TWAS IS HEADQUARTERED IN TRIESTE, ITALY, ALONG WITH A NUMBER OF OTHER SCIENCE CENTRES. IN SEPTEMBER 2012, THE CITY HELD ITS FIRST 'TRIESTE NEXT' CELEBRATION BRINGING SCIENTISTS FROM AROUND THE WORLD TOGETHER WITH 30,000 PEOPLE. TWAS INTERVIEWED TWO SPEAKERS, ROGER BEACHY, A PIONEER IN PLANT BIOTECHNOLOGY, AND NICK DAVIDSON, A GLOBAL AUTHORITY ON WETLANDS PRESERVATION.

GMOs AND SUSTAINABLE DEVELOPMENT

During more than two decades of research, Roger Beachy established some of the basic principles for the genetic engineering of plants that make them resistant to viral diseases. He is held in high esteem worldwide for his work in molecular virology, gene expression and for the development of virus-resistant transgenic plants. Some see him as the father of green biotechnology. But Beachy also knows well the fears provoked by genetically modified organisms (GMOs) and their perceived threat to human health and the environment.

Beachy was elected a TWAS Associate Fellow in 2009. As the former director of the National Institute for Food and Agriculture (NIFA), part of the US Department of Agriculture, Beachy served as an adviser to President Barack Obama. At Trieste Next, he helped to focus the discussion by presenting a historical overview of the rationale for GMOs and describing the first experimental steps that led to the green-biotech era.

Cristina Serra, from the TWAS Public Information Office, interviewed Beachy after his presentation at Trieste Next. An excerpt of the interview follows.

Professor Beachy, when you took your first steps using recombinant techniques aimed at genetically engineering plant genomes, these techniques were in their infancy. Did you envision possible environmental risks or drawbacks for human health at that time?

The first experiments we carried out were conceived to test the feasibility of the techniques that result in genetic engineering of plants. For this reason, the GMOs were confined to laboratories and controlled glasshouses where they grew under controlled conditions. When we moved to field trials, we took precautions such as removing flowers or fruits before pollen or seeds could

Roger Beachy

be dispersed into the environment. However, we were quite optimistic about the idea of genetic modification *per se*. The reasoning behind our enthusiasm was the following: When nature shuffles genes by standard genetic cross-pollination, it does so on a random basis, and the results can be positive or negative in terms of the outcome; hence, the results could be positive or negative for the environment and human health. In the case of such genetic crosses, neither scientists nor consumers demand in-depth examination of the genetic configuration of the hybrid plants. Nor does any authority assess the safety of newly arisen variants of 'natural products' that result. On the contrary, when scientists and plant breeders introduce a foreign gene into a host genome by means of laboratory techniques, which is indeed what genetic engineering does, we now can determine precisely where the gene has been inserted, when it is switched on and what protein or other gene products it produces. In addition, food authorities perform a safety assessment on products of genetic engineering before sending them to the marketplace.

GM technology was developed to provide innovative solutions to the ever-increasing demand for food. Will conventional breeding be discontinued if this technology becomes well-established?

I like to point out that the technology we use today is not the first example of genome modification. Back in the 1940s and 50s, the Italian Creso durum wheat variety (with shorter and more resistant stems) was obtained by irradiating the Cappelli wheat variety with X-rays and inducing unknown mutations, some of which were valued as potential new traits. In 1974, the Creso wheat was included in the Italian national register of durum wheat varieties and in a few years it became the most cultivated variety in Italy.

Coming to lab-engineered GM crops, I think they should be regarded as one solution to develop new crop varieties that can increase food production, not as the sole solution. Nature, and the world itself, is much too intricate and it would be wrong to think that we can devise a one-size-fits-all answer to most problems in biological systems. Whether it relates to agriculture, biofuels, or other topics of general concern – for example, climate change – we have to keep in mind that we must walk along many roads in parallel. Biotechnology is one of the roads being used to improve agriculture, and like solutions taken in other biological systems, should be evaluated on a case-by-case basis.

People's concern about GMOs sits at various levels. The practice of mixing genes from different species in the same genome, for example, placing an animal gene into a plant genome, sounds worrisome. Could it pose a real danger?

