Editorial: Genetic Engineering and Water
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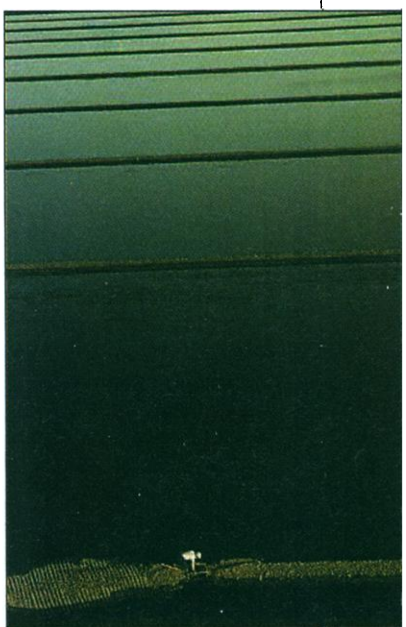
Genetic Engineering and Water

During the next 25 years, world population is expected to increase by about 2.5 billion people, with most of this projected population growth expected to occur in developing countries. The food requirements in the developing world are expected to double by 2025. However, there has been a progressive decline in the annual rate of increase in cereal yield, so that at present, the annual rate of yield increase is below the rate of population increase. There are limited options for increasing the amount of land under cultivation for production of food crops without imposing undesirable environmental costs. Thus, the increased demand for food and fiber must be met primarily by increasing production on land already under cultivation. In addition to the limitations of intrinsic yield and available land, there is a significant water problem. Of the water that is available for use, about 70% is already used for agriculture.* Water systems are under severe strain in many parts of the world. Many rivers no longer flow all the way to the sea; 50% of the world's wetlands have disappeared; and many major groundwater aquifers are being mined unsustainably, with water tables in parts of Mexico, India, China, and North Africa declining by as much as 1 m per year. Approximately 40% of the world's food is produced from irrigated land,† and 10% is grown with water mined from aquifers. There is growing competition for water between cities and industry, with agriculture being the user of lowest value and last resort. Thus, the projected doubling of food production must largely take place on the same land area and using less water. More effective management of water requires a series of institutional and managerial changes in addition to a new generation of technical innovations that includes advances in genetic engineering of plants.*



Photosynthetic carbon dioxide fixation by plants is associated with a large amount of water loss through transpiration. Thus, to prevent desiccation-induced growth arrest and injury, most plants require adequate soil moisture. The production of one pound of cotton by irrigated agriculture requires 17,000 pounds of water; production of a pound of rice requires about 4700 pounds of water.‡ Recent advances in understanding the genetic control of drought tolerance offer new opportunities to develop crops that are less damaged by short periods of low soil moisture.§ This might enable the use of less water for irrigation and reduce drought-induced yield reduction caused by the vagaries of weather in rain-fed agriculture. In addition, there is a promising opportunity to increase the average water use efficiency of agricultural systems by minimizing losses to pests and pathogens.

Although many innovations in modifying plant water use are theoretically possible, one opportunity is related to the focus of this special issue of *Science* on plant pathology. It has been estimated that up to 40% of plant productivity in Africa and Asia, and about 20% in the developed world, is lost to pests and pathogens. Approximately one-third of the losses are due to viral, fungal, and bacterial pathogens, and the remainder is due to insects and nematodes. Much of the loss occurs after the plants are fully grown: a point at which most or all of the water required to grow a crop has been invested. Thus, reducing losses to pests and pathogens is equivalent to creating more land and more water.

Most plants are resistant to most pests and pathogens. Knowledge of the mechanisms by which plants naturally resist pests and pathogens is rapidly increasing.|| As knowledge about the molecular mechanisms for such resistance or susceptibility advances, it will become possible to transfer the genes responsible for resistance mechanisms from one species to another. The success of the genetically modified insect-resistant corn and cotton plants grown on a large scale in the United States provides a first example of the feasibility of the approach. Plants engineered for pest and pathogen resistance could be distributed without cost to subsistence farmers in the developing world by the International Crop Research Centers. The benefits of such developments would be substantial in terms of income and food for the poor, reduced demand for water, and limiting the expansion of land area under cultivation, all of which would also generate environmental benefits.

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*See www.worldwatervision.org/Vision/Documents/CommissionReport.pdf. †N. Johnson, C. Revenga, J. Echeverria, *Science* **292**, 1071 (2001). ‡H. W. Kendall, D. Pimentel, *Ambio* **23**, 198 (1994). §M. Kasuga *et al.*, *Nature Biotechnol.* **17**, 287 (1999). ||B. Baker, P. Zambryski, B. Staskawicz, S. P. Dinesh-Kumar, *Science* **276**, 726 (1997).

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