Keeping tabs on genetically modified crops

By Dr Alec Basson

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Genetic engineering and plant breeding techniques are used in biofortification programmes to improve the nutritional quality of African cereals such as sorghum and pearl millet. Apart from being important food sources for many poor people around the world, especially those in drought-stricken areas, these cereals also contain important plant-based chemicals that can assist in the fight against cardiovascular disease, hypertension, Type 2 diabetes and some cancers.

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In South Africa, about 55% of sorghum grain is consumed as sorghum meal - commonly referred to as 'Mabele' - which is served as a breakfast cereal or as a soured porridge. The grain is also used for malting and brewing in the production of traditional sorghum beer. Pearl millet is mainly produced as a subsistence crop in rural areas of Limpopo, KwaZulu-Natal and the Free State. Sorghum and pearl millet are important food security crops in countries like Namibia, Botswana, Malawi and Zimbabwe.

Ensuring 'improvements' are as inteded

"Improving the nutritional quality of sorghum and pearl millet is important, but it is equally vital to determine whether altering the composition of these cereals may lead to unforeseen and/or undesirable consequences that may not be immediately obvious," says Dr Roya Ndimba a postdoctoral researcher at iThemba Labs in Cape Town.

A recent PhD graduate in Plant Biotechnology from Stellenbosch University, Ndimba adds that we need extensive testing of biofortified sorghum and pearl millet to ensure that 'improvements' are as intended, and that they do not introduce any unwanted or undesirable changes in the composition of the grains. She points out that biofortification - the process of increasing the nutritional value of crops through agronomic practices, conventional plant breeding, or modern biotechnology - is considered the most cost-effective and sustainable approach for improving the iron and zinc content in staple foods.

As part of her research, Ndimba set out to determine if there was a difference between the key physical and chemical characteristics as well as the protein profile of genetically modified sorghum and sorghum that hasn't been altered. She also endeavoured to find out whether using plant breeding techniques to increase the concentration of two essential minerals iron and zinc in pearl millet was evident in the most nutritionally important grain tissues.

Ndimba used various techniques and experiments to compare biofortified sorghum and pearl millet with wild types that have not been altered; to study the distribution and concentration of mineral elements within cereal grain tissues, and to assess the effect of biofortification on the composition and other important quality characteristics of the grain.

Sorghum

"As far as biofortified sorghum and wild types are concerned, important differences were found in grain weight and density, as well as the texture of the nutritive tissue inside the grains," says Ndimba. "There was also a difference in the lysine content of biofortified sorghum and wild types. Lysine is an essential amino acid and building block of protein. The highest increase in grain lysine content was observed in biofortified sorghum."

"An increase in lysine content is indicative of an increase in the overall protein quality of the grain."

"In genetically modified sorghum, the protein called kafirin, which serve as repositories of carbon, nitrogen and sulphur for seed germination, was suppressed." Making up 70-80% of the total proteins found in sorghum wholegrain flour, kafirins have a low lysine content and are also hard to digest.

Ndimba says about 1,742 genes that exhibited different expression patterns in genetically modified and wild-type sorghum grain samples were also identified. Gene expression is a complex series of processes in which the information encoded in a gene is used to produce a protein that dictates cell function. "The vast majority of these genes were upregulated or, in other words, displayed higher expression levels in the genetically modified samples as compared to those not modified the non-transgenic counterpart."

"Of note, amongst the top most up-regulated genes, were genes encoding for two types of albumin proteins, which are considered to be more nutritionally valuable in comparison to kafirins."

"However, there was also some evidence of an increase in expression for certain proteins that may be allergenic or that may be indicative of increased plant stress. Further research is therefore needed to establish more clearly if the changes in gene expression adversely impact the overall nutritional value of the genetically modified grain.

Pearl millet

Regarding her analysis of pearl millet grains, Ndimba says her research showed that biofortified pearl millet contains more iron and zinc.
"The analysis confirmed an approximate two-fold increase in iron and zinc levels in the grain of the biofortified variety in comparison to the normal pearl millet."

"The intended impact of the biofortification of the pearl millet was to increase the concentration of two essential minerals iron and zinc in specific grain tissues. My study confirmed that a certain variety (Dhanashakti) had significantly higher concentrations of iron and zinc in the most valuable portions of the grain."

Towards the development of climate tolerant and nutritionally superior African grain crops

Ndimba points out that iron and zinc deficiency can lead to poor growth and compromised psychomotor development in children, reduced immunity, muscle wasting, sterility, increased morbidity and in acute cases even death.

She says her study contributes towards a deeper understanding of the intended and perhaps non-intended changes that may arise in biofortified grains. “This information can help plant scientists to improve the nutritional quality of important staple foods that sustain millions of the world’s most poor and marginalised people.”

“Scientists who work on cereals and are involved in the development of nutritionally improved grains for global food security and health could benefit from this research.”

In light of increasing droughts and an expected global population growth, Ndimba calls for the cultivation of more sorghum and pearl millet to help address critical food security needs across Africa.

She says she would like to work closely with agricultural research institutions to gain access to the vast array of millet species that may be developed into the next generation of climate tolerant and nutritionally superior African grain crops.