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CGIAR CLIMATE CHANGE RESEARCH

Breeding climate-resilient crops

Reducing plants' thirst at the molecular level

Drought reduces annual worldwide maize yields by as much as 15 percent, representing losses of in excess of 20 million tons of grain. The International Maize and Wheat Improvement Center (CIMMYT) is using conventional breeding to develop maize for small farmers in Southern Africa that withstands drought and infertile soils and produces yields 30 to 50 percent greater than traditional varieties. CIMMYT scientists are working to achieve even greater gains by using tools from molecular biology. With the aid of a genomic map that combines data for different types of tropical maize in diverse environments, they are identifying genetic "hot spots" in maize, that is, areas of the crop's chromosomes that confer drought tolerance. This work is critical in light of a recent study that says climate change could inflict a 10 percent reduction in maize yields in Africa and Latin America during the coming decades.

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Breeding climate-resilient crops

New technology helps scientists identify "stay-green" genes to help sorghum cheat the heat

Crops such as sorghum and millet—staple cereal grains and fodder crop grown by subsistence farmers in the hottest, driest regions of sub-Saharan Africa and the Indian subcontinent—are the most heat- and drought-hardy crops addressed by CGIAR breeders. Their treasure chest of stress tolerance genes may someday be unlocked to benefit other crops, through the marvel of "comparative genomics" research underway within the CGIAR's Generation Challenge Programme. For this dream to be realized, the valuable genes have to be mapped and their functions understood. Researchers at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) are using a technique known as marker-assisted selection (MAS) to identify and isolate genes in sorghum that display the "stay-green" characteristics that allow the plant to mature normally in low-moisture, high-heat areas. MAS accelerates classical breeding by locating desired genetic traits on the chromosomes, setting the stage for plant breeders to transfer those genes into popular but drought-susceptible varieties or, eventually, into other cereal crops. "Stay-green" genes delay the premature death of leaves and plants, help the normal grain filling, and reduce the incidence of plants "lodging," or falling over on the ground.

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Breeding climate-resilient crops

Boosting rice's photosynthesis

As climate change continues to shrink the area suitable for rice production, and population growth continues apace, researchers at the International Rice Research Institute (IRRI) have turned their attention to a radical new way to increase yields that involves completely refiguring what's known as the engine of rice production: photosynthesis. Armed with new knowledge from the rice genome, the researchers' aim is to enable the plant to capture solar energy more efficiently so that it can, in turn, produce greater yields. Photosynthetically, rice and other so-called C3 plants like wheat, are underachievers because as much as 40 percent of the atmospheric carbon dioxide they work to convert to sugar is lost by respiration in daylight—releasing carbon dioxide into the atmosphere—a wasteful process called "photorespiration." To create a more efficient and thus higher yielding rice plant, researchers would convert the grain to a C4 plant (where "C" stands for the number of carbon molecules captured by photosynthesis for growth) that has evolved biochemical "carbon dioxide pumps" to concentrate atmospheric carbon dioxide in the leaf, thus overcoming photorespiration. These plants are up to 50 percent more efficient in converting solar energy into biomass and are fast growing, efficient users of water and soil nutrients.

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Breeding climate-resilient crops

Fine-tuning a plant's internal clock

Sorghum and millet breeders at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) are focusing new attention on photoperiod-sensitive breeding stocks that give farmers an added tool to adapt to rainfall variability. Plants, like humans and other organisms, have internal clocks that tell them when to flower by taking cues from the length of daylight. During the Green Revolution, breeders of many grains eliminated photoperiod sensitivity so that plants could be grown anywhere, anytime. The catch was that these non-photoperiod-sensitive plants required ideal growing conditions—sufficient water and the right temperature. In many sorghum-growing regions, the onset of the rainy season—always unpredictable—may become even more so as the climate changes. So breeders have had to "program" the crop to mature at the time of year when conditions are most likely to be favorable for grain development, regardless of when they are planted. Photoperiod-sensitive sorghum and millet will catch up or slow down so their flowering and grain filling occurs at a roughly constant calendar date, which tends to be the period when the rains are winding down but there is still enough water in the soil to complete grain development.