Each DNA fragment is a sequence of units, called nucleotides, that are joined to form a chain which contains genetic instructions to assemble RNAs and proteins, the combination of which

Beachy with a group of colleagues in a field of maize in Niger

defines the nature of an organism. These units are 'chemical bricks', similar to letters of an alphabet that must be combined and read in the proper way; all living organisms have similar codes, and many of the RNAs and proteins from different organisms are similar but not identical to each other. Others are unique to specific organisms. Hence, using the DNA instructions from one organism in different organisms can result in very modest, but useful, changes to the recipient. And whether the gene comes from a bacterium or a plant and is introduced to another bacterium or plant, the modest change can be quite useful. What is important is that the process gives rise to a useful and safe product. Although the process itself is safe, scientists cannot entirely rule out that unpredictable results might occur, just as in more classical types of plant breeding. However, products developed through genetic engineering are strictly controlled and evaluated before they are released to farmers for planting, while other breeding products are not similarly evaluated.

Since their inception, gene-transfer techniques in agriculture have mainly focused on two kinds of modifications: herbicide tolerance and insect resistance. This seems a limited achievement compared to the investments this strategy has received and the hopes it has raised.

The first targets that scientists in universities and the private sector selected were experimental in nature. Subsequently, as the technologies were perfected, scientists in the private sector focused efforts on the two traits that you mentioned. Others, including my lab, worked to develop technologies that would result in disease-resistant crops with the hope that the new varieties would require less use of chemicals to control the insects and diseases. Scientists were becoming increasingly aware of the potential damage that may come from a naïve over-use of agrichemicals. To give you an example, in the report entitled 'Tropical Farmers at Risk from Pesticides', the International Rice Research Institute (IRRI) showed that 55% of Philippine farmers who worked with pesticides suffered abnormalities in eyes, 54% in cardiovascular systems and 41% in lungs. Of the estimated 400,000 to 2 million pesticide poisonings that occur in the world each year, resulting in between 10,000 and 40,000 deaths, most occur among farmers in developing countries.

After 20 years of experience, and with the reality of climate change and increased food demand by a growing population, the work in modern gene technologies and plant breeding have shifted towards new targets. Scientists are identifying genes that trigger tolerance to drought or induce a reduced need for irrigation, and are transplanting such genes into crops that lack these traits. Others are working to increase the production of valuable chemicals in plants, or to develop plants that have a higher nutritional content.

In addition to technical changes, we are observing a marked shift in research groups to focus more on local problem-solving in the way agro-biotechnology is used. Africa is a good example of this. Many African universities are now implementing agricultural research programmes by working to solve local problems by using advanced genetic technologies to complement local indigenous knowledge, often by forging strong links between scientists, farmers and business communities. The isolation of a drought-tolerant gene in maize and the development of high-yielding, *Striga*-resistant sorghum varieties, carried out by Sudanese scientists, are good examples of locally driven research. Another example is to attempt to eliminate a severe virus disease of African sweet potatoes, which are often heavily infected by feathery mottle virus and chorotic stunt virus. These viruses propagate very easily leading to small stunted growth, whitening of the tissues (chlorosis) and reduced production of the edible roots. As a result of a partnership between scientists and farmers in Uganda and Kenya and my lab at the Danforth Plant Science Center, we are working together to develop disease-resistant varieties. Finding an effective strategy to counter these sweet potato viruses, through collaborative partnerships, is extremely important for people who depend on sweet potato as a primary source of food.

Can we consider GM technology among the possible responses to climate change?

GM technologies give us the chance to modify crop features, including adjusting them to adapt to environmental changes brought about by climate change. Extreme events such as droughts, floods or abrupt temperature increases or decreases often expose crops to severe conditions that result in significant damage to yields. Water scarcity, whether it is caused by pollution or by the need to irrigate more fields, is also a real problem. Between 1950-51 and 1965-66, 4.5 million additional hectares came under irrigation worldwide. Furthermore, between 1965-66 and 1979-80, 9 million new hectares required irrigation. GM technologies make it possible to develop varieties that are more resilient to changes in climate than are conventional varieties: such new varieties are expected to become available for farmer use in 2013 and beyond. While some farmers will choose not to use new genetic technologies *per se,* others will adapt the new varieties and under most conditions will see improved yields as a consequence.

