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DOUBLE HELIX

DECODING BIOTECH STRAND BY STRAND

SENIOR HS

What is Climate Change?

**Improved Crops
for Climate Change**

**Improved Animals
for Climate Change**

**Contributions of Biotech Crops
to Food Security, Sustainability,
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Let's Learn from Klima!**

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Welcome!

Dear Teachers, Students, and Readers,

Welcome to the fourth issue of the *Double Helix*, the only magazine supplement on agricultural biotechnology for senior high school students in the Philippines!

The world is facing major challenges as climate change affects agriculture and threatens farming while decreasing global productivity. Innovative tools such as gene editing allows scientists to develop crops and animals that are adapted to the changing climate.

This issue of the *Double Helix* presents a background on climate change, improved crops and animals for climate change, and an infographics on the contributions of biotech crops to food security, sustainability, and climate change solutions. We also included a fun science activity with *Klima* for all of you to enjoy in school or at home.

Through the *Double Helix*, we hope to share with you biotech crops help in finding solutions to the challenges brought about by climate change.

If there are topics that you want to be covered in the *Double Helix*, send us a message at double.helix@isaaa.org. Please share the *Double Helix* with your family and friends!

— *Double Helix* Editorial Team

NEWS BRIEFS

STUDY REVEALS LINKAGES BETWEEN CROP BIOTECH AND CLIMATE CHANGE MITIGATION

Researchers from the University of Saskatchewan and the University of Victoria in Canada analyzed and evaluated peer-reviewed research on the contribution of crop biotechnology to climate change mitigation and adaptation. The study concludes that GM crops offer benefits for climate change mitigation. The assessment used the Maryland Scientific Methods Scale and citation analysis to find that GM crops provide benefits for climate change mitigation.

GLOBAL CLIMATE CHANGE IMPACT ON MAIZE AND WHEAT EXPECTED WITHIN 10 YEARS, NASA STUDY FINDS

A study by NASA predicts that the production of maize and wheat will be affected by climate change as early as 2030 under a high greenhouse gas emissions scenario. The study reveals that maize crop yields are projected to decline by 24%, while wheat could potentially see growth of about 17%. This is due to the projected increases in temperature, shifts in rainfall patterns, and elevated surface carbon dioxide concentrations from human-caused greenhouse gas emissions. The team's projections also showed soybean and rice yields will decline in some regions.



CLIMATE CHANGE SLOWED AGRICULTURAL PRODUCTIVITY GROWTH BY 21% SINCE 1961

Using a robust model of weather effects on productivity, the study from Cornell University, the University of Maryland (UMD), and Stanford University showed a 21% reduction in global agricultural productivity since 1961, which according to the researchers is equivalent to completely losing the last seven years of productivity growth. The study found that warmer regions such as Africa, Latin America, and the Caribbean have already experienced a slows in growth of 26-34%, while the United States seems to be less affected, with slows in growth of approximately 5-15%.



CLIMATE CHANGE AFFECTING BILLIONS OF LIVES, LATEST IPCC REPORT SAYS

The latest report from the United Nations Intergovernmental Panel on Climate Change (IPCC) reveals that despite efforts to reduce the risks, human-induced climate change is causing dangerous and widespread disruption in nature and affecting the lives of billions of people around the world. Increased heatwaves, droughts, and floods are already exceeding plants' and animals' tolerance thresholds, driving mass mortalities in species such as trees and corals. These extreme weather conditions are occurring simultaneously, causing cascading impacts that are increasingly difficult to manage, exposing millions of people to acute food and water insecurity, especially in Africa, Asia, Central and South America, on Small Islands, and in the Arctic.

STUDY REVEALS CLIMATE CHANGE BOOSTS BANANA DISEASE

A new study at the University of Exeter in England reveals that climate change has raised the risk of Black Sigatoka, a fungal disease that ravages banana crops. The study, which combined experimental data on Black Sigatoka infections over the past 60 years says changes to moisture and temperature conditions have increased the risk of Black Sigatoka by more than 44% in Latin America and the Caribbean since the 1960s. Dr. Daniel Bebbier of the University of Exeter explained that climate change has made temperatures better for spore germination and growth, and made crop canopies wetter, raising the risk of Black Sigatoka infection in many banana-growing areas of Latin America.