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Breeding climate-resilient crops

"Waterproof" rice to protect farmers from devastating floods'

The risk of flooding in southern Asia's low-lying, rice-growing regions will continue to increase as climate change leads to greater precipitation in this and many other regions. In Southeast Asia alone, annual flood-related losses surpass USD$1 billion**,** placing millions of lives at risk of hunger. Rice supplies the majority of calories for more than 3 billion people worldwide and is the only cereal crop that can withstand any submergence. Yet even rice will die if fully submerged for too long. Taking advantage of the recently sequenced rice gene, researchers at the International Rice Research Institute (IRRI) and the University of California at Davis have identified a gene, called Sub1A, found in a little-used variety of rice, which allows the plant to survive completely submerged for up to two weeks. When the plant is covered with water, its oxygen and carbon dioxide supplies are reduced, which interferes with photosynthesis and respiration—in which the plant converts sugars into energy for growth. Lacking air and sunlight, growth is inhibited, and most plants die after three days. The Sub1A gene, when overexpressed, or hyperactivated, essentially waterproofs the plant. The flood-tolerant trait has already been transferred into a variety of rice, called Swarna, widely grown in Bangladesh, which has benefited farmers by withstanding floods without sacrificing its high yield, acceptable taste, or adaptation to regional growing conditions.

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Managing greenhouse gases

Satellite imagery helps poor farmers participate in carbon markets

Researchers at the World Agroforestry Centre (ICRAF) are using satellite data and advanced measurement techniques to help developing-country farmers participate in and receive fair payment for carbon-removal programs. Poor farmers are among the world's largest producers of sequestered carbon, yet they are unable to calculate or verify how much they are removing from the atmosphere and, thus, are ill-equipped to participate in carbon sequestration programs. The carbon stored in trees is derived from carbon dioxide, one of the greenhouse gases responsible for global climate change. Scientists believe that removing carbon dioxide from the atmosphere and storing it in trees is one of the best ways to reduce global warming. It's also one of a limited number of options available to industries that need to offset carbon dioxide emissions under the Kyoto Climate Change Protocol or that have decided voluntarily to reduce their emissions. The new measurement technology, developed by researchers from Michigan State University and ICRAF, can remotely calculate and verify the carbon being stored across millions of square kilometers of agricultural land and forests thousands of kilometers away. The new technique, which is highly accurate, greatly reduces the need for expensive on-the-ground verification. With fair payment, ICRAF believes that millions of dollars in carbon credits could begin flowing to the world's rural poor by 2007, providing an infusion of cash into rural economies and facilitating sustainable development in many of the world's poorest countries.

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Managing greenhouse gases

Alternatives to slash and burn: Income from tree products

Every year approximately 130,000 square kilometers of humid tropical forest are destroyed, accounting for up to 25 percent of net annual carbon dioxide emissions. The devastation is caused in part by poor farmers who often have no other option for feeding their families than slashing and burning a patch of forest, growing crops until the soil is exhausted, and then moving on. The Alternative to Slash and Burn (ASB) Program, a CGIAR system-wide initiative, is working with farmers to provide them with livelihood options that would reduce the incidence of forest burning. The program has identified "best-bet" alternatives for slash-and-burn farmers, including integration of trees into farming—agroforestry. Researchers are working with farmers to reduce the pressure on forests by providing them with a nearby, convenient source of food, fuel wood, and timber for construction and fences. By improving products from the vast and largely untapped genetic wealth of trees found in tropical forests, researchers are also demonstrating to farmers the income-generating potential of tree products such as fruits, nuts, oils, resins, medicines, cosmetics, fibers, fodder, and dyes.

