Using SNP-Based Genotyping to Select for Climate-Resilient Livestock

Illumina sheep and goat BeadChips help Iowa State University researchers identify selection signatures associated with heat and drought tolerance.

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.

IOWA STATE UNIVERSITY

2014 Illumina Greater Good Initiative Award Winner

Introduction

Temperature fluctuations put real stress on livestock. For instance, the Midwestern United States has experienced several very hot and dry seasons over the last 10 years that have led to phenomenal losses of livestock, subjecting some farms to financial risk. While the public debate continues about whether these temperature extremes are the result of global warming, most people would agree that the temperature fluctuations worldwide are more severe than they used to be. Climate change is of particular concern for smallholders, poor farmers that depend on livestock for their very existence. More broadly it could impact sustainable food production worldwide.

In the developed world, farmers moderate temperature by constructing shade structures and using fans and water spray to ameliorate heat stress in livestock. However, these materials are not widely accessible in the developing world. In perennially hot and dry regions, such as the Middle East, natural selection may provide clues in solving the problem. Sheep and goats in these regions demonstrate far higher heat tolerance than breeds found in more temperate climates.

Natural selection in Middle Eastern herds has occurred over centuries. Archaeological evidence indicates that the earliest domestication of sheep and goats occurred in the Middle East about 10,000 years ago. These herds provide communities with meat and milk for food, animal skins and fiber for clothing, and manure for fertilizing crops. They are also the sole source of livelihood for large numbers of small and marginal farmers and are an important source of export earnings, especially of skins and hand-knotted carpets.[1,2]

Max F. Rothschild, Ph.D., Distinguished Professor in animal science at Iowa State University, Ahmed R. Elbeltagy, Ph.D. from the Animal Production Research Institute in Egypt, and their colleagues at the International Center for Agricultural Research in the Dry Areas are seeking to understand how certain breeds of sheep and goats have developed over thousands of years, and how they thrive in very hot and dry climates. Illumina sheep and goat BeadChips, containing SNPs that represent the genetic diversity of these animals, are helping them look for genes that are associated with resilience to heat stress and drought conditions.

Max Rothschild with a goat and sheep herder in the arid region of Jordan in 2012.

Max F. Rothschild, Ph.D., is a Distinguished Professor of animal science at Iowa State University.

The Genomics of Climate-Resilient Sheep and Goats

"As a geneticist by training, I'm interested in finding genes in a variety of species that are associated with production traits," said Dr. Rothschild. "In this project, we are specifically interested in studying climate-resilient sheep and goats." Dr. Rothschild met Dr. Elbeltagy while on a USAID* mission in Egypt. They had similar interests in genetics and began collaborating to study genes that underlie heat stress and drought resistance. "Understanding the genomics of climate-resilient sheep and goats will help us select livestock that could be further adapted to hot, dry weather" Dr. Rothschild added.

Dr. Elbeltagy and his colleagues in Egypt identified the most climate-resilient animals in herds from hot and dry regions. They measured respiration rate and rectal temperatures of animals exercised in the hottest part of the day during the driest climate. "The internal temperatures of heat-tolerant animals may go up for a while, but they don't stay elevated for long," said Dr. Rothschild. "Extended temperature elevation would show an animal under stress. We wanted to identify animals whose temperature and respiration rates returned to normal quickly."

SNP-Based Genotyping Reveals a Selection Signature

Dr. Rothschild used the Illumina sheep and goat SNP BeadChips to conduct an initial survey of Dr. Elbeltagy's samples from the region. They looked for a genotypic signature, a fixed region or regions of the genome specific to the climate-resilient animals. "At the beginning of a project, we never know what that genotype is. We're looking for the data to tell us something," said Dr. Rothschild. "In the small sheep and goat genotyping samples we've completed so far, we identified four or five regions in the genome that appear to have selection signatures."

The Greater Good Initiative award will provide the team with more BeadChips and allow Dr. Rothschild to triple the number of animals they genotype. "We can further study the genes that control the response to heat stress and drought tolerance," Dr. Rothschild said. "We're trying to understand what metabolic pathways are involved in the animals' ability to withstand these types of stresses. At least we have some indication of that looking at the selection signatures."

Broader Applications to Global Food Security

Sheep and goats have similar chromosomal gene arrangements and, according to Dr. Rothschild, they essentially found one selection signature that was the same in both species. This suggests there is something going on in this region that has helped push natural selection for heat resilience. "We're in the process of further investigating these regions," said Dr. Rothschild. "We're using these animals as indicators for what genes are involved in heat and stress tolerance. Next, we'll look for these regions in breeds that live in more temperate climates. If we can increase the frequency of these alleles, it may help those animals be more heat and stress resilient as the climate changes."

According to the World Bank, supporting smallholders is the most effective way of stimulating economic growth and poverty reduction. Helping smallholders improve their herds will ultimately help provide a better standard of living for them and their families.[3] "We're offering training and development to Egyptian scientists to ensure our findings can be implemented to improve farming practices in the region. Our hope is that this research can be translated into improved productivity and food availability for people around the world."

References

1. http://www.penn.museum/documents/publications/expedition/PDFs/22-4/Nyerges.pdf
2. http://www.fao.org/docrep/009/ah221e/ah221e14.htm
3. http://www.worldbank.org/

*U.S. Agency for International Development that works to end extreme global poverty.

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