SCIENCE BRIEF: BIOFORTIFICATION NO.1 | MAY 2017

Zinc-Biofortified Wheat: Harnessing Genetic Diversity for Improved Nutritional Quality

As one of the world's major staple food crops, wheat is consumed by 35% of the human population, contributing almost 20% of dietary energy and protein to the diets of developing countries. Due to its significant role in ensuring food security, wheat is an ideal candidate for biofortification.

The largest numbers of people suffering from mineral and vitamin deficiencies live in South Asia and sub-Saharan Africa. Wheat is a widely-consumed food staple in South Asia, a close second to rice.

Thanks to the pioneering activities of the late Nobel Peace Prize laureate Dr. Norman Borlaug in the 1950s, which led to the creation of the International Maize and Wheat Improvement Center (CIMMYT) in 1966, Mexico has served as a hub to breed wheat for improved grain yield and disease resistance. Biofortification at CIMMYT has been undertaken through funding and collaboration with partners of the interdisciplinary HarvestPlus program, which was launched in 2003.

Breeding for enhanced zinc (Zn) concentrations was initially quite challenging, due to (i) the limited genetic variation for micronutrients in the adapted varieties and elite breeding germplasm and (ii) the complexity of genetic and metabolic networks controlling the equilibrium levels of Zn in wheat grain. In the early 2000s, scientists conducted large-scale screening for Zn content of wheat landraces (local, indigenous varieties) and wild relatives conserved in CIMMYT's germplasm bank.[5] This rich genetic diversity has provided novel genes for the enhancement of Zn content in wheat grain (Box 1).

Biofortification Addresses the Serious Public Health Problem of Mineral and Vitamin Deficiencies

All forms of malnutrition are estimated to contribute to 45% of all child deaths in developing countries.[1] Importantly, more than two billion people do not get enough essential vitamins and minerals because their diets are not properly balanced. Consumption of staples is high so that the poor do not go hungry for the most part, but more nutritious foods, whose prices continue to rise significantly, are not affordable. Vitamin A, iron, and zinc deficiencies are the most widespread and serious. These deficiencies result in higher mortality and morbidity, reduced cognitive abilities, and lower work performance.

Through breeding staple foods that are both high-yielding and dense in minerals and vitamins -- a process known as **biofortification** -- HarvestPlus[2] and its partners seek to reduce "hidden hunger". Biofortified varieties, developed through research at a central location, can be made available to multiple countries, and once released, are available in national food systems year after year at no additional cost to farmers and consumers.

For more information on the twelve biofortified crops being developed at CGIAR Centers, see Bouis and Saltzman (2017a).[3] For information about progress on biofortification in general, see Bouis and Saltzman (2017b).[4]

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BOX 1

CIMMYT's Germplasm Bank manages the most diverse germplasm collections of maize and wheat

Wheat holdings at CIMMYT comprise some 150,000 seed samples from more than 100 countries; the largest unified collection in the world for a single crop. The maize bank contains 28,000 samples of seed, including the world's largest collection of maize landraces – varieties developed by farmers over decades, centuries or even millennia – along with samples of maize's wild relatives, teosinte and *Tripsacum*, and of improved varieties.

The Genetic Resources Program of CIMMYT manages the germplasm bank, with oversight from the CGIAR Genebank Platform. The program conserves, and together with the Global Wheat and Global Maize Program, studies, documents, and facilitates the use of maize and wheat genetic resources.

For more information: http://www.cimmyt.org/germplasm-bank/

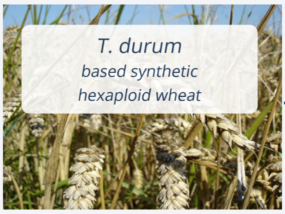
CIMMYT initiated biofortification in wheat breeding in 2006. Specifically, high micronutrient carrying accessions of synthetic wheats, spelt wheats, and wheat landraces were crossed with high-yielding adapted bread wheats. Synthetic wheats are recreated hexaploid wheat developed by crossing improved tetraploid *T. durum* (also known as pasta wheat) or high Zn containing wild tetraploid *T. dicoccon* accessions with *Aegilops squarrosa*, the goat grass that is D-genome donor of wheat. Plants were then selected for particular agronomic and disease resistance traits, as well as high Zn.[6] This conventional breeding approach has resulted in the incorporation of several novel alleles for grain Zn in elite, high-yielding germplasm.[7]

