

Could Epigenetics Help Feed the World?

A look at how this novel approach offers “budding” opportunities over GMOs to improve crop productivity

July 14, 2015 Natalie Crowley



Climate change and agriculture

According to the World Health Organization, hunger is a leading threat to the world’s public health and undernourishment is a leading cause of death in children, attributing to about half of all cases. While relief organizations and other humanitarian efforts have saved lives, the hunger problem unfortunately is being compounded by climate change and its critical impact on agriculture. The fact is we are already experiencing the effects of climate change right now – storms are becoming more volatile and droughts more severe. And, these changes are ultimately affecting crop production. Changes such as extreme cold, extreme heat, and excessive amounts of snow and rain are causing crop damage, plant disease, pest infestation, and shorter growing seasons around the world.

Over the past century, biotechnology has tackled the issue of climate change by contributing solutions that decrease greenhouse gases and by developing sustainable food crops that can withstand hazardous conditions. Some farmers concerned with failing crop yields have embraced certain biotechnologies, such as genetically modified crops, also known as genetically modified organisms (GMOs). However, controversy exists regarding their overall value and safety.

GMO concerns and research

Agricultural biotechnology companies, Monsanto and Syngenta, two of the largest producers of agrichemical products and seeds, have faced significant protest in recent years as the prominence of

GMOs and consumer awareness have increased. Concerns over genetically modified crops on health and the environment as well as political controversy have led to increased regulation in regions such as the European Union. The companies counter that GMOs are safe and continuously conduct research and testing in support of this claim. According to Monsanto's website, "GMO crops have been reviewed and tested more than any other crops in the history of agriculture and have been shown to be as safe as conventional crops." Their efforts over the years have been broadly accepted by farmers since, basically, they work and are cost effective. A farmer I spoke with in Upstate New York said, "We use their seed because it saves us from needing special equipment and chemicals, which can be very expensive."

But legitimate concern regarding GMOs remains, particularly involving the potential for allergies since GMOs may use foreign genetic material to alter an organism. In a previous article about the origins of developing allergies, we discussed some allergic complications. An unknown protein in genetically modified food might trigger an allergic response, and for some, this could be detrimental. It's understandable why some consumers want GMO labeling and more available organic or certified non-GMO products, especially in light of the allergic epidemic.

So many food items today contain GMOs and this concerns a growing number of people. I think it's important that agribusinesses, especially those involved in genetic engineering, use their research capabilities to address these concerns and look to newer technologies as prospective "breeding grounds" for more naturally-contrived methods to improve crop production.

Epigenetic approach to benefit agriculture

Genetic modifications happen naturally and farmers have been taking advantage of this phenomenon for centuries by cultivating plants with desirable characteristics. This does, however, take some time to perfect. So why not explore a different approach. Could crops be improved without directly editing their DNA? Plant scientists are already working on this and their findings offer tremendous promise for better performing crops without gene mutation. Their research, of course, is in epigenetics.

The science of epigenetics is of keen interest to all who want to understand the underlying biology of epigenetic gene regulation and its potential application for crop improvement.

The study of epigenetics deals with heritable changes in trait variations that are not caused by alterations in DNA sequence. DNA methylation, histone modification and RNA interference (RNAi) are three commonly used mechanisms for epigenetic gene regulation in plants. Once these epigenetic changes are established, it's possible for them to be inherited from one generation to the next. Inheritance occurs through epigenetic alleles (or alleles having the same DNA sequence but different DNA methylation patterns), which in turn leads to higher polymorphism and eventually to newer phenotypes. This new source of variation is vital to the crop improvement process ³. Plant breeders already know that heritable variation provides basis for selection in plant breeding. Therefore, because novel phenotypes are obtainable through epigenetic processes, there's great potential for epigenetics to improve crop production.

"The science of epigenetics is of keen interest to all who want to understand the underlying biology of epigenetic gene regulation and its potential application for crop improvement," says Michiel Van Lookeren Campagne, Head of Biology Research at Syngenta. "We are keenly interested in how we can leverage epigenetic processes to bring innovation to farmers, especially in the area of heterosis." Although Campagne and his colleagues believe it may be a number of years before new

products are designed, they do acknowledge that epigenetics is involved in many processes that are key to agricultural productivity.

In addition, “the USDA Agricultural Research Service supports fundamental and applied research on the applications of epigenetics for crop improvement,” according to Roy A. Scott, Ph.D., Interim Deputy Administrator for Agricultural Research Service at the USDA. “Epigenetic processes are important players in the orchestration of crop gene activity in the field, and hence influence key crop traits.” Examples of their research include: whole-genome level DNA methylation to identify complex traits in row crops and specialty crops; understanding the epigenetic processes involved plant flowering time and resistance to pathogens; and utilizing gene silencing techniques to confer virus resistance in crops such as papayas and plums. It is without a doubt that the potential of epigenetics is being recognized by researchers, agricultural companies and the federal government.

Increasing stress tolerance in crops

Crops can experience an assortment of environmental stresses throughout their entire development, including drought, salinity, prolonged rain-fall and extreme temperatures to name a few. Their ability to tolerate or adapt to these stresses, as well as their inability to do so, is a very multifaceted phenomenon. However, epigenetic technologies could be used effectively to down regulate the genes related to stress responses. For instance, researchers investigating drought tolerance in rice at various developmental stages have found that RNAi mediated disruption of certain genes improves the crops’ ability to extract soil water and avoid dehydration. This process which inhibits gene expression occurs without adversely affecting plant architecture, growth or development.