SCIENTISTS DEVELOP NEW METHOD TO PRODUCE DROUGHT-RESILIENT WHEAT QUICKLY, CHEAPLY, AND ACCURATELY

Scientists at the Australian National University, ARC Centre of Excellence in Plant Energy Biology, and CSIRO have developed a new method to identify drought-resilient wheat quickly, cheaply, and accurately. The simple test measures the relative abundance of four amino acids in wheat plants. This predicts the plants' ability to maintain yield under drought much more accurately than current state-of-the-art methods.



What is climate change?

By Dr. Jaime A. Manalo IV

Seasoned farmers would usually comment about delayed onset of rain, and that it's hotter now than three decades ago. Experts say these changes could be due to climate change.

Climate change refers to the long-term shifts in weather patterns and temperatures. By long-term, experts usually look at the weather patterns for 30 years or so to say whether what is going on is climate change-related or not.

Climate change results from massive greenhouse gas emissions, such as carbon dioxide and methane, which trap the sun's heat, and, consequently, raise Earth's temperature; hence, global warming. Given that the Earth is a system, which means that everything is interconnected and that it is composed of various processes, climate change comes with a host of devastating impacts such as seawater rise and more frequent drought and typhoon occurrences.

Globally, there is a strong consensus that climate change is caused by human activities. Any activity that requires burning of fossil fuel, coal, or gas, such as driving cars and using air-conditioning units, contributes to climate change. Yes, even cultivating rice contributes to climate change because of methane emissions. The question is, "How worried should we be about the impacts of climate change?"

Experts, such as those from the International Food Policy Research Institute (IFPRI) based in Washington DC, USA, project there could be food shortages in the future due to climate change. In some parts of the world, such as the Chhattisgarh State in India, there have been reports of complete crop failure because of drought. What can be done?

Mitigation

Efforts to lessen greenhouse gas emissions are called mitigation. An example of a climate change mitigation intervention is consuming locally grown food. It means that the distance traveled by that food is shorter, hence, a lesser amount of fossil fuels was burnt to bring the food to your plate.

Another example is carbon trading where richer and major polluter countries such as the US and China pay for carbon emission-reducing efforts done elsewhere, usually in developing countries. An example of an emission-reducing effort is the use of the Alternate Wetting and Drying (AWD) technology in rice, which has been shown to reduce methane emissions. AWD is a water management technology that guides farmers when to irrigate their fields, thereby avoiding wasteful use of water.

Adaptation

For countries such as the

Philippines, whose contribution to global warming is rather small, efforts gravitate around adaptation. Adaptation refers to efforts to minimize losses, usually in terms of livelihood, due to climate change impacts. In agriculture, adaptation may come in the form of using climate-adaptive crops such as drought- and flood-resistant ones. In rice, an example of a flood-tolerant variety is called Submarino, which can withstand flooding longer than the usual rice variety.

Another option is to practice income diversification outside the agriculture sector. They get into jobs such as tricycle driving, hairdressing, and maintaining *sari-sari* stores to compensate for income loss.

The short message about climate change is that it is here already. While some quarters argue that climate change is not real, it is important to address the impacts that we are experiencing now.

Dr. Jaime A. Manalo IV is the Head of the Socioeconomics Division of the Philippine Rice Research Institute.

LEARN MORE
ABOUT
CLIMATE
CHANGE
SCAN THIS!



Improved Crops for Climate Change

By Dr. Gabriel O. Romero

Farming problems, despite modern solutions, continue to threaten farm productivity, especially so that climate change is upon us. Climate change is intensifying challenges such as drought, heat, cold, flooding, and whipping winds. Pests and diseases are bound to pose higher pressure on crops as the warming planet causes them to reproduce faster and expand to other areas in search of more conducive environments.

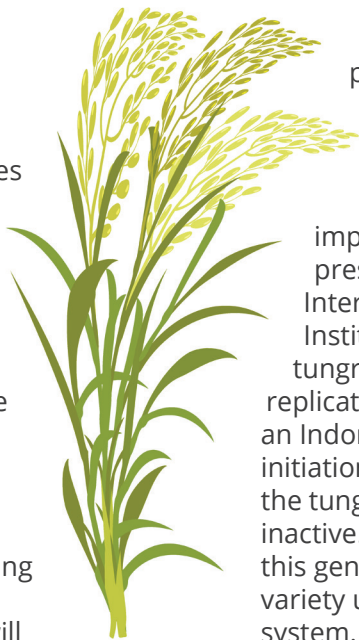
With these heightened challenges, precision farming using data science and digital tools can help farm productivity through customized inputs. Precision breeding allows breeders and molecular biologists to develop new varieties with little uncontrolled perturbation of the genome or DNA juggling. For the first time, as long as the sequence of the target gene is known, scientists can now make the desired changes “as is where is”.

