Science & Technology

Biochemistry key to agriculture's future

by Vin Berg

The mighty gains in U.S. farm productivity achieved in the years since World War II were based on hybrid crop strains, pesticides and herbicides, improved nutritional and medical practices in animal husbandry, and increased use of energy and fertilizer. The new revolution in the next two decades is likely to have a different basis: biochemistry in application to both crops and farm animals.

In particular, three areas of potential breakthrough stand out: development of new photosynthetic capacities in plants; control of bioregulators, the chemicals that control plant growth and differentiation; and increase in beef reproduction rates through twinning.

Photosynthetic capacities

The capture and transformation of solar energy into new biological material—foodstuffs—occurs at about 1 percent efficiency in a great many important crop plants. If this could be increased to just 2 percent, it is possible that twice the yield could be realized, assuming additional farm inputs.

Large differences in net photosynthetic efficiencies exist in nature, between C3 and C4 plant types, for example (C3 and C4 refer to the metabolic pathways that differentiate plant efficiencies). C3 plants, which have the lower efficiency, include wheat, rice, soybeans, potatoes, peanuts, barley, sugar beets, and bananas. A typical C4 plant is maize.

One reason for C3 plants' lower efficiencies is that there is a much more rapid loss of photosynthetically fixed carbon dioxide, through the process of photorespiration. C3 plants photorespire at rates three to five times those of C4 plants. Different metabolic pathways or different anatomical makeup may account for this.

Researchers aim to transform C3 into C4 plants. One potential method is protoplast fusion techniques, in which individual cells are denuded of their cell walls, and joined together to form hybrids. The trick is to combine the desired characteristics and genetic makeup of each. Recombinant DNA techniques, another avenue of research, would "engineer" C3 cells with genes from C4 plant cells. Selection techniques would treat C3 plants with radiation or particular chemicals to increase their number of mutations, and then grow them out under conditions that allow the transformed plants to be selected out and subsequently used to develop crops.

Bioregulators

Bioregulators are natural or synthetic compounds that can be applied to crops to stimulate growth or enhance ripening, increase the harvestability of a crop, or even prolong shelf life of the farm-food product.

For example, tricontanol, a natural fatty alcohol isolated from alfalfa, has experimentally demonstrated increases in yields from 34 to 63 percent in asparagus and from 11 to 24 percent in sweet corn. Application of tricontanol to the guayule plant results in a twofold to sixfold increase in natural rubber yields.

Despite successes, little is understood about the basis for this particular bioregulator's effects. What tricontanol demonstrates is the ability to bring about substantial changes in crop yield through such biochemical manipulators—not that we have yet mastered them.

Twinning capacities—multiple births in beef cattle and other livestock—could massively increase the supply of animal protein for human populations. The leading scientific obstacle to increased beef supplies, for example, is the bovine reproduction cycle itself: the cow produces only one calf every year, and an average of five calves over its lifetime. One result is that a substantial portion of any nation's herd is tied up in the breeding process at all times.

Twinning research is focusing on several approaches, including selection and hormone induction. Perhaps the most promising method is that of nonsurgical embryo transplantation, which occurs when multiple fertilized eggs, obtained from heifers bred just prior to slaughter, are transplanted to the unbred recipient. Work is being done to fertilize the eggs *in vitro,* combining the most favorable genetic traits of desired donors.

The recent progress of biochemical sciences leaves little doubt that breakthroughs in each of these areas are possible provided governments commit themselves to realizing the increases in productivity each would ensure. In America's land-grant research and extension institutions, a broad-based and experienced research staff needs only the funding to carry out the required research, and to ensure that the next generation of scientists is prepared to make further levels of breakthroughs. Well-funded extension services at state universities and farm agencies would ensure optimal testing and use of new results from the early stages.