Photos: Univ. of Neb.

High-protein wheat is now being evaluated in many countries.

Green Revolution: Phase 2

by Joan Arehart-Treichel

Plant scientists, encouraged by increased yields of wheat and rice, are now trying to improve the

Plant scientists have worked feverishly in the last two decades to come up with higher-yield cereals. Their efforts have led to spectacular results, even in the developing countries. Wheat yields have doubled or tripled over large areas, especially in India, Pakistan, Mexico and Tunisia. Rice yield has increased in the Philippines to the extent that the Philippines could start exporting rice in 1971. There have been significant increases in rice production in South America. As far as cereal yield is concerned, the "Green Revolution" has arrived.

But there are several things the Green Revolution has not harvested. One is improved yields of legumes. Not much progress has been made in this area. Nor has the Green Revolution vastly improved the protein content of cereals and legumes. Such improvement is vital, especially to peoples in developing countries, where cereals and legumes are the major foods. In fact, one of the drawbacks of India's wheat revolution is that farmers have decreased legume production in favor of wheat. Since legumes contain more protein than wheat, Indians' protein intake has probably become worse instead of better.

Now that the Green Revolution has produced ample results with yield, plant scientists are working to improve the protein content of cereals and legumes. Virgil A. Johnson of the U.S. Department of Agriculture at the University of Nebraska, and a pioneer in improving plant proteins, puts this new emphasis in perspective: "We began to be concerned about wheat protein in the 1950's. At that time there was virtually no breeding work aimed at improving wheat protein. It has only been during the past few years that such work has caught on. We are now seeing similar efforts with other cereals and legumes as well."

Notable progress has already been made. Corn with improved protein quality is already on the market and is being used in the United States, Latin America and other places. Several dozen high-protein strains of wheat, largely developed by Johnson, are in advanced tests to determine their commercial potential. Improved strains of barley, rice, sorghum and other cereals are in the research and development stage.

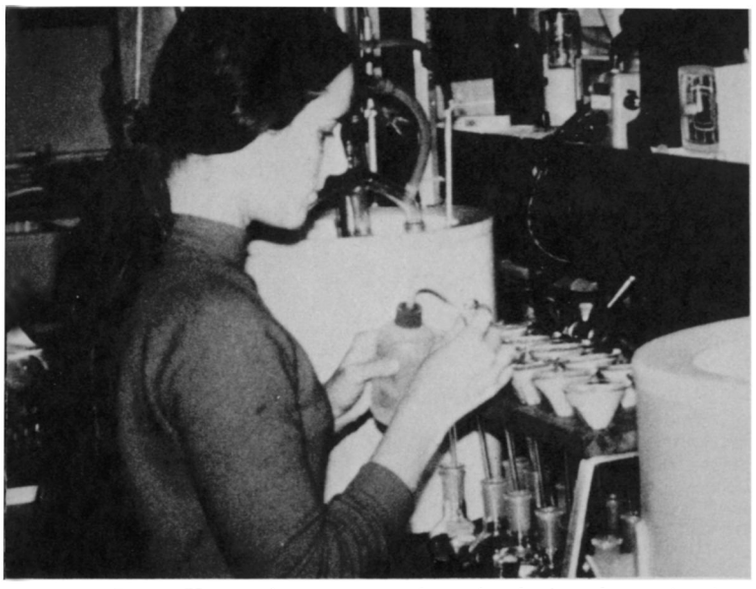
L. P. Reitz of the USDA's Agricultural Research Center in Beltsville, Md., considers the corn advances most exciting, not just because of their value to peoples in developing countries, but because they are helping feed livestock more economically. Livestock feed shortages are a major factor behind soaring food costs in the United States and elsewhere.

One of the main challenges to plant scientists is that efforts to improve yield tend to reduce protein content. "High-lysine corn is not being grown on any large acreage at present because these lines tend to be less productive," says Johnson. "The same with wheat. The same with rice. We know we can make them more nutritious by either increasing protein content or by improving the quality of the protein. There is no doubt about that any more. But can we make them more productive *and* more nutritious?"

Looking for strains of plants with high-protein content is not unlike looking for a needle in a haystack. First the plant geneticists have to locate strains that possess genes for improved protein. Then strains have to be crossed, recrossed and crossed again, and their hybrid offspring screened for any changes in protein content.

In 1963, a mutant corn strain with vastly improved nutritional value was identified. A single gene, opaque-2, was found to improve the quality of the corn so that its protein value approached that of skim milk. Plant scientists were heartened by this discovery, since one gene is fairly easy to manipulate by classical breeding experiments. They hoped that protein quality in other crops would also turn out to be simply controlled. Unfortunately that was not the case. As M. W. Adams of Michigan State University admits, "We do not know the number of genes that control proteins in most plants, nor whether these genes act as dominant, recessive or in between."