RICE

Gene editing is a powerful tool to combat the mounting challenges of climate change. Land conversion has already dampened rice production in the Philippines. Climate change will further reduce available rice farms due to salination brought about by encroaching seawater. Saline-tolerant varieties will help this challenge.

Chinese researchers bred rice lines for saline tolerance using gene editing technology. They used the CRISPR-Cas9 system to knock out the rice gene *RR22*, which encodes a transcription factor in plant metabolism. The knock-out lines showed significant salinity tolerance compared to the wild-type.

Rice tungro is the most damaging rice disease in the Philippines which is transmitted by the insect vector green leafhopper. This vector will multiply faster and invade new areas as the temperature rises, bringing along the tungro virus. At present, varieties with moderate resistance to tungro and synchronous



planting can fairly manage the tungro pressure, but not for long as the vector will behave differently.

To mitigate the impending rise of tungro pressure, scientists at the International Rice Research Institute (IRRI) have developed tungro-resistant rice lines. They replicated the natural mutation in an Indonesian variety in which an initiation factor, *elf4G*, hijacked by the tungro virus for multiplication is inactive. The IRRI team deactivated this gene in a popular high-yielding variety using the CRISPR-Cas9 system. Loss or addition of a few bases in the gene rendered it non-functional and therefore not available for virus multiplication, thus successfully generating lines resistant to tungro.

Another major disease of rice is bacterial leaf blight (BLB), which causes substantial yield loss. The susceptibility genes for BLB help produce substances that the BLB pathogen consumes for its multiplication and infection around the plant. The same IRRI team edited four susceptibility genes by CRISPR-Cas9, depriving nutrition for the pathogen and thereby controlling the disease from further developing. The edited lines showed a lesion length of 2-5 cm compared to 20-25 cm long in the unedited plants.

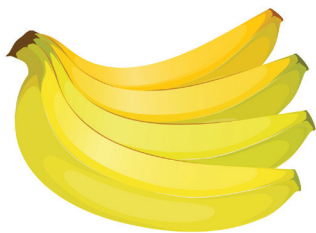
CORN



Corn is the second staple of Filipinos and the main ingredient in livestock and poultry feeds. The Philippines is nearly self-sufficient in corn production largely due to the use of genetically modified (GM) corn hybrids with built-in insect resistance and herbicide tolerance.

Lodging has been one of the major constraints in corn production and this will further intensify with more violent storms and typhoons caused by climate change. Height reduction of the corn plant is a suitable strategy against ferocious winds.

Chinese scientists knocked out a gene encoding the growth hormone gibberellic acid using the CRISPR-Cas9 system in corn. The mutants displayed a semi-dwarfing phenotype, and almost no yield loss was generated compared with wild-type plants.



BANANA

Banana is a high-value crop for domestic consumption and export market. Its trunk is not woody but an assemblage of leaf sheaths that is vulnerable to breakage, especially during typhoons. Tall banana trees coupled with a heavy bunch of fruits are prone to lodging. Semi-dwarf and dwarf banana plants can better withstand whipping winds generated by climate change. Chinese scientists used the CRISPR-Cas9 system to knock out a gene

coding for the growth hormone gibberellic acid. Seven mutant lines were generated measuring only 25% or 35% of the height of the conventional banana plants at 180 days old. The lines had greener leaves indicating better health and higher yields.

Banana production in the Philippines is constrained by diseases with banana streak virus (BSV) among the most prevalent ones. Yield losses may reach up to 90% depending on the severity of the infection. Climate change is anticipated to increase disease severity and incidence as

rising temperatures foster pathogen reproduction coupled with the host plant becoming more susceptible. Stronger disease resistance should be conferred in the plant to cope with the increasing virulence of the pathogens. Certain sequences of BSV are integrated into the banana genome, which allows BSV to multiply and spread in the plant.

Scientists at the International Institute of Tropical Agriculture (IITA) deactivated these BSV sequences using the CRISPR-Cas9 system. The edited lines remained healthy in comparison to the non-edited plants.

POTATO



Potato is a favorite component in the traditional Filipino diet, a major dish as french fries in fast food chains, and a raw material in the growing potato chips industry.