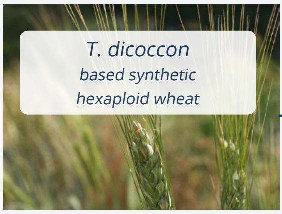
To date, four biofortified wheat varieties have been released – 'Zincol 2016' in Pakistan, 'Zinc Shakti (Chitra)', 'WB02' and 'HPBW-01' in India (Box 2). The now proven high bioavailability (% absorption) of Zn from wheat in human diets translates to significant nutritional impact. Nutrition trials with high Zn wheat have shown (i) an increase in Zn intake[8] and (ii) a reduction in child morbidity.[9]

BOX 2

High-yielding lines with high Zinc content

Progenitors





Zinc Shakti (Chitra)
*Pedigree: CROC1_/AE.SQUARRO-SA(210)//INQALAB 91*2/KUKUNA/3/PBW343*2/KUKUNA*
Extra-early with +14 ppm Zn (40% increase) grown by farmers in North-Eastern Plain Zones of India

Zincol 2016
*Pedigree: OASIS/SKAUZ//4*BCN/3/2*PASTOR/4/T.SPELTA PI348449/5/BACEU#1/6/WBLL1*2/CHAPIO*
First high zinc wheat in Pakistan with +9 ppm Zn and with initial seed multi-plication in 2016-17

WB02 and HPBW-01
*Pedigree: T.DICOCCON,CI9309/AE.SQUARROSA (409)//MU-TUS/3/2*MUTUS*
Two sister lines with +7 ppm Zn released in 2017 for North-Western Plain Zones of India

- *Zinc Shakti (Chitra)* was developed through participatory variety selection (registered by private seed companies and growers). It has profitable yield potential and matures nearly two weeks earlier than common wheat.
- *Zincol 2016* was developed in the background of Pakistani variety *NARC2011*.
- *WB02 and HPBW-01* have been released in 2017 by the Indian Institute of Wheat and Barley Research and Punjab Agricultural University through the central variety release system in India. The varieties are high-yielding and demonstrate a good level of yellow (stripe) rust resistance.

Zinc Wheat being harvested in India
Photo: HarvestPlus

Expanding adoption of Zn wheat varieties in India and Pakistan is in the early stages and further testing and scaling out to other South Asian countries (Bangladesh, Nepal, and Afghanistan) and in Ethiopia is underway.[10] Over the next two decades, as mainstreaming of Zn in the CIMMYT wheat breeding program is implemented, and as additional high-yielding, Zn-rich varieties are released to farmers, it is expected that a large percentage of total wheat supplies in South Asia will be dense in Zn. The ratio of public health benefits to the costs of developing and deploying these varieties is estimated to be 100-to-1, if adoption rates of biofortified varieties reach at least 60% of total supply.[11]

BOX 3

Securing Crop Diversity Forever: The Global Genebank Partnership

The Genebank Platform (2017-2022), previously the CGIAR Research Program for Managing and Sustaining Crop Collections (2012-2016), aims to conserve the diversity of plant genetic resources in the eleven crop genebanks managed by the Centers, in partnership with the Crop Trust under the International Treaty on Plant Genetic Resources for Food and Agriculture. The goal is to make this diversity available to breeders and researchers in a manner that meets international scientific standards and which is cost efficient, secure, reliable, and sustainable over the long-term.

For more information: http://www.cgiar.org/about-us/our-programs/cgiar-genebank-platform-2017-2022

Conclusion

Crop diversity contributes to a stable, sustainable, and diverse food production system and plays an important role in improving nutritional outcomes for the consumers. The CGIAR, in partnership with the Global Crop Diversity Trust (Crop Trust), is working towards ensuring the conservation and availability of plant diversity essential for food and agriculture, in perpetuity (Box 3). Indeed, there is a genetic resource history behind every widely-grown crop cultivar, which has economic benefits that far exceed the costs of the collection and conservation of germplasm.[12] This progress described in improving the Zn content of wheat in high-yielding varieties is made possible by the genetic variation preserved in the CGIAR germplasm banks.

