Revolutionizing Agriculture with Low-emissions, Resilient Crops

Halting climate change requires addressing agricultural greenhouse gas (GHG) emissions. In the United States, agriculture accounts for 26 percent of total GHG emissions, including CO_2 and the 298-fold more potent N_2O. About a third of these emissions come from the synthesis and use of nitrogenous fertilizer and its volatilization as N_2O. Over the next century, pressure on agriculture will worsen as the demand for food is expected to double.

Further, the "green economy" envisions a future where products currently derived from petroleum come instead from the fermentation of renewable feedstocks—but the biomass needs to come from somewhere. This pressure will require balancing "food versus fuel"—in other words, equalizing humanity's need to eat with its need for other products that contribute less to climate change. More food will need to be obtained from less land without damaging the environment; however, right as it is needed most, agricultural productivity is projected to decline as a result of the environmental impact of climate change.

This proposal seeks to nucleate and coordinate agricultural biotechnology at MIT through two grand challenges for addressing climate change.

OBJECTIVES AND PROPOSED SOLUTIONS

Objective 1. Reduce GHG emissions from food production by creating zero-GHG fertilizer.

- Self-fertilizing crops through the genetic engineering of plants and their associated microbes to produce nitrogenous fertilizer.
- Mimicking legume-rhizobia symbiosis for fertilizer production in cereals.
- Sustainable phosphorous (P) and potassium (K) extraction through conversion of currently inaccessible nutrient-rich minerals into fertilizing products.

Objective 2. Create resilient crops that remain productive under new climate stresses.

- Quantify the role of primary metabolic pathways in nitrogen assimilation under climatic stress.
- Promote crop resilience under adverse weather conditions through the engineering of asexual seed production in non-apomictic plants to conserve hybrid crop vigor.
- Biopolymer-based microbial seed coatings to promote resiliency in plants in arid and saline regions.

ADDRESSING EQUITY IN AGRICULTURE

Agriculture is at the core of human civilization, and it is critical to pursue a research agenda that prioritizes environmental, social, and governance factors that are equitable and just. Climate change disproportionately affects communities already suffering from socioeconomic inequalities. More than 1.3 billion people are living on agricultural land with depleted soils that fall short of meeting adequate harvest yield—limiting food supply and increasing hunger, poverty, and displacement. Lack of access to fertilizer has led to poor crop yields in poorer regions, as well as wars and famine. Eighty percent of drought damage was sustained by agriculture in low- and lower-middle-income countries.

Our solutions have the potential to address some of this inequality; for example, by eliminating the restrictions of Haber-Bosch–driven megafactories and crops that are more robust to changes in climate. However, access to these solutions as well as perceptions and local regulations around genetically engineered crops could inhibit their use. Through this project, MIT will adopt a leadership role in the public and global engagement with the development of agricultural solutions.

TEAM EXPERTISE AND LEADERSHIP

We have assembled an interdisciplinary MIT team to devise a plan focused on mitigating GHG emissions while promoting resilience of crops for climate adaptation. The group spans biological engineering, biology, materials science, chemical engineering, and civil and environmental engineering.

The team is led by **Christopher Voigt** (Biological Engineering) and consists of **Antoine Allanore** (Materials Science and Engineering), **David Des Marais** (Civil and Environmental Engineering), **Mary Gehring** (Biology), **Benedetto Marelli** (Civil and Environmental Engineering), **Kristala Prather** (Chemical Engineering), and **Jing-Ke Weng** (Biology).