The national production is all sold on the fresh market and imported potatoes up to 30% goes to french fries and the chips industry. The Cordillera Autonomous Region accounts for 85% of the country's total production, and Mindanao for 15%. Long dry spells cause drought in potato planting areas, which now occur with more intensity and regularity under climate change. Drought-tolerant varieties would enable potato production to continue under water-deficit conditions.

European scientists inactivated through the CRISPR-Cas9 system a transcription factor CDF that suppresses FLORE which closes the stomata. The CDF mutants allowed higher production of FLORE thereby minimizing water loss from closed stomata during drought conditions.

TOMATO



Tomato is an important and popular vegetable grown in all parts of the country. It is one of the most profitable crops for off-season production and is a source of Vitamins A and C. The Philippines is one of the leading tomato-producing countries in the Asia-Pacific region, but production is severely constrained by long dry spells especially during El Niño causing irreversible damages and yield loss. Using CRISPR technology, researchers from Israel developed tomatoes that consume less water without affecting yield, quality, and taste. The researchers induced a modification in the tomato and targeted the *ROP9* gene. The ROP proteins function as a switch, and the modified *ROP9* caused more stomata to close in the afternoon thereby reducing water loss. In addition, the mutant plants retained the photosynthetic rate, crop quantity,

or the amount of sugar in the fruits, as the wild type.

Tomato production is also restrained by the powdery mildew disease, causing plant growth reduction, premature defoliation, and reduction in fruit quality and yield, resulting in significant economic loss if not managed in the early stages. With the increased carbon dioxide emissions and rising temperatures in Southeast Asia, powdery mildew disease may continuously aggravate in the future through increased colony establishment and susceptible openings such as stomata. British scientists developed a tomato variety resistant to the powdery mildew fungal pathogen using the CRISPR-Cas9 technology. They targeted mildew-resistant locus o (MLO), which confers susceptibility to fungi causing the powdery mildew disease. The loss-of-function mutations resulted in resistance to powdery mildew.

The daunting challenges brought about by climate change to crop production may be addressed efficiently and quickly through gene editing technology. These major crops in the Philippines are directly impacted by climate change. Gene editing used by various researchers around the world has already yielded excellent breeding lines and varieties that make these crops cope with drought, salination, and violent winds, and has beefed up their resistance to diseases.

Dr. Gabriel O. Romero is the Executive Director of the Philippine Seed Industry Association, Inc.

Improved Animals for Climate Change

By Dr. Ernelea P. Cao

Climate change, the long-term shift in temperature and weather patterns, has produced havoc on the environment and created problems in agriculture and fisheries. Extreme temperatures have affected not only the flowering and fruiting times of plants but also the survival of animals. Extreme heat and severe cold have caused the decline in reproduction and death of non-tolerant animals. Pollution of various substances in the environment has aggravated the situation. The emergence of new pathogens and diseases has also been observed with changes in the environment.

Biotechnology for improved animals

Farm animals and fishes have been improved either through traditional biotechnology or modern biotechnology. Traditional biotechnology involves the breeding of different strains of a farm animal or fish and has been used to produce offspring with improved characteristics like more milk production or bigger biomass for food. Modern biotechnology involves the use of molecular biology techniques to improve certain species or strains. Cloning, the production of genetically the same cells or organisms, has been used as a new reproductive technology in animals to generate the same set of desired characteristics.

GM animals to address environmental problems

With the advent of genetic engineering, animals including fish, can be produced to incorporate desired traits. In 1995, scientists at the University of Guelph in Ontario, Canada developed a genetically modified (GM) pig called Enviropig™. This GM pig has a gene that encodes for the enzyme phytase in its salivary glands. This enzyme can digest phosphorus found in animal feeds and therefore reduce phosphorus pollution in the environment. Excessive phosphorus pollution is a problem in hog production since it is excreted in



pig manure in large amounts, polluting the land and making it unproductive. In February 2010, Environment Canada granted approval to the University of Guelph for the reproduction and exportation of Enviropig™ through a "Significant New Activity Notice," allowing the reproduction of GM or transgenic pigs in controlled facilities.

