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COVER Enhanced Landsat Thematic Mapper image of the area of the Cady Mountains and Bristol Mountains in the eastern Mojave Desert, California. Color variations primarily denote contrasting iron- and hydroxyl-bearing constituents of the surficial rocks and sediments. The image enhancement reveals faults and associated structural features that were overlooked in previous field mapping. See page 1000. [Processing by Jet Propulsion Laboratory, California Institute of Technology]

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Opportunities in Agricultural Research

Research activity in agriculture is destined to be fostered by a conjunction of factors. The new farm legislation will change provisions of the existing laws that have subsidized monoculture of major crops. The new legislation will increase funds for competitive agricultural research grants. Societal pressures aimed at reducing pollution due to excessive use of pesticides and fertilizers is mounting. Increasing use of no-tillage agriculture reduces soil erosion, but it may lead to additional severity of plant diseases. Continuing advances in molecular biology have created important tools for research in pure and applied plant biology. Of particular significance are the possibilities of improving plant defense mechanisms against predators and diseases.

Insertion of certain genes into plant genomes improves resistance to insects and diseases. Because damage to plants above the soil line is visible, attention has tended to focus on it. Less attention has been accorded invisible damage that affects the health of plants, including their roots, rootlets, and root hairs.

A dramatic example of the deleterious effects of soil microorganisms involves strawberries. When virus-free plants were grown from meristem culture in a fumigated soil, yields were three to four times the usual ones. The cost of fumigating soils devoted to major field crops is excessive, but experimental fumigation procedures inform us that plant soil pathogens are responsible for substantial reductions in yields. When diseases and pests are eliminated by experimental treatments, yields in field trials are sometimes improved 50 to 100%.

When monoculture is practiced, yields tend to decrease with time regardless of the amount of fertilizer applied. A steady annual presence of a particular root system favors a few organisms—bacteria, fungi, nematodes—that are pathogenic to plant roots. Changing to a different crop alters the circumstance, and all but the most unspecialized pathogens are unable to thrive in the absence of their usual hosts.

R. James Cook and collaborators at Washington State University have made extensive studies of monoculture of wheat. This crop is grown in eastern Washington under conditions ranging from sparse moisture to irrigation. Through studies with the use of fumigated soil, they have demonstrated a large role for the soil-borne fungi *Gaeumannomyces graminis*, *Rhizoctonia solani*, and *Pythium* spp. *Gaeumannomyces graminis* causes take-all, the most economically important root disease of wheat worldwide. Effects of the root-infecting fungi diminish with crop rotation. After 2 years of growth of other crops, yields of wheat approach those attainable in fumigated soil. Investigations in the state of Washington also showed that *G. graminis* can be controlled by strains of fluorescent *Pseudomonas* species. Some of the best strains produce phenazine-type antibiotics that are strong inhibitors of *G. graminis*. The genes responsible for creating these antibiotics are being isolated. In principle, other genes for producing antibiotics to plant enemies will also be isolated and incorporated in microorganisms associated with plant roots.

Cook and collaborators have noted that the health of wheat can be impaired by applying too much nitrogen fertilizer. In regions where moisture is limited, the stimulus of the fertilizer leads to excessive foliage and in turn to excessive transpiration. The resultant stress on the plants makes them susceptible to pathogens and leads to reduced yields.

In the warfare that goes on underground, not all fungi are enemies of plants. Some of the more beneficial plant-microbe associations include mycorrhizal fungi that help plants take in their nutrients and water while providing some protection against root disease. Some fungi establish themselves inside plant tissues and produce substances that inhibit or are obnoxious to insect pests. Other root-colonizing microorganisms inhibit or displace pathogens at the root-soil interface.

What happens to a crop in any given place is dependent on local conditions, including soil and moisture. The variables are many. However, with a combination of traditional and modern scientific approaches, substantial improvements in agriculture are possible. The use of recombinant DNA techniques and polymerase chain reactions is applicable to both the plants and to their associated microflora. Enough progress has already been made to justify optimism. Even if new plant enemies ultimately evolve, human ingenuity will deal with the circumstances.—PHILIP H. ABELSON