New plant protein discoveries could ease global food and fuel demands

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Applying the new discoveries could substantially increase the productivity of crops grown for food and biofuels, such as this cornfield in England. Credit: Wikipedia

New discoveries of the way plants transport important substances across their biological membranes to resist toxic metals and pests, increase salt and drought tolerance, control water loss and store sugar can have profound implications for increasing the supply of food and energy for our rapidly growing global population.

That's the conclusion of 12 leading plant biologists from around the world whose laboratories recently discovered important properties of plant transport proteins that, collectively, could have a profound impact on global agriculture. They report in the May 2nd issue of the journal *Nature* that the application of their findings could help the world meet its increasing demand for food and fuel as the global population grows from seven billion people to an estimated nine billion by 2050.

"These membrane transporters are a class of specialized proteins that plants use to take up nutrients from the soil, transport sugar and resist toxic substances like salt and aluminum," said Julian Schroeder, a professor of biology at UC San Diego who brought together 11 other scientists from Australia, Japan, Mexico, Taiwan, the U.S. and the U.K. to collaborate on a paper describing how their discoveries collectively could be used to enhance sustainable food and fuel production.

Schroeder, who is also co-director of a new research entity at UC San Diego called Food and Fuel for the 21st Century, which is designed to apply basic research on plants to sustainable food and biofuel production, said many of the recent discoveries in his and other laboratories around the world had previously been "under the radar"—known only to a small group of plant biologists—but that by disseminating these findings widely, the biologists hoped to educate policy makers and speed the eventual application of their discoveries to global agriculture.

"Of the present global population of seven billion people, almost one billion are undernourished and lack sufficient protein and carbohydrates in their diets," the biologists write in their paper. "An additional billion people are malnourished because their diets lack required micronutrients such as iron, zinc and vitamin A. These dietary deficiencies have an enormous negative impact on global health resulting in increased susceptibility to infection and diseases, as well as increasing the risk of significant mental impairment. During the next four decades, an expected additional two billion humans will require nutritious food. Along with growing urbanization, increased demand for protein in developing countries coupled with impending climate change and population growth will impose further pressures on agricultural production."

"Simply increasing inorganic fertilizer use and water supply or applying organic farming systems to agriculture will be unable to satisfy the joint requirements of increased yield and environmental sustainability," the scientists added. "Increasing food production on limited land resources will rely on innovative agronomic practices coupled to the genetic improvement of crops."

One of Schroeder's research advances led to the discovery of a sodium transporter that plays a key role in protecting plants from salt stress, which causes major crop losses in irrigated fields, such as those in the California central valley. Agricultural scientists in Australia, headed by co-author Rana Munns and her colleagues, have now utilized this type of sodium transporter in breeding research to engineer wheat plants that are more tolerant to salt in the soil, boosting wheat yields by a whopping 25 percent in field trials. This recent development could be used to improve the salt tolerance of crops, so they can be grown on previously productive farmland with soil that now lies fallow.

Another recent discovery, headed by co-authors Emanuel Delhaize in Australia and Leon Kochian at Cornell University, opens up the potential to grow crops on the 30 percent of the earth's acidic soils that are now unusable for agricultural production, but that otherwise could be ideal for agriculture.

"When soils are acidic, aluminum ions are freed in the soil, resulting in toxicity to the plant," the scientists write. "Once in the soil solution, aluminum damages the root tips of susceptible plants and inhibits root growth, which impairs the uptake of water and nutrients."

Crops could be made more drought tolerant by using plant transport proteins to regulate the “stomatal pores” in the epidermis of leaves, where plants lose more than 90 percent of their water through transpiration. Credit: Wikipedia

From their recent findings, the plant biologists now understand how transport proteins control processes that allow roots to tolerate toxic aluminum. By engineering crops to convert aluminum ions into a non-toxic form, they said, agricultural scientists can now turn these unusable or low-yielding acidic soils into astonishingly productive farmland to grow crops for food and biofuels.

Other recent transport protein developments described by the biologists have been shown to increase the storage of iron and zinc in food crops to improve their nutritive qualities. "Over two billion people suffer from iron and zinc deficiencies because their plant-based diets are not a sufficiently rich source of these essential elements," the biologists write.

The scientists also discovered transporters in plants and symbiotic soil fungi that allow crops to acquire phosphate—an element essential for plant growth and crop yield—more efficiently and to increase the uptake of nitrogen fertilizers, which are costly to produce. "Nitrogen fertilizer production consumes one percent of global energy usage and poses the highest input cost for many crops," the scientists write. "Nevertheless, only 20 to 30 of the phosphate and 30 to 50 percent of the nitrogen fertilizer applied are utilized by plants. The remainder can lead to production of the greenhouse gas nitrous oxide, or to eutrophication of aquatic ecosystems through water run-off."

The biologists said crops could be made more efficient in using water through discoveries in plant transport proteins that regulate the "stomatal pores" in the epidermis of leaves, where plants lose more than 90 percent of their water through transpiration. Two other major goals in agriculture are increasing the carbohydrate content and pest-resistance of crops. A recent discovery of protein transporters that move sugar throughout the plant has been used to develop rice plants that confer pest resistance to crops, the biologists said, providing a novel way to simplify the engineering of crops with high yields and pest resistance, which could lead to reduced use of pesticides in the field.

"Just as our cell phones will need more advanced technology to carry more information, plants need better or new transporters to make them work harder on existing agricultural land," said Dale Sanders, director of the John Innes Centre in the U.K. and a corresponding co-author of the paper. "Synthetic fertilizers and pesticides are the current solution, but we can make plants better at finding and carrying their own chemical elements."

These recent developments in understanding the biology of plant transporters are leading to improved varieties less susceptible to adverse environments and for improving human health. Says Schroeder, "More fundamental knowledge and basic discovery research is needed and would enable us to further and fully exploit these advances and pursue new promising avenues of plant improvement in light of food and energy demands and the need for sustainable yield gains."

Provided by University of California - San Diego

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