GE animals for better survival

Genome editing, as the name implies, involves changing or modifying the genome of an organism by replacing, deleting, or silencing a DNA sequence or a gene without the introduction of a foreign gene in the final product, in contrast to genetic engineering. In May 2023, researchers reported the results from a collaborative study among the United States Department of Agriculture - Agricultural Research Service, the University of Nebraska-Lincoln, the University of Kentucky, and industry partners, Acceligen and Recombinetics Inc. on the use of CRISPR-mediated homology-directed repair and somatic cell nuclear transfer (SCNT) to produce a live calf with a six amino acid substitution in the bovine viral diarrhea virus (BVDV) binding domain of bovine CD46. This resulted in a gene-edited calf with significantly reduced susceptibility to BVDV infection.

In March 2022, the United States Food and Drug Administration cleared Acceligen's genome-edited cattle with the slick-coat trait of safety concerns.

The slick-coat trait allows cattle to better tolerate hot weather and is identical to naturally-occurring mutations found in some cattle grown for food in tropical or subtropical climates.

Future directions

As the world faces continued changes in the environment either due to natural or man-made causes, efforts are continuously being made to address and mitigate such changes. The development of climate-resilient or tolerant animals will continue in laboratories and field stations. While animals need additional consideration in terms of containment due to their mobile characteristics compared to plants, safety nets are being put in place. In the Philippines, the regulatory framework and policies to enable the safe use of animal biotechnology has been crafted, with full benefits and adherence to food and environmental safety.

Dr. Ernelea P. Cao is a Professor Emeritus of the Institute of Biology, College of Science, University of the Philippines Diliman.



For further reading

Transgenic Yorkshire pigs
<https://tinyurl.com/EnviroPig>

First gene-edited calf
<https://tinyurl.com/GEdCalf>

Contributions of Biotech Crops to Food Security, Sustainability, and Climate Change Solutions

INCREASE CROP PRODUCTIVITY



BIOTECH CROPS CONTRIBUTE TO
FOOD, FEED, AND FIBER SECURITY

US\$261.3 BILLION

FARM INCOME GAINS IN 1996-2020
FROM PLANTING **BIOTECH CROPS**

REDUCED PRODUCTION COSTS



LESS PLOWING
LESS PESTICIDE SPRAYS
LESS LABOR

MORE AFFORDABLE FOOD



CONSERVE BIODIVERSITY



BIOTECHNOLOGY IS A
LAND-SAVING TECHNOLOGY
INCREASING YIELDS WITH LESS LAND

183 MILLION HECTARES

CONSERVED LAND DUE TO
PRODUCTIVITY OF BIOTECH CROPS



PREVENTS
DEFORESTATION



PROTECTS
BIODIVERSITY

PROVIDE A BETTER ENVIRONMENT



IN 1996-2020, BIOTECH CROPS HELPED
REDUCE PESTICIDE APPLICATION BY

748.6 MILLION KGS

DECREASED ENVIRONMENTAL IMPACT
FROM HERBICIDE &
INSECTICIDE USE BY **17.3%**



INSECT RESISTANT COTTON
LARGEST CHANGE IN PESTICIDE USE
**SAVED 339 MILLION KG
INSECTICIDES**

REDUCE CO2 EMISSIONS



BIOTECH CROPS HELPED SAVE
39 BILLION KGS CO2



REDUCED FUEL USE **14.6 BILLION LITERS**
EQUIVALENT TO REMOVING



25.9 MILLION CARS
OFF THE ROAD FOR 1 YEAR



REDUCED RELEASE OF
GREENHOUSE GASES
FROM GM CROPPING AREAS



HELP ALLEVIATE POVERTY AND HUNGER



BIOTECH CROPS UPLIFTED THE LIVES OF
17 MILLION FARMERS

AND THEIR FAMILIES TOTALING
>65 MILLION PEOPLE

SINCE 1996, BIOTECH CROPS HAVE
PROVIDED FOOD, FEED, AND SHELTER
TO THE WORLD'S 8.2 BILLION POPULATION



BIOTECH CROPS HELP FARMERS
EARN REASONABLE INCOMES



**BETTER LIVELIHOODS
FROM HIGHER YIELDS**

IN 2019, BIOTECH CORN WAS PLANTED
IN **14 COUNTRIES**, BENEFITTING SMALL,
RESOURCE-POOR FARMERS

SOURCES:

Graham Brookes. 2022. Genetically Modified (GM) Crop Use 1996–2020: Impacts on Carbon Emissions. *GM Crops & Food* 13:1, pages 242-261.
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ISAAA. 2019. Global Status of Commercialized Biotech/GM Crops in 2019. ISAAA Brief No. 55. ISAAA: Ithaca, NY.

LET'S LEARN WITH KLIMA!

