Genomics Powers Development of Higher Yielding, More Nutritious Orphan Crops in Africa

Illumina sequencing accelerates gene function studies and plant breeding programs.

Recognizing that its technology could play a critical role in alleviating global hunger, malnutrition, and poverty, Illumina created the Agricultural Greater Good initiative. Each year, Illumina awards Greater Good grants to agricultural research organizations that are focused on identifying and breeding plants and animals that will increase the sustainability, productivity, and nutritional density of crop and livestock species. Under the grants, Illumina sequencing and genotyping reagents are provided free of charge.

AOCC

2015 Greater Good Initiative Award Winner

Introduction

A child malnourished during its first 1000 days of life will often succumb to the effects of stunting, a form of growth failure. An irreversible syndrome, stunting reduces a child's chance of survival and impairs cognitive ability. In Sub-Saharan Africa, 35–40% of children under 5 years old are stunted. The long-lasting effects include a reduction in school and work performance, which impacts the development potential of nations[1].

Chronic malnutrition in Africa is caused primarily by insufficient amounts of 5 nutrients in the diet: vitamin A, vitamin C, iron, zinc, and iodine. The species of crops grown by African smallholder farmers have not been bred for high yield, increased nutritional value, or the ability to adapt to abiotic and biotic stress from the environment or pests. Neglected by researchers and industry because they are not economically important on the global market, these "orphan crops" form the basis of diets in many African countries.

The African Orphan Crops Consortium (AOCC) wants to change this. AOCC is an open collaboration with a mission to curb malnutrition and the incidence of stunting in African children. The consortium was conceived in 2011 by Howard-Yana Shapiro, PhD, Chief Agricultural Officer at Mars Corporation and Ibrahim Mayaki, CEO of the New Partnership for Africa's Development (NEPAD). Its goal is to identify robust species of orphan crops, and to train African plant breeders in developing new varieties that improve African diets and health. Allen Van Deynze, PhD, Director of Research at UC Davis and member of the AOCC Steering Committee, is a leader in applying genomics to identify traits rapidly that breeders can use to select for higher yielding, more nutritious crops.

Combining Plant Breeding with Genomics

"Through AOCC, we're combining genomics and breeding to make crops more productive," explains Dr. Van Deynze. "Illumina sequencing and genotyping technologies enable us to essentially skip the 10–15 years of basic breeding used to select for traits in the field. Using DNA markers, we can advance the breeding process and reduce the timeline to 5–10 years depending on the crop's life cycle."

Allen Van Deynze, PhD, is technical lead for the AOCC program and Director of Research for the Seed Biotechnology Center at UC Davis. He specializes in applying genomic technologies to plant breeding.

The Greater Good Award will support RNA sequencing of 50 orphan crop plant species, including finger millet (left) and the leafy spider plant (right), with the HiSeq® System.

The AOCC program will sequence 101 species, and 100 plant lines per species. Crops include trees, vegetables, and legumes, which produce the fruits, nuts, leaves, and seeds used as food. One of the first species that will be sequenced is finger millet (*Eleusine coracana*), a highly nutritious methionine-containing grain used to make a food similar to grits, but with more texture. The leafy spider plant (*Cleome gynandra*), which resembles spinach and is eaten cooked, will also be sequenced. The varieties of these plants that exist in Africa are not improved or selected to grow well in areas such as Kenya or Benin. The idea is to select crops and use genetic selection and crossbreeding to produce varieties that deliver the best yield and nutritional traits for specific geographies.

A Multi-Phase Sequencing Program to Optimize Orphan Crops

There are several phases to the AOCC's sequencing program, with the first focused on DNA sequencing of each species to establish reference genomes. The reference genome is used to compare plant species. "Of the 101 crops we're working on, only 15 have been sequenced or have a completed genome published by other groups," said Dr. Van Deynze. The next phase of the program involves resequencing at least 100 varieties to reveal genetic diversity and define the alleles useful for breeding. Breeders will grow these 100 plant lines in the field to identify which ones have the desired traits. They'll use crossbreeding to combine these plant lines into better varieties.

The Greater Good Initiative will support the annotation and gene discovery phase of the program. In this phase, transcriptome sequencing (RNA-Seq) of 50 species will be used to analyze gene expression. RNA-Seq using Illumina HiSeq® Systems will be performed in Dr. Jasper Rees' laboratory at the Agricultural Research Council in Pretoria, South Africa. "Illumina jump-started the program," Dr. Van Deynze said. "With expression data, we'll know which genes are expressed in these 50 species as the plants grow. We'll have expression data for half of our species in about a year. The Greater Good Initiative is making a vital contribution and is a perfect collaborator for this project."

"The advantage with Illumina sequencing systems is throughput," Dr. Van Deynze said. "We can obtain genome and genome annotation data quickly and with good quality. While we want a very strong reference genome, we also need to sequence it over and over to sample genetic diversity. One sequence is interesting, but the practical part of genomics and plant breeding is diversity. To capture diversity we have to be able to sequence things quickly and affordably, something Illumina systems enable us to do. We need data from tens of thousands of plant lines in weeks, not years, or even months. That's how fast a breeding program works."

Training and Funding for a Sustainable Future

Part of the AOCC is a plant breeding academy where 120 of the best African breeders will be trained to integrate the sequence information into their breeding programs. "We have a grant that will support our work with breeders, helping them to introduce new plant varieties using the genomic tools that we're creating," Dr. Van Deynze said. "Yet, our real long-term goal is to make the African Plant Breeding Academy obsolete within the next 4 years. Because most African plant breeding programs are not well funded, the AOCC is also working with participants to obtain long-term funding and persuade African governments to invest in breeding of their country's crops."

The program has already been successful. "This year, 1 of our plant breeding academy students, Dr. Firew Mekbib, convinced his government to provide funding," Dr. Van Deynze added. "They've opened a center focused on 38 crops indigenous to Ethiopia, which is a global center of orphan crop diversity. They're funding PhD students' education and the breeding programs to develop these crops. We're pleased that the AOCC plant breeding academy has already replicated itself in less than a year through the efforts of 1 of our own students. That's our biggest success right now."

References

1. Improving Child Nutrition: The achievable imperative for global progress, 2013. UNICEF. data.unicef.org/corecode/uploads/document6/uploaded_pdfs/corecode/NutritionReport_April2013_Final_29.pdf

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