If five genes control protein expression, Adams says, and a person were looking for one recessive trait, the chances of finding a high-protein strain in the second generation would be only one out of 1,024 plants. To assay 3,000 plant lines for protein content with a 95 percent probability of detecting higher-protein strains, a dozen technicians would have to work six days a week for seven weeks, and during specific growing seasons. Although strains that give promise of higher protein content can be fed to animals later, to see whether biological effects tally with chemical content, such assays are expensive. Breeders rarely have enough material to carry out all the assays they would like to. What is needed, Adams stresses, is a quick test for protein quality that is only reasonably precise and that can be applied to small quantities of seeds in large plant populations.



Betsy Hancock prepares wheat for lysine determination.

Johnson examines wheat with high-protein potential.

protein content of these and other cereals and legumes. Notable progress has been made.

Then there is the difficulty of distinguishing genetic control from environmental control. There is mounting evidence, Adams says, that protein in plants depends on where they are grown and at which seasons. Johnson and his colleagues have analyzed 17,000 strains of wheat. They have found the strains vary 7 to 22 percent in protein. Most of this protein variability, Johnson says, is the result of environmental effects. Only five to six percent appears to be under genetic control.

He and his co-workers have found that nitrogen fertilizer has a positive impact on the protein in plants. Max Milner, scientific secretary of the Protein Advisory Group of the United Nations, reports that efforts to improve nitrogen fertilization of soils, with an eye to improving plant protein, is under way in India. M. S. Swaminathan of the Indian Agricultural Research Institute and one of India's leading agricultural scientists, says traditional crops in India are hardly sensitive to such fertilization. Yet high-yield crops require it.

The National Science Foundation agrees that nitrogen fertilization is beneficial to plant protein, yet points out that the costs of such fertilization are reaching the point of diminishing returns. Only half the nitrogen in fertilizer is used by plants, and the excess nitrogen runs off soil and pollutes the environment. NSF is funding research to find ways by which legumes might get more nitrogen through the air. Whether such research might eventually improve the protein content of legumes, only time will tell.

Plant researchers must concern themselves with more than improving the protein quantity in cereals and legumes. They must also contend with amino acid imbalances in plant proteins. Cereals are deficient in the amino acid lysine, legumes in the amino acids methionine and cystine. Although rice contains 8 percent protein, compared with 12 percent in wheat and 25 percent in legumes, the amino acids in rice are better balanced. If one or more essential amino acids are in short supply in a plant, and the plant is the major protein source in the diet, the deficient amino acids can seriously alter protein use in people. M. L. Kakade, a biochemist at Land O'Lakes, Inc. in Minneapolis showed such effects in experimental animals. A protein fraction taken from navy beans and fed to animals increased their need for methionine and decreased their uptake of cystine.

Researchers have had some success in countering the problem of amino acid imbalances. Their greatest success to date has brought lysine more into balance with other amino acids in corn. The lysine content of barley has also been increased. As protein in regular wheat increases, lysine expressed as a percentage of the protein tends to decrease. However the amount of lysine in high-protein wheat strains increases along with the other amino acids. Researchers have also recently found that several moderately high lysine wheat strains have additive effects if they are crossed genetically.

Plant scientists are also trying to improve the digestibility of high-protein cereals and legumes. Some proteins are more resistant to breakdown than are others. According to Kakade, protein molecules in beans have helical structures. Such structures make them stable and hard for digestive enzymes to get at and break down.

Consumer acceptance of high-protein cereals and legumes must also be considered. Notes Harold Graves of the World Bank and an authority on cereal and legume needs in the developing countries: "When you eat wheat you eat it in bread or in other baked products. You eat rice pretty much in its grain form. There are all sorts of preferences in the developing countries for different rice textures. A rice that is high-yielding or high in protein may not be the rice people will accept."

Although the high-protein wheats developed by Johnson and others work fine for milling and baking, products such as cake flour, cookies, ice cream cones, shredded wheat biscuits, cereals, sweet rolls and pie crusts require low-protein wheat. If cookies are made from a high-protein wheat they come out of the oven like stones and have to be dunked. And as Reitz says, "My grandchildren look with disdain on anybody who dunks his cookies."

Despite all these constraints, plant scientists are optimistic that they can come up with more nutritious and also higher-yielding cereals and legumes. What is needed are more research funds and more scientific cooperation toward these aims. Recently the United Nations and the World Bank coordinated research of different institutes. Investigators at these centers will work to increase protein in cereals and legumes, to improve their amino acid balance and to ensure that their high-protein content can be digested. Particular attention will be paid to the legumes, which have been largely neglected.

Declares Johnson: "We can make progress proportionate to the efforts we put into it." □