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Managing greenhouse gases

Ray guns and African grasses help farmers reduce harmful nitrous oxide emissions

Nitrogen is one of the keys to healthy plant growth, which is the very reason that farmers the world over apply nitrogen fertilizer to their crops. Yet these fertilizers also increase a process called denitrification in which microbes convert nitrogen in the soil into nitrate and nitrous oxide—

a greenhouse gas with 310 times the warming power of carbon dioxide. Researchers at the International Maize and Wheat Improvement Center (CIMMYT) and the International Center for Tropical Agriculture (CIAT) are using two different approaches to reduce nitrogen emissions. A new hand-held infrared sensor is being calibrated at CIMMYT to help developing-country wheat and maize farmers maintain their yields using far less fertilizer. Held above the young, growing wheat plants, the sensor measures how much light is reflected in two different wavelengths—red and invisible infrared—which then helps the farmers determine precisely how much fertilizer should be applied. Scientists from CIAT and the Japan International Center for Agricultural Sciences (JIRCAS) are working to exploit a chemical released from the roots of an African grass grown widely in South American pastures that naturally triggers biological nitrification inhibition (BNI). BNI slows the conversion of ammonium—the form of nitrogen in most fertilizers—first into nitrite and then into nitrate and nitrous oxide. Nitrate is crucial to crop growth, but much of it leeches away, and nitrous oxide has a dual negative effect on the environment—it is a powerful greenhouse gas, and it contributes to depletion of the stratospheric ozone layer, making humans more vulnerable to UV radiation. Slowing nitrification to a rate compatible with good crop growth would reduce fertilizer needs and lessen agriculture's impact on the environment.

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Improving resource-use efficiency

Providing local water management authorities with a low-cost eye in the sky

Planners and policy makers in poor countries often lack the data to manage their regional water resources effectively. The International Water Management Institute (IWMI) has created low-cost satellite imaging techniques that interpret publicly available satellite images to give an accurate picture of water and land resources at global and local levels. IWMI recently released a global irrigated-area map (see http://www.iwmigiam.org) that provides data and products on irrigation at various resolutions of sub-national to national levels. These remote sensing tools complement traditional methods for tracking water availability and measuring the productivity of water used in agriculture. Because they often use high–quality, public-domain satellite images that are available free of charge from reliable sources such as United States Geological Survey and the (U.S.) National Aeronautics and Space Administration (NASA), this approach offers developing countries a low-cost way to improve water management. The satellite images help local water management authorities determine (e.g., http://www.iwmidsp.org) where there is available water in a river basin at various times of the year; where water is reaching—or not reaching—crops in an irrigation system; spatial distribution of irrigated areas and their cropping intensities; areas affected by droughts and their intensities; and the interaction between the water and the plant in natural vegetation and agricultural areas.

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Improving resource-use efficiency

Drip irrigation: Increasing crop yields while saving water

In Africa and South Asia, the International Water Management Institute (IWMI) is working with local partners to scale up simple "bucket and drip" irrigation system for poor farmers. For as little as USD$5**,** this technology allows farmers to apply limited amounts of water to their crops in a way that saves water and increases yields. In drip irrigation, water flows from a raised bucket through a filter into special drip pipes with emitters located at different locations throughout the plot. Water is discharged through the emitters directly into the soil near the plants through a special slow-release technology. IWMI's efforts focus on countries such as South Africa where large numbers of small farmers are already feeling the bite of climate change-induced water scarcity.