However, to gain a true advantage from both older and new technologies, such as GM crops, we still need to build well-conceived

SNAPSHOT: ROGER BEACHY

Roger Beachy – plant biologist, geneticist and expert in molecular virology and gene expression – obtained his PhD from Michigan State University, and became a leading expert in plant virology and biotechnology. He is internationally recognized as the founding father of green biotechnology, the scientist who created the first genetically modified crop: a virus-resistant tomato that was tested in a growth chamber, a greenhouse and eventually in field experiments, indicating the potential for use of genetically engineered protection in agriculture.

From 1978 to 1991, Beachy was a member of the Biology Department at Washington University in St. Louis, Missouri, where he served as professor and director of the Center for Plant Science and Biotechnology. From 1991 to 1998, he headed the Division of Plant Biology at the Scripps Research Institute in La Jolla, California. Then, from 1999 until 2009, he was the founding president of the Donald Danforth Plant Science Center in St. Louis, where he helped establish the scientific mission of the centre. From 2009 to 2011 he served as an appointee of President Barack Obama as founding director of the National Institute of Food and Agriculture in the US Department of Agriculture.

He is a member of the US National Academy of Sciences and a recipient of the Wolf Prize in Agriculture (2001) "for the use of recombinant DNA technology to revolutionize plant and animal sciences, paving the way for applications to neighbouring fields." He was elected a TWAS Associate Fellow in 2009.

agricultural policies where engineered crops are part of a strategy that will not eliminate traditional breeding and where water management and improved soils are considered to be part of a long-term solution. Once such new policies are set in motion, technological innovations will become part of our world. This was valid centuries ago and remains valid now.

GM foods are often dubbed 'Frankenfood'. Do we have evidence of any hazard for people?

As I said earlier, GM crops are highly regulated by multiple government bodies (European Food Safety Agency in Europe; Food and Drug Administration, Environmental Protection Agency and US Department of Agriculture in the USA) and undergo many studies before they leave laboratories or experimental fields. What I can stress is this: Foods derived from GM crops have been consumed by hundreds of millions, perhaps bil-

Beachy in Uganda at the time of opening of a field site to test genetically engineered cassava for resistance to virus infection

Beachy with the members of his laboratory in St. Louis, Missouri, USA

lions, of people across the world for more than 15 years, with no reported ill effects, or even any legal cases related to damage to human health.

But let us do some more reasoning: Why should one expect that approved GM foods would be harmful when consumed? Just because they contain a foreign DNA sequence? In fact, many of the foods that we consume contain certain amounts of 'foreign DNA' or proteins that were introduced by wide species cross-breeding, or by significant mutations. In the early years of genetic engineering, scientists developed a crop that would confer better nutrition, but it was later discovered that the gene came from a nut tree to which some people are allergic. Work on the GM crop was then abandoned because of the rules and regulations that govern GM crops.

GMOs have always polarized debates among experts and the public. In addition, some farmers are skeptical about the use of this technology compared to conventional breeding techniques. What should scientific institutions do to promote the correct dissemination of information?

To ensure that proper and transparent data are provided to farmers, to the media and others, I think that information should come from people who are trained both in science and in the art of communications. It is true that, if not properly handled, genetic engineering techniques could pose some risks. But we have to understand that these risks are not dissimilar to those that we cope with in agriculture every day. I do not have the perfect recipe for gaining farmer and consumer acceptance of GM crops, but my view is that scientists should assist policymakers in their decisions, when it comes to the environment, agriculture and climate change. In addition, scientists and communication experts should work closely in order to guarantee that the right message is delivered to the public. I think that GMOs resemble the first car: initially they were a scary innovation, but today we can't do without them.

You are an Associate Fellow of TWAS. How do you rate TWAS's work aimed at sustainable development in the South?

I like the way TWAS carries out its mission. TWAS holds a low profile, avoiding boastful claims. It works, instead, to provide substantial solutions to local problems. Its International Programme on Science and Diplomacy, for example, perfectly fits the increasing demand for cooperation at various levels, while its ever-increasing support to young scientists helps develop skills and expertise.

What I'd personally like to see is a more comprehensive involvement of young scientists from the North with their colleagues from the South: Sharing ideas from different perspectives – such as different civil, social and geographic backgrounds – would be highly beneficial for all concerned. ■