations of all breeding materials each year, if possible, to speed varietal development.

D. Grow segregating populations under a wide range of soil, climate, disease, and insect conditions. Whenever possible, exchange genetic materials (and visits) with scientists working on the same crops in other parts of the world.

E. Select for broad adaptation in varietal development.

F. Incorporate resistance to major genetic and/or insect diseases as soon as possible. (See III A)

G. Work closely with biochemists and nutritionists to identify the lines that are outstanding for nutritional value and to discard those that are undesirable from a toxic, palatable, or digestible standpoint.

II. Agronomic Practices

A. Develop cultural practices that will utilize the maximum amount of genetic yield-potential available in a new variety by manipulating:

1. Soil fertility
2. Moisture conservation and utilization
3. Weed control
4. Proper ratio of planting dates

III. Pest Control

A. Develop effective control practices for major insect pests and diseases.

Conclusions

I recommend the funding and initiation of a dynamic, interdisciplinary research and production program on a few carefully chosen species of grain legumes and oil-seed legumes. If the experiences of the CIMMYT wheat and IRRI rice programs are used as a guide or model, if the programs are staffed with imaginative, aggressive, well-motivated scientists, and if bureaucracy can be minimized, I believe that spectacular results can be achieved in increasing the world's plant-protein production.

I am confident that if we act aggressively, great progress can be achieved in raising production of protein grain legumes during the next eight to ten years. The time has come to stop talking about the need to launch programs and to concentrate on achieving a self-evident goal. In summary, let us not slow down. Let us speed up the "slow runner" and build a protein revolution on grain legumes.