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Improving resource-use efficiency

Microdoses of fertilizer allow plants to use precious water

Much of the limited precipitation that occurs in low-rainfall regions is, paradoxically, wasted from a farming point of view. This precious resource flows right by the crop and the farmer because it often comes in flood surges, it cannot be absorbed by the degraded soils, or the crops themselves are malnourished and thus unable to draw water efficiently from the soil. Researchers at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) are remedying the situation by rectifying the soil's severe phosphorus and nitrogen deficiency with minute applications of fertilizer—about a soda-pop bottle capful per plant, just one-sixth of the amounts used in developed countries. This practice, called "microdosing," causes the roots to shoot out early and capture water and nutrients that otherwise would have gone to waste. Even with African fertilizer costs approximately three times higher than in those in the developed world, microdosing is profitable and has resulted in yield increases averaging around 50 percent in thousands of trials with millet, sorghum, and maize in West and Southern Africa.

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Improving resource-use efficiency

Doing more with less: No-till agriculture mitigates greenhouse gases

Using data on soil nutrients and carbon emissions—and equipped with tractors—researchers at the Rice-Wheat Consortium (RWC), convened by the International Maize and Wheat Improvement Center (CIMMYT), are helping farmers in India and elsewhere radically transform agriculture while mitigating the release of gases that cause global warming. Much of soil's carbon content is released into the atmosphere when it is plowed, or tilled, which farmers do with tractors up to 12 times per planting season. Tilling not only contributes to atmospheric carbon buildup, but it also increases the need for fertilizer as the soil is depleted of the carbon needed to maintain nutrients essential to healthy crop production. In India's Indo-Ganges region, an increasing number of farmers now plant wheat seeds directly into the stubble remaining from the just-harvested rice on a single tractor pass or on the drastically reduced till fields—not the 12 they are accustomed to. On each hectare of land, farmers save 50-60 liters of diesel and approximately 1 million liters of irrigation water. Using a conversion factor of 2.6 kilograms of carbon dioxide per liter of diesel burned, this represents about a quarter-ton fewer emissions per hectare of carbon dioxide, the principal contributor to global warming. A study has revealed that zero till (ZT) agriculture-induced water savings (in 3 million hectares, the current acreage of ZT wheat in South Asia) may be close to 1.18 billion m^3 of irrigation water. In financial terms, ZT practice on 3 million hectares has resulted in a net income increase of USD$23 million per season, comprising a "cost-saving effect" of USD$146 million and "yield effect" of USD$92 million. Annual diesel fuel savings would amount to a half-billion liters—equivalent to a reduction of nearly 1.3 million tons in carbon dioxide.

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Improving resource-use efficiency

Water harvesting: Learning from desert dwellers'

In dryland regions, meager seasonal rainfall is diffused over such a wide area that it is of little benefit to plants before it runs off or soaks into the soil. For hundreds, even thousands of years, farmers in West Asia and North Africa, some of the driest regions on earth, have diverted rainfall from large areas into smaller parcels where the precious moisture can benefit crops or trees. While the technique, known as water harvesting, is neither high-tech or new, researchers at the International Center for Agricultural Research in Dry Areas (ICARDA) are working to compile details on scores of traditional systems to help farmers refine them and introduce them to new communities. For example, on the dry steppes of Jordan and elsewhere in the region, gentle hillsides resemble large checkerboards covered with a series of diamond-shaped plots, called negarim, which are bordered by low earthen ridges. Sprouting from the downhill tip of the diamond, where the slope's run-off collects, are trees—almond, olive, apricot, and pistachio. Researchers have helped make negarim even more efficient by working with farmers to line the pits with polymer sheets to minimize evaporation from soil surface, and to use polymers to increase the storage capacity of the soil so sufficient run-off is kept for the harshest days of the long, dry summer. In North Africa, farmers build terraced stone and earth walls, called tabias, across the beds of steep wadis—dry gullies that flood during rain—to collect and retain soil and water that otherwise would be washed down the wadis. The tabias retain enough moisture in the captured soil to grow olives and barley, the traditional crops, and sometimes apples, apricots, and chickpeas. In Syria, degraded rangelands benefited from water harvesting by mechanizing the construction of the traditional microcatchment ridges using a specialized plow. Shrubs' survival rate was increased, and the plants survived prolonged drought.

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