In a different study, scientists discovered that by epigenetically modifying or “turning off” the gene MSH1 in crops like soybean and sorghum, they were able to simulate high stress exposure. Then, after reactivating the gene and crossbreeding with unaltered plants, they found that the hybridized plants had enhanced growth, biomass and yield. The genes themselves did not change in this experiment, only the way they were expressed changed. This is different from transgene-mediated modification, which is a controversial genetic modification because it involves taking a segment of DNA from one organism and introducing it to a different organism. In addition, the researchers found that the transformation was successful by the second generation, rather than by the 10th generation or more which is common for most genetic modifications to catch on. Although scientists are still learning how to epigenetically breed more varieties of stress resistant plants, given the sense of urgency to feed a growing population, the prospects for this new approach are appealing and should be further explored.

Raising nutritional value in crops

Commercially grown food is produced in far greater quantities today than was 50 years ago, yet the overall nutritional value of these crops has declined. Studies show that modern crops contain 10 to 25 percent less protein, iron, zinc, calcium, vitamin C and other important nutrients than the lower yielding crops of the past. Unfortunately, this only adds to the prevailing malnutrition affecting billions of people worldwide, primarily the poor, who do not have access to adequate and diverse food choices.

In many developing countries, a significant portion of the population relies on one or more of a staple crop like rice, corn or wheat for nutrition. Though important sources of calories and carbohydrates, these crops do not contain enough protein or micronutrients for proper cellular development and sole reliance on them for diet can lead to major health conditions. For example,

vitamin A deficiency is common and widespread in developing countries, contributing to blindness and high mortality rates. Other deficiencies like zinc, iron and folate have been linked to anemia, low birth weight and genetic disorders. While the practice of fortifying certain staple foods has been successful over the years, it is not always achievable or accepted in certain countries.

Enhancing a crop's ability to acquire added nutrients may be more feasible and effective in the long run. Currently, research using RNAi technologies to modify gene expression at a specific stage of development is being used to improve the nutritional value of plants. In cotton, it has been applied to develop lines with low gossypol levels, a protective toxin naturally found in the cottonseed. By suppressing the production of this toxin, the cottonseed becomes a viable source of protein and calories that can be used for human or livestock consumption. This is worthwhile since cotton is produced in abundance for its fiber and the seed is frequently underutilized.

In wheat and other grains, RNAi constructs have been designed to suppress the genes that promote starch levels. The results are grains with higher amylose content which is beneficial for lower blood sugar and cholesterol. As well, RNA applications have shown to improve carotenoid and flavonoid levels in tomatoes and lower the natural caffeine levels in coffee without affecting plant growth.

Nutrient-rich foods are beneficial to everyone, but more so to groups that are vulnerable to micronutrient deficiencies. Further study involving epigenetic mechanisms to enhance crop nutritional content is desirable and necessary. It will allow us to better understand overall plant metabolism and consequently help us to improve upon human and animal health and well-being.

Improving pest and disease resistance in crops

Plant diseases and pests have been known to lay waste to entire harvests. The Irish potato famine of the 1840s caused by a simple fungus-like microorganism was so devastating it caused widespread starvation and forced many to uproot their families and leave the country. Western and Northern Africa are continuously invaded by swarms of locusts that destroy all kinds of vegetation in their path, often claiming large hectares of staple crops and devastating the economy of rural communities.

Some farmers employ pesticides to improve crop yield, yet pesticides come with a cost. The quality of the food is tainted by the chemicals and the environment endures contamination, not to mention, the harmful effects on human health after consumption. Instead of pesticides, plants could be epigenetically triggered to naturally fend off pests and disease, as many plants are known to adapt to their environment. In fact, some can produce natural defense compounds against herbivore attacks.

In a study investigating epigenetic mechanisms involved in plant defense response, in particular siRNAs, researchers found that tomato plant exposure to caterpillar herbivory triggered a chemical reaction. This defense response was then seen in future generations that had not been exposed to the pest. In a related study, *Arabidopsis* plants deliberately infected with benign bacteria were able to produce offspring that showed resistance or had immunity to the bacteria. While these findings imply that siRNAs may play a role in plant memory, they also demonstrate opportunity for use in other crops, especially those grown in areas with heavy pesticide use. Strategies to utilize these transgenerational plant memory responses could prove to be cost effective, better suited for the environment and lessen the need for GMOs to strengthen crop production.

What lies ahead?

Perhaps someday, we won't need concerts to raise money to end hunger. A wonderful thought, I know. But, we do have the knowledge and we're learning more each day on how to combat hunger and malnutrition by improving crop production. And, thanks to ongoing efforts, the science of epigenetics is proving to be a very promising route to explore. By naturally modifying plant gene expression without altering the genome, epigenetic processes could provide farmers better yields, higher quality food, and more stress tolerant crops. All of this is possible and would likely cost less, happen in a shorter time, and not be damaging to the environment. In the foreseeable future, I believe we shall see a strong presence of epigenetics, not only in crop improvement, but in food production, nutrition and human health. With more research, the field of epigenetics may bring to the table real results that will help to cover the growing food demand of the world.