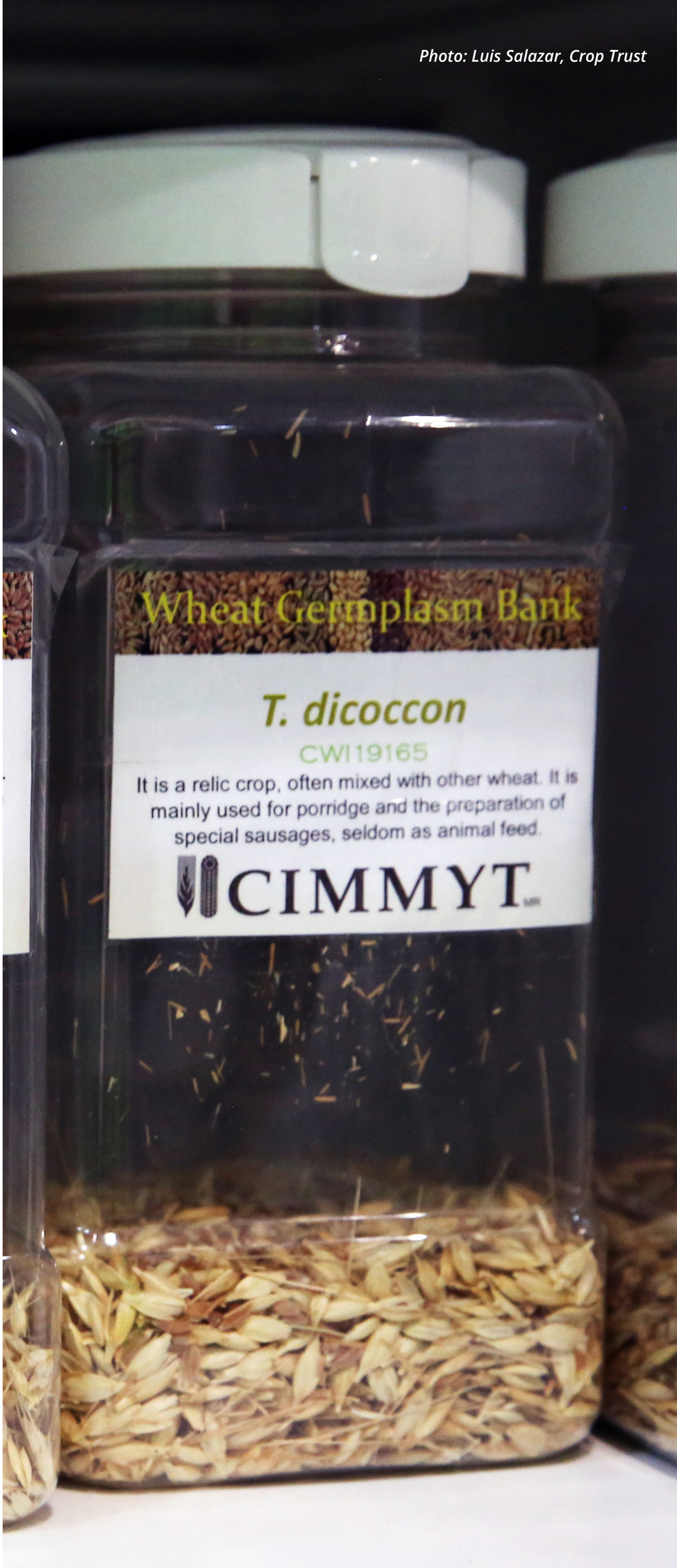


Photo: Luis Salazar, Crop Trust

Endnotes

[1] http://www.who.int/mediacentre/factsheets/fs178/en/

[2] HarvestPlus is one component of the CGIAR Research Program on Agriculture for Nutrition and Health (A4NH). It is a joint venture of two CGIAR Centers, the International Food Policy Research Institute (IFPRI) and the International Center for Tropical Agriculture (CIAT).

[3] Bouis, H. and A. Saltzman (editors). 2017a. Special Issue on Biofortification. African Journal of Food, Agriculture, Nutrition, and Development. Volume 17, No.2, April 2017.

[4] Bouis, H. and A. Saltzman. 2017b. Improving Nutrition Through Biofortification: A Review of Evidence from HarvestPlus, 2003 Through 2016. Global Food Security, Volume 12, March 2017, p. 49-58 -67.

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[6] Ortiz-Monasterio, I., Palacios-Rojas, N., Meng, E., Pixley, K., Trethowan, R., and R. J. Pena. 2007. Enhancing the mineral and vitamin content of wheat and maize through plant breeding. Journal of Cereal Science, 46: 293–307. http://www.sciencedirect.com/science/article/pii/ S0733